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Proceedings, U.S. Department of Commerce Public Workshop on Critical Materials Needs in the Aerospace Industry, February 9-10, 1981

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, DC 20234

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DEPARTMENT OF COMMERCE

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PROCEEDINGS, U.S. DEPARTMENT OF COMMERCE PUBLIC WORKSHOP ON CRITICAL MATERIALS NEEDS IN THE AEROSPACE INDUSTRY, FEBRUARY 9-10, 1981

John B. Wachtman, Jr., Editor

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, DC 20234

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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Foreword

On February 9 and 10, 1981, the Department of Commerce held a Public Workshop to obtain the views of the American public on three questions directly pertinent to the Department's responsibilities under the Materials and Minerals Policy, Research and Development Act of 1980, Public Law 96-479. These questions were:

1) What are the materials issues of primary concern to the American aerospace industry and its suppliers?

2) What recommendations do the American aerospace industry and its suppliers have for Federal action to address these issues?

3) Which specific materials should the Department of Commerce review in detail over the next few months in order to recommend the most urgently needed programs for Federal action?

The Workshop addressed these questions within three distinct areas:

I. Critical raw materials

II. Critical engineering materials

III. Substitution, conservation, specialized recycling, and higher performance.

This report includes the formal views presented to the plenary workshop sessions, the reports of the Workshop Task Forces in each of the three above areas, and the written submissions invited in the Federal Register notice of the Workshop.

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VII. Written Submissions (cont'd)

Public Law 96-479
96th Congress

An Act

To provide for a national policy for materials and to strengthen the materials research, development, production capability, and performance of the United States, and for other purposes.

Oct. 21, 1980
[H.R. 2743]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Materials and Minerals Policy, Research and Development Act of 1980". National Materials and Minerals Policy, Research and Development Act of 1980. 30 USC 1601 note.

FINDINGS

SEC. 2. (a) The Congress finds that— 30 USC 1601.

(1) the availability of materials is essential for national security, economic well-being, and industrial production;

(2) the availability of materials is affected by the stability of foreign sources of essential industrial materials, instability of materials markets, international competition and demand for materials, the need for energy and materials conservation, and the enhancement of environmental quality;

(3) extraction, production, processing, use, recycling, and disposal of materials are closely linked with national concerns for energy and the environment;

(4) the United States is strongly interdependent with other nations through international trade in materials and other products;

(5) technological innovation and research and development are important factors which contribute to the availability and use of materials;

(6) the United States lacks a coherent national materials policy and a coordinated program to assure the availability of materials critical for national economic well-being, national defense, and industrial production, including interstate commerce and foreign trade; and

(7) notwithstanding the enactment of the Mining and Minerals Policy Act of 1970 (30 U.S.C. 21a), the United States does not have a coherent national materials and minerals policy.

(b) As used in this Act, the term "materials" means substances, including minerals, of current or potential use that will be needed to supply the industrial, military, and essential civilian needs of the United States in the production of goods or services, including those which are primarily imported or for which there is a prospect of shortages or uncertain supply, or which present opportunities in terms of new physical properties, use, recycling, disposal or substitution, with the exclusion of food and of energy fuels used as such. "Materials."

DECLARATION OF POLICY

SEC. 3. The Congress declares that it is the continuing policy of the United States to promote an adequate and stable supply of materials 30 USC 1602.

necessary to maintain national security, economic well-being and industrial production with appropriate attention to a long-term balance between resource production, energy use, a healthy environment, natural resources conservation, and social needs. The Congress further declares that implementation of this policy requires that the President shall, through the Executive Office of the President, coordinate the responsible departments and agencies to, among other measures—

(1) identify materials needs and assist in the pursuit of measures that would assure the availability of materials critical to commerce, the economy, and national security;

(2) establish a mechanism for the coordination and evaluation of Federal materials programs, including those involving research and development so as to complement related efforts by the private sector as well as other domestic and international agencies and organizations;

(3) establish a long-range assessment capability concerning materials demands, supply and needs, and provide for the policies and programs necessary to meet those needs;

(4) promote a vigorous, comprehensive, and coordinated program of materials research and development consistent with the policies and priorities set forth in the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6601 et seq.);

(5) promote cooperative research and development programs with other nations for the equitable and frugal use of materials and energy;

(6) promote and encourage private enterprise in the development of economically sound and stable domestic materials industries; and

(7) encourage Federal agencies to facilitate availability and development of domestic resources to meet critical materials needs.

IMPLEMENTATION OF POLICY

30 USC 1603.

SEC. 4. For the purpose of implementing the policies set forth in section 3 and the provisions of section 5 of this Act, the Congress declares that the President shall, through the Executive Office of the President, coordinate the responsible departments and agencies, and shall—

(1) direct that the responsible departments and agencies identify, assist, and make recommendations for carrying out appropriate policies and programs to ensure adequate, stable, and economical materials supplies essential to national security, economic well-being, and industrial production;

(2) support basic and applied research and development to provide for, among other objectives—

(A) advanced science and technology for the exploration, discovery, and recovery of nonfuel materials;

(B) enhanced methods or processes for the more efficient production and use of renewable and nonrenewable resources;

(C) improved methods for the extraction, processing, use, recovery, and recycling of materials which encourage the conservation of materials, energy, and the environment; and

(D) improved understanding of current and new materials performance, processing, substitution, and adaptability in engineering designs;

(3) provide for improved collection, analysis, and dissemination of scientific, technical and economic materials information and data from Federal, State, and local governments and other sources as appropriate;

(4) assess the need for and make recommendations concerning the availability and adequacy of supply of technically trained personnel necessary for materials research, development, extraction, harvest and industrial practice, paying particular regard to the problem of attracting and maintaining high quality materials professionals in the Federal service;

(5) establish early warning systems for materials supply problems;

(6) recommend to the Congress appropriate measures to promote industrial innovation in materials and materials technologies;

(7) encourage cooperative materials research and problem-solving by—

(A) private corporations performing the same or related activities in materials industries; and

(B) Federal and State institutions having shared interests or objectives;

(8) assess Federal policies which adversely or positively affect all stages of the materials cycle, from exploration to final product recycling and disposal including but not limited to, financial assistance and tax policies for recycled and virgin sources of materials and make recommendations for equalizing any existing imbalances, or removing any impediments, which may be created by the application of Federal law and regulations to the market for materials; and

(9) assess the opportunities for the United States to promote cooperative multilateral and bilateral agreements for materials development in foreign nations for the purpose of increasing the reliability of materials supplies to the Nation.

PROGRAM PLAN AND REPORT TO CONGRESS

SEC. 5. (a) Within 1 year after the date of enactment of this Act, the President shall submit to the Congress— 30 USC 1604.

(1) a program plan to implement such existing or prospective proposals and organizational structures within the executive branch as he finds necessary to carry out the provisions set forth in sections 3 and 4 of this Act. The plan shall include program and budget proposals and organizational structures providing for the following minimum elements:

(A) policy analysis and decision determination within the Executive Office of the President;

(B) continuing long-range analysis of materials use to meet national security, economic, industrial and social needs; the adequacy and stability of supplies; and the industrial and economic implications of supply shortages or disruptions;

(C) continuing private sector consultation in Federal materials programs; and

(D) interagency coordination at the level of the President's Cabinet;

(2) recommendations for the collection, analysis, and dissemination of information concerning domestic and international long-range materials demand, supply and needs, including con-

sideration of the establishment of a separate materials information agency patterned after the Bureau of Labor Statistics; and

(3) recommendations for legislation and administrative initiatives necessary to reconcile policy conflicts and to establish programs and institutional structures necessary to achieve the goals of a national materials policy.

(b) In accordance with the provisions of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6601 et seq.), the Director of the Office of Science and Technology Policy shall:

(1) through the Federal Coordinating Council for Science, Engineering, and Technology coordinate Federal materials research and development and related activities in accordance with the policies and objectives established in this Act;

(2) place special emphasis on the long-range assessment of national materials needs related to scientific and technological concerns and the research and development, Federal and private, necessary to meet those needs; and

(3) prepare an assessment of national materials needs related to scientific and technological changes over the next five years. Such assessment shall be revised on an annual basis. Where possible, the Director shall extend the assessment in 10- and 25-year increments over the whole expected lifetime of such needs and technologies.

(c) The Secretary of Commerce, in consultation with the Federal Emergency Management Administration, the Secretary of the Interior, the Secretary of Defense, the Director of the Central Intelligence Agency, and such other members of the Cabinet as may be appropriate shall—

(1) within 3 months after the date of enactment of this Act, identify and submit to the Congress a specific materials needs case related to national security, economic well-being and industrial production which will be the subject of the report required by paragraph (2) of this subsection;

(2) within 1 year after the date of enactment of this Act, submit to the Congress a report which assesses critical materials needs in the case identified in paragraph (1) of this subsection, and which recommends programs that would assist in meeting such needs, including an assessment of economic stockpiles; and

(3) continually thereafter identify and assess additional cases, as necessary, to ensure an adequate and stable supply of materials to meet national security, economic well-being and industrial production needs.

(d) The Secretary of Defense, together with such other members of the Cabinet as are deemed necessary by the President, shall prepare a report assessing critical materials needs related to national security and identifying the steps necessary to meet those needs. The report shall include an assessment of the Defense Production Act of 1950 (50 U.S.C. App. 2061 et seq.), and the Strategic and Critical Materials Stock Piling Act (50 U.S.C. App. 98 et seq.). Such report shall be made available to the Congress within 1 year after enactment of this Act and shall be revised periodically as deemed necessary.

(e) The Secretary of the Interior shall promptly initiate actions to—

(1) improve the capacity of the Bureau of Mines to assess international minerals supplies;

(2) increase the level of mining and metallurgical research by the Bureau of Mines in critical and strategic minerals; and

(3) improve the availability and analysis of mineral data in Federal land use decisionmaking.

A report summarizing actions required by this subsection shall be made available to the Congress within 1 year after the enactment of this Act.

(f) In furtherance of the policies of this Act, the Secretary of the Interior shall collect, evaluate, and analyze information concerning mineral occurrence, production, and use from industry, academia, and Federal and State agencies. Notwithstanding the provisions of section 552 of title 5, United States Code, data and information provided to the Department by persons or firms engaged in any phase of mineral or mineral-material production or large-scale consumption shall not be disclosed outside of the Department of the Interior in a nonaggregated form so as to disclose data and information supplied by a single person or firm, unless there is no objection to the disclosure of such data and information by the donor: *Provided, however,* That the Secretary may disclose nonaggregated data and information to Federal defense agencies, or to the Congress upon official request for appropriate purposes. Nonaggregate data, disclosure.

THE MINING AND MINERALS POLICY ACT OF 1970

SEC. 6. Nothing in this Act shall be interpreted as changing in any manner or degree the provisions of and requirements of the Mining and Minerals Policy Act of 1970 (30 U.S.C. 21a). For the purposes of achieving the objectives set forth in section 3 of this Act, the Congress declares that the President shall direct (1) the Secretary of the Interior to act immediately within the Department's statutory authority to attain the goals contained in the Mining and Minerals Policy Act of 1970 (30 U.S.C. 21a) and (2) the Executive Office of the President to act immediately to promote the goals contained in the Mining and Minerals Policy Act of 1970 (30 U.S.C. 21a) among the various departments and agencies. 30 USC 1605.

SEC. 7. Section 1001(a) of title X of the Act of November 3, 1978 (Public Law 95-586), is revised to read as follows: Geothermal resources, conveyance to Boise, Idaho.

"SEC. 1001. (a) The Congress hereby authorizes and directs that the rights to the geothermal resources, including minerals present in the geothermal fluid, presently vested in the United States of America in real property designated as Tract 37, located in sections 2 and 11, township 3 north, range 2 east, Boise meridian, Idaho, containing 4.13 acres more or less;

"Tract 38, located in sections 1, 2, 11, and 12, township 3 north, range 2 east, Boise meridian, Idaho, containing 449.16 acres more or less;

"Unofficial tract 39, located in section 2, township 3 north, range 2 east, Boise meridian, Idaho, described as follows: from the corner of sections 2, 3, 10 and 11, north 76 degrees 26 minutes 17 seconds, east, 1,705.44 feet, thence north 60 degrees 08 minutes east, 593.41 feet, thence north 25 degrees 28 minutes west, 911.46 feet to the southeast corner of tract 39 and point of beginning, thence north 25 degrees 28 minutes west, 660.0 feet, thence north 69 degrees 47 minutes west, 933.24 feet, thence south 26 degrees 24 minutes east, 544.50 feet, thence south 57 degrees 26 minutes east, 240.24 feet, thence north 64 degrees 32 minutes east, 795.30 feet and point of beginning, containing 14.644 acres more or less;

"Unofficial tract 40, located in section 11, township 3 north, range 2 east, Boise meridian, Idaho, described as follows: from the corner of sections 2, 3, 10, and 11, south 84 degrees 44 minutes east, 905.7 feet to the northwest corner of tract 40 and point of beginning, thence south

22 degrees 40 minutes east, 593.75 feet, thence north 84 degrees 45 minutes east, 940.20 feet, thence north 16 degrees 15 minutes west, 315.2 feet, thence north 87 degrees 45 minutes west, 516.6 feet, thence south 68 degrees 14 minutes west, 141.3 feet and point of beginning, containing 4.95 acres more or less;

"Unofficial tract 44, located in section 2, township 3 north, range 2 east, Boise meridian, Idaho, described as follows: from the corner of sections 2, 3, 10 and 11, north 76 degrees 26 minutes 17 seconds east, 1,705.44 feet to the southwest corner of tract 44 and point of beginning, thence north 60 degrees 08 minutes east, 593.41 feet, thence north 25 degrees 28 minutes west, 911.46 feet, thence south 64 degrees 32 minutes west, 795.30 feet, thence south 67 degrees 21 minutes east, 373.03 feet, thence north 58 degrees 18 minutes east, 264.53 feet, thence south 74 degrees 02 minutes east, 154.31 feet, thence south 14 degrees 50 minutes west, 585.02 feet, thence south 9 degrees 31 minutes east, 165.79 feet and point of beginning, containing 9.94 acres more or less; be transferred by the Secretary of the Interior in fee to the city of Boise upon payment by the city of Boise of the fair market value, as determined by the Secretary, of the rights conveyed.".

SEC. 8. Title X of the Act of November 3, 1978, is further amended by adding a new section 1003 to read as follows:

Boise District Office Site, geothermal resources utilization.

"SEC. 1003. The Secretary of the Interior, through the Bureau of Land Management, is authorized to utilize geothermal resources found under the parcel known as the Boise District Office Site, described as commencing at the southwest corner of the Old Fort Boise Military Reservation, thence north 70 degrees 0 minutes east, 1,448.2 feet; thence north 4 degrees 32 minutes east, 627 feet to the true point of beginning; thence the following courses and distances: south 87 degrees 8 minutes west, 696.5 feet; thence north 21 degrees 2 minutes west, 532 feet; thence south 69 degrees 4 minutes west, 21.9 feet; thence north 22 degrees 40 minutes west, 86.3 feet; thence north 84 degrees 50 minutes east, 993.6 feet; thence south 4 degrees 32 minutes west, 624.95 feet to the point of beginning; consisting of 11.53 acres, more or less, contained in section 11, township 3 north, range 2 east, Boise meridian, Idaho.".

Approved October 21, 1980.

LEGISLATIVE HISTORY:

HOUSE REPORT No. 96-672 (Comm. on Science and Technology).
SENATE REPORTS: No. 96-897 (Comm. on Commerce, Science, and Transportation) and No. 96-937 (Comm. on Energy and Natural Resources).
CONGRESSIONAL RECORD:
Vol. 125 (1979): Dec. 3, 4, considered and passed House.
Vol. 126 (1980): Oct. 1, considered and passed Senate, amended.
Oct. 2, House concurred in Senate amendments.

O

Office of the Secretary

Definition of Aerospace Industry Materials Needs; Invitation for Expression of Public and Private Sector Materials Needs and Recommendations for Federal Action

AGENCY: Assistant Secretary of Commerce for Productivity, Technology and Innovation.

ACTION: Solicitation of written comment from the public and private sector and notice of public workshop to review these public and private sector views.

SUMMARY: In Section 5(C) of the Materials and Minerals Policy, Research and Development Act of 1980, Pub. L. 96–479, the Secretary of Commerce, in consultation with the Federal Emergency Management Agency, the Secretaries of Interior and Defense, and the Director of the Central Intelligence Agency, is directed to report to the Congress before October 21, 1981, on critical materials needs in a specific case related to national security, economic well-being and industrial production.

As used in the Act, the term "materials" means substances, including minerals, of current or potential use that will be needed to supply the military, industrial and essential civilian needs of the United States in the production of goods or services, particularly those which are primarily imported or for which there is a prospect of shortages or uncertain supply, with the exclusion of food and of energy fuels used as such.

The Department is considering the aerospace industry as a focus for the first study and has begun to examine anticipated materials used in the aerospace industry. An early goal is to select at least three to five selected materials for detailed study of industry needs, anticipated supplies, and the implications of severe shortages or supply interruptions. Using several alternative scenarios, the study will estimate the industrial demand for several selected materials. These demands will be compared with total world supply/demand estimates for the selected materials in order to support analyses of the national security, economic, and industrial production implications of anticipated supply/demand disparities.

The Department, by this Notice, is soliciting information from affected individuals and organizations supporting identification of (1) the particular materials to be examined and (2) the current or anticipated problems with these materials. Suggestions for corrective action will also be appreciated.

Written statements should be addressed to Dr. John B. Wachtman, Jr., National Bureau of Standards, Materials Building B308, Washington, D.C. 20234 for receipt by February 5, 1981.

On February 9–10, 1981, the Department of Commerce will hold a Workshop that will be conducted by John B. Wachtman, Jr., of the National Bureau of Standards, Philip Goodman of the Office of Productivity, Technology and Innovation and James Owens of the Bureau of Industrial Economics. Various Departmental activities in the critical materials area are being coordinated with Pub. L. 96–479 responsibilities through a Task Force under the Chairmanship of Jordan J. Baruch: John B. Wachtman, Jr., Vice Chairman; James Owens; Philip Goodman; Antonio Macone, Office of Commodity Policy; Leon Karadbil, Office of Industrial Mobilization; Candice Stevens, Office of Policy; and Robert B. Ellert, Office of the General Counsel. The members of this Task Force will also participate in the Workshop. This Workshop will consist of summary presentations of responses to the above questions by the institutions submitting them, followed by a general discussion. This Workshop will take place in the Green Auditorium of the National Bureau of Standards, in Gaithersburg, Maryland beginning at 9:00 a.m. both days and ending no later than 4:00 p.m. on February 10th.

SUPPLEMENTARY INFORMATION: All major critical materials needs areas of the aerospace industry will be open for discussion:

(1) Supplies of, and requirements for, raw and bulk materials;

(2) Supplies of, and requirements for, specifically engineered materials and forms, including special parts; and

(3) The development of substitute materials including advanced highly engineered materials.

Among the concerns that will be addressed are:

(1) Anticipated requirements in the foreseeable future;

(2) Current or anticipated difficulties in obtaining materials in any form;

(3) Prospects for, and implication of, fluctuations in demand, supply, and prices;

(4) Timely availability of processed materials and parts; and

(5) Other materials issues of prime concern to the aerospace industry.

The materials finally chosen for detailed study will be specific and should typify the full range of materials needs of the industry. For example, possible specific materials for close examination might include the following:

(1) Cobalt, as a raw material on which the U.S. is import dependent;

(2) Titanium forgings, as a special processing capacity need; and

(3) Rapidly-solidified alloys, as a promising route to both conservation of materials or increased performance.

Public and private sector views are also solicited on recommended actions to deal with aerospace materials problems such as:

(1) improvement in materials production base;

(2) stockpiling, both public and private;

(3) Federal emergency allocation procedures;

(4) improvement of capacity for airframes, engines, and components;

(5) expanded conservation and recycling of materials; and

(6) improved research and development of new materials both for subsitution and for higher performance.

All written comments that are furnished in response to this invitation will be available for inspection and copying prior to the workshop in the Department's Central Reference and Records Inspection Facility, Room 5317, Main Commerce Building, 14th Street between E Street and Constitution Avenue, NW., Washington, D.C. 20230.

Signed: January 6, 1981.

Jordan J. Baruch,

Assistant Secretary for Productivity, Technology, and Innovation.

[FR Doc. 81-730 Filed 1-8-81; 8:45 am]

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WORKSHOP ON CRITICAL MATERIALS NEEDS OF THE AEROSPACE INDUSTRY

February 9

8:30	Registration	
	Introductory Remarks	John Wachtman
9:00	Summary of Inputs Received	John Wachtman
9:15	Congressional Concerns	Edwin Hall/Paul Maxwell
9:30	Economic Analysis of Aerospace Industry	James Owens
	Session I: Supplies of Critical Raw Materials	Antonio Macone
9:45	Keynote Talk	Walter Hibbard
10:15	Break	
10:30	Supplementary Remarks	
11:20	Further Supplementary Remarks from Floor	
	Session II: Supplies of Critical Engineering Materials	Philip Goodman
12:00	Keynote Talk	William O'Donnell
12:30	Supplementary Remarks	
1:00	Lunch	
2:00	Supplementary Remarks, continued	
2:20	Further Supplementary Remarks from Floor	
3:00	Break	
	Session III: Substitution, Conservation, Specialized Recycling, and Higher Performance	John Wachtman
3:15	Keynote Talk	Allen Gray
3:45	Supplementary Remarks	
4:35	Further Supplementary Remarks from Floor	
5:15	General Discussion	
6:00	Adjourn	

February 10

9:00	Task Force Preparation of Views on Issues, Possible Actions, and for Specific Materials for Study*	
	I. Critical Raw Materials Supplies	James Owens Exec. Sec.
	II. Critical Engineering Materials Supplies	Philip Goodman Exec. Sec.
	III. Substitution, Conservation, Recycling, and Higher Performance	John Wachtman Exec. Sec.
	Lunch	
	Reports of Task Force Chairperson	John Wachtman
1:30	I. Critical Raw Materials Supplies	
1:45	Discussion	
2:15	II. Critical Engineering Materials Supplies	
2:30	Discussion	
3:00	Break	
3:15	III. Substitution, Conservation, Recycling, and Higher Performance	
3:30	Discussion	
4:00	Adjourn	

* Chairperson to be elected by Working Groups

SPEAKERS

Critical Raw Materials

Keynote:	Professor Walter Hibbard Virginia Polytechnic Institute
Supplementary Remarks:	E. Andrews Vice President for Materials & Sciences Allegheny Ludlum
	Russell Babcock Exploration Manager Bear Creek Mining Co.
	Robert Brumwell Executive Vice President Cabot Mineral Resources
	John Morgan Chief Staff Officer U.S. Bureau of Mines
	David Swan Vice President, Environmental Issues Kennecott Copper

Critical Engineering Materials

Keynote:	William O'Donnell Manager, Materiel Sperry Gyroscope
Supplementary Remarks:	C. J. Beagle Manager, Material Administration Rockwell International
	Sally Couluris Financial Analyst Gruman Aerospace
	Everett Gray Acting Corporate Director of Materials General Dynamics
	John M. Kerr Director of Materiel Rockwell International
	William Owczarski Manager, Technical Planning Pratt & Whitney

Substitution, Conservation, Recycling & Higher Performance

Keynote:	Dr. Allen Gray Technical Director American Society for Metals
Supplementary Remarks:	John J. de Barbadillo Research Recovery Section Manager Inco
	Edward Dulis President Colt Industries
	William Owczarski Manager, Technical Planning Pratt & Whitney
	Professor John K. Tien Columbia University
	Dr. Edward Whelan Research Supervisor Climax Molybdenum

Further information can be obtained from:

Dr. John B. Wachtman, Jr.
Director, Center for Materials Science
National Bureau of Standards
Washington, DC 20234

(301) 921-2891

or

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INTRODUCTORY REMARKS

John B. Wachtman, Jr.
National Bureau of Standards

REMARKS FOR INTRODUCTORY SESSION

WORKSHOP ON CRITICAL MATERIALS NEEDS OF THE AEROSPACE INDUSTRY

February 9-10, 1981

National Bureau of Standards, Gaithersburg, MD

John B. Wachtman, Jr.

Director, Center for Materials Science

Good morning ladies and gentlemen. I would like to call this meeting to order. This is a Public Workshop on Critical Materials Needs in the Aerospace Industry. I am John Wachtman, Director of the Center for Materials Science, National Bureau of Standards, Department of Commerce.

. . . . .

This workshop has been organized into three sessions to bring out the full range of materials uses in the aerospace industry from raw materials, through products and recycling, and to bring out needs associated with future developments.

In each of the three sessions today, we will follow the same format. First, a keynote talk. Second, supplementary remarks by several speakers designed to highlight special areas of materials concern within the general topic of the keynote talk. Third, short presentations by members of the audience. We are asking that the latter be held to a maximum of 5 minutes oral presentation in order to accomodate as many speakers as possible within the time available. Additional short presentations would be welcome during the general discussion session at the end of the day. If still more time is needed for short presentations and general discussion, we are prepared to modify the schedule to take another hour tomorrow. Please help allow everyone to be heard by making your point directly and concisely.

This is a completely open meeting. It was announced in the Federal Register. All written material submitted will be placed on file at the Department of Commerce and will be available to the public through the Department's Reference and Records room. Also, we have made copies of the written input received through last Friday for distribution today. We ask that everyone having a written report to submit to us today, please give it to one of the secretaries at the registration desk. We will attempt to duplicate this material and have it available for distribution tomorrow. We are not, I repeat <u>not</u> recording the discussion, so it is important that we have your written input. It would be most useful to have any additional input by the end of February.

In tomorrow's workshop session we plan to divide up into three task forces. Please sign up at the registration desk for your choice of task force. This will enable us to assign meeting rooms appropriate to the size of the task force. Each task force will elect its own chairperson preferably someone outside government. We are asking one task force to take the area of critical raw materials, a second to take the area of critical engineering materials, and a third to take the area of substitution, conservation, specialized recycling and higher performance materials. We would like each task force to deliberate for half a day. Beginning at 1:30 p.m. tomorrow, each task force chairperson should present a 15-minute report summarizing the various issues on materials needs, possible programs to meet these needs, and possible choices of materials for later detailed study to illustrate these needs and programs.

Following this workshop, the Department of Commerce team will carry out a more detailed study of a few materials selected as examples. We will certainly work closely with private sector groups at the later stages of the study. Details of our later work have not been fixed, but will be decided upon after review by the Secretary of Commerce of the results of this workshop. We thank you very much for your participation and look forward to hearing your views during the next 2 days.

A total of 30 written comments were received by the close of business Friday. Copies of these can be picked up at the registration desk. Many of the respondents are present today and can summarize their views later. To give a general overview of the main views expressed, we prepared a series of brief summary statements. A number of themes ran through many of the submissions, although conflicting views were expressed in some cases.

Slide 1. There were general comments on the potential for materials limitations in national security, economic well-being, and industrial production. Need for a concerted national policy to avoid such limitations was expressed. There was complete agreement with the choice of the aerospace industry for a case study, with one exception who wanted the Secretary's report to deal only with certain imported materials, especially chromium, cobalt, platinum, and manganese.

Slide 2. These are, of course, included in this workshop. Concerns were expressed with widely fluctuating prices for some materials, including cobalt. Great concern was expressed over the impact of a cutoff in supply of critical imported materials. The specific materials included Cr, Co, Pt, Mn, Ti, Ta, Ni, Nb, and Al.

Slide 3. Suggested actions included concerted free-world resource management through NATO and other alliances. Strengthening of the domestic exploration, mining, and related industries was strongly recommended. Suggestions included greater access to Federal lands and modification of regulations that inhibit development of domestic resources.

Slide 4. Concern was expressed about future supply of special engineering materials and products such as titanium, certain stainless steels, and certain aluminum alloys. Long lead times have been a problem. They are apparently decreasing but may lengthen if a buildup occurs.

Slide 5. Additional concern with engineering materials included special processing capacity, in particular, very large presses, and the impact of high energy costs.

Slide 6. A common view concerned the importance of relying on market mechanisms and private industry to solve problems. It was suggested that special situations could justify the use of the Defense Production Act and that market guarantees may be needed for certain cyclical defense industries.

Slide 7. One recommended help in this area is the use of multi-year contracts by the Defense department. Tax incentives were recommended to favor expanded or modernize production.

Slide 8. Another type of suggested action involved stockpiling. Strong recommendations for upgrading stockpiled materials were made. Suggestions for increased stockpiling were also made, including the encouragement of private stockpiling. Consideration of stockpiles for related non-defense purposes was recommended in a few cases, but appears controversial.

Slide 9. Continued effort to develop advanced materials and resources was strongly recommended. Specific needs include improved high temperature materials for engine and high strength-to-weight and stiffness-to-weight materials for more fuel-efficient aircraft, spacecraft and missles.

Accelerated efforts in conservation and substitution through the application of technology was recommended, as was the development of specialized recycling procedures for critical materials.

Slide 10. It was suggested that both known and new substitution technologies should be documented and "stockpiled" to make them more rapidly useable and to identify gaps. Improved materials characterization is recommended to support both new development and specifications for substitution. Better industry/university/government cooperation and a more favorable climate for longer-term research and development were recommended.

Let me turn now to a brief mention of groups outside the Department of Commerce who are associated with this activity. The Secretary's team is being assisted by liaison representatives from other executive branch agenices of the Federal Government. These include representatives from the Federal Emergency Management Agency, the Department of the Interior, the Department of Defense, the Central Intelligence Agency, the National Aeronautics and Space Administration, the Department of State, the Department of Transportation, and the Department of Energy.

The Secretary's team is maintaining contact with the staff of several committees of Congress which are especially concerned with National Materials Policy. The following staff members have indicated their intention to attend this workshop:

1) From the Senate Committee on Commerce, Science, and Transportation: Ed Hall, Ed Smick, Cheryl Troph, and Mel Ciment.
2) From the House Committee on Science and Technology: Paul Maxwell and Tony Scoville.
3) From the Senate Committee on Energy and Natural Resources: Debbie Bogossian.
4) From the House Committee on Interior and Insular Affairs: Tom Wolfe and Sharon Cockayne.

Our next speaker is Mr. Paul Maxwell from the staff of the House Science and Technology Committee. This Committee has played a leading role in discussion of National Materials Policy and introduced a bill which eventually became the Act which lead to today's Workshop.

. . . . .

Our next speaker is Mr. James Owens, Director of the Office of Basic Industries of the Department of Commerce. He will briefly describe the Department's plans for economic analysis to support the Secretary's report.

. . . . .

We will turn now to the first session, which is on Critical Raw Materials. I would like to introduce the Session Chairperson, who is Mr. Anthony Macone, Acting Director of the Office of Commodity Policy of the International Trade Administration.

GENERAL COMMENTS

- An effective national materials policy needs to be developed and implemented
- Agree with choice of aerospace industry for case study

RAW MATERIALS

- Concern with fluctuating prices in recent years
- Potential supply disruptions of imported materials
- Specific concerns with: Cr, Co, Pt, Mn, Ti, Ta, Ni, Nb, Al
- Need concerted free world management through NATO and other alliances
- Step up exploration and development of domestic deposits, including increased access to Federal lands
- Modify environmental and other regulations that inhibit development of domestic resources

ENGINEERING MATERIALS

- Long lead times (forgings and extrusions) have occurred and may increase if an aerospace buildup takes place.
- Larger press capacity (75,000 - 200,000 tons) needed
- Large scale power use restrictions inhibit new capacity construction (e.g., aluminum)

MARKET FACTORS

- Country should rely primarily on free-market mechanisms, removing barriers to market
- Defense Production Act needed for special situations
- Market guarantees are needed for cyclical defense industries
- Multi-year contracts should be utilized by Defense Department
- Tax incentives are required to expand or modernize production capacity

STOCKPILING

- The quality of specific stockpiles such as that for cobalt should be partially upgraded for higher technology uses; material should be kept up to date
- Increased stockpiling of certain commodities is needed
- Encourage private stockpiling
- Consideration of stockpile use in non-defense situations

ADVANCED MATERIALS

- Higher performance materials and related processing technology are needed to improve aircraft performance and fuel efficiency: one example, rapid solidification technology
- Specialized recycling technology needed, e.g., for tantalum
- "Substitution preparedness" should be systematically developed
- Materials characterization is needed as a basis for the development of innovative materials
- Industry/university/Government cooperation on research and development should be stimulated
- More favorable climate for longer-term research and development is needed

CRITICAL ENGINEERING MATERIALS
ISSUES AFFECTING THE U.S. SUPPLY OF MATERIALS

W. R. Hibbard, Jr.
Virginia Polytechnic Institute and State University

CRITICAL ENGINEERING MATERIALS

ISSUES AFFECTING THE U.S. SUPPLY OF MATERIALS

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Historically, concerns for the supply of materials have been related to those materials (manganese, chromium, tin, cobalt, rubber) which are not found in the U.S., and those shortages created by unanticipated actions by governments such as war, embargos and regulation as well as over zealous purchasing agents.

In 1908 during the first Conservation Movement, Theodore Roosevelt sponsored a Governors Conference which estimated finite amounts of materials, calculated exhaustion dates, and prescribed conservation.

After World War I, in response to supply concerns, the U.S. Geological Survey studied the availability of materials and in 1920 reported that supplies were adequate.

During World War II when sources became unavailable or capacities were inadequate, the government rushed new facilities and R & D leading to new substitutes.

After World War II, government and industry worked closely together in an era of economic growth, largely because it was recognized that the winning of the war was related to such cooperation and the splendid performance of industry and innovation.

In 1952, the President's Materials Policy Commission expressed concern for the rate of materials consumption in World War II and the Korean War and forecast certain shortages by 1970. (They did not occur.)

Prepared for Department of Commerce Workshop on Critical Materials Needs of the Aerospace Industry, February 9, 1981.

In 1962 Scott pointed out that goods require materials with certain properties in order to perform at economically acceptable levels. Competition between materials derives from the most beneficial source of these properties.

Barnett and Morse reported in 1963 that there was no evidence of increasing resource scarcity between 1870 and 1957 because when a particular material becomes more scarce, the rate of increase in its price tends to be offset by substitution of other resources or new resources or new technology.

By the mid 1960's, the government and industry honeymoon was over and starting with the environment movement, an government and industry adversary position developed between them, which led to the decade of regulation.

In 1968 I testified before the Senate Interior's Subcommittee on Materials that the U.S. was the largest producer and consumer of materials because even in the face of lower grade ores, rising labor and environmental costs, it had an aggressive program of advancing technology. Thus between 1900 and 1965, copper reserves grew from 18 to 85 million tons as a result of technology even though the average ore grade dropped from 4% to 0.7%.

At that time, the U.S. had become the largest importer of materials. Trends indicated that without new technology, new discovery and with government intervention on price, and long lag times on new facilities, shortages might develop. (Not in resources but in materials production).

Assuming an adversary posture toward industry the government undertook an era of public protectionism which increased the costs and uncertainties of innovation (an early case was new drugs) and stifled productivity to protect the workers (an early case was coal mining). At that time, technology was not a factor--it existed, but was not used in the face of dis-economies created by the government. Japan adopted our technologies, and now lead us in this regard. We did not develop newer technology to overtake them. R & D shrunk to short term fixes. The mining & materials industries became the whipping boy of the government and the media.

Under these conditions, economic growth was constrained - consumer confidence disappeared in the era of hassle, recessions developed, and the wage and energy spirals led to inflation. Voters could believe either side depending on their wishes.

In 1970 the Mining and Mineral Policy Act became law and required an annual report on the state of the mineral industry. Both the law and the reports were ineffective.

In 1973 the National Commission on Materials Policy reported concern for the supply of materials and recommended actions to preserve such supplies.

After the shortages of 1974, the Commission on Supplies and Shortages reported in 1976 that the problem was not resource limitations but government policies.

In 1979 the G.A.O. reported that the future of the materials industry was dim because government actions have discouraged investment in domestic projects so that imports of zinc rose 89%, copper over 19% and aluminum by 50%. Basic U.S. materials industry is moving out of the U.S. where tax incentives and friendlier governments promote foreign investments.

Every step of the materials cycle is controlled by Federal Agencies which promulgated 19,366 new regulations in 1979. As a result, regulation controls the destiny of the U.S. materials industry. The total costs of Federal regulation to industry is estimated at $100 billion/yr. As the government grew by $100 billion/yr to $600/billion in 1980, the GNP has changed to an economy with only 43% in goods and products. $315 billion in transfer payments to 65 million people (7 million unemployed, 25 million poverty, 28 million retired*) are not included in the GNP. The government competes in a captive market against goods and products for the dollar of the taxpayer, who is required to pay taxes. Can a service dominated economy support 100 million workers with 65 million getting transfer payments?

With $500 billion in regulation costs and transfer payments, $95 billion in interest payments and $75 billion in government borrowing, it is no wonder imports are about $250 billion. The goods producing industry has been struggling through the recession without aid from the government and without sympathy from the press or the people (except those unemployed thereby). R & D concentrated on regulation. Innovation in new materials, processes and productivity disappeared.

Due to regulation lag and excessive costs for domestic products, the U.S. is importing large amounts of materials in the form of finished products and components. Most of these materials could be available from domestic sources. Due to the effect of imports on inflation, unemployment and the balance of payments, the true cost of imported materials is probably twice their import price.

Unmindful, the government did not intervene; but generated the National Materials and Minerals Policy Act of 1980 to restudy the question again. It is hopeful that the new administration will listen, understand and relieve the situation.

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*Poverty level can be calculated several ways which result in the poverty level population ranging from 11.5 to 25 million. There are 25 million over 62 years of age, but 33 million receive the original basic type of Social Security.

Laws friendly to interveners have increased the time lag for construction and the economic uncertainty of regulatory demands for new or expanded facilities. Inflation due to increased government spending ($100 billion/yr increase for last several years) and government borrowing which has limited available capital has led industry not only not to expand U.S. capacity but also to withdraw from the domestic materials business, as in the case of Anaconda who is shipping its copper to Japan.

What is the broad outlook for materials availability in the U.S.? World interdependence! Certainly for the critical materials: Chromium, cobalt, titanium, nickel, aluminum and tantalum.

Is this disasterous? Japan is dependent on imports for most materials and yet has a strong economy based on goods and products. Without large military costs, Japan can focus on economic growth through the import of raw materials, the export of high value-added products and yet with a concern for the environment -- through careful planning and unique cooperation between industry and government.

Perhaps the U.S. should seek similar cooperation and understanding between government and industry. Perhaps some of the $500 billion now spent by the government for non-productive purposes could be used to balance the budget, support innovation and productivity and return the U.S. to a position of leadership in technology.

Economic growth will not be restored, in my opinion, until we return to government-industry cooperation and confidence, until public protectionism is suppressed to the level which exists in Japan and West Germany (based on government-industry understanding and cooperation) and consumer confidence is restored based on a single set of facts (not controversies) coming from both industry and government, and finally, the media returns to the traditional role of accurately informing the public rather than seeking out only controversies.

The choice is before us. We need action, not studies or new laws. Let's get the existing regulations back to reality.

Development or disaster ..... Quo Vadis?

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CRITICAL AEROSPACE MINERAL MATERIALS

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•For: Dept. of Commerce Workshop on
Critical Materials Needs of the Aerospace Industry
Gaithersburg, Md.
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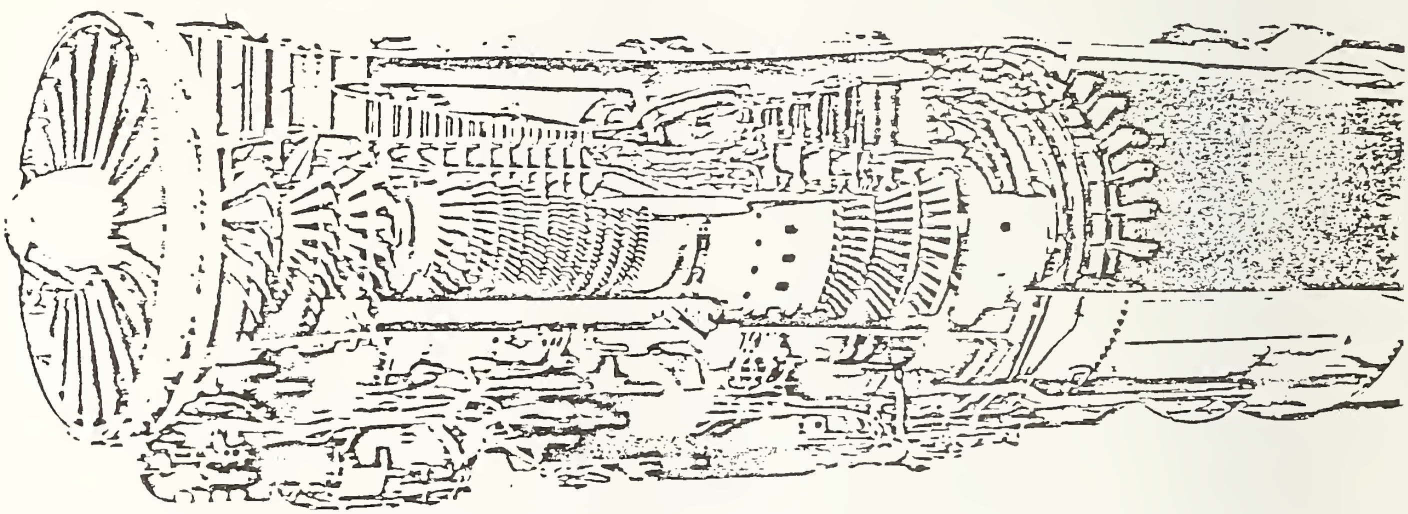
CRITICAL AEROSPACE MINERAL MATERIALS

Accelerating defense and energy programs can be expected to generate increased demands for such materials as chromium, cobalt, columbium, molybdenum, nickel, platinum, tantalum, and titanium; especially materials with resistance to high temperatures, corrosion, and erosion. For example, the Pratt & Whitney F-100 Turbofan engine (below) for the F-15 and F-16 planes requires 5366 lb of titanium, 5204 lb of nickel, 1656 lb of chromium, 910 lb of cobalt, 720 lb of aluminum, 171 lb of columbium, and 3 lb of tantalum. Table 1 and Appendix A provide more details on several important aerospace materials



The efficiency of thermodynamic processes is enhanced by increased temperature differentials and the number of elements with high melting points is very limited (Fig. 1). Even electric power generation in conventional steam power-plants will make unprecedented demands upon special property materials if air quality regulations are to be realized. At the present time in the United States over 565 million tons of coal are burned annually by electric utilities, and about half of our electricity is derived from coal. At least 15 tons of air are required to burn one ton of coal. If vigorous stack gas cleanup is to become a reality, 8 billion tons of hot corrosive gases will have to be handled. While the major constituents in powerplant stack gases are well known, mineral fuels contain many more elements when analyzed at the parts-per-million range, and these trace elements also will be found in some form in stack gases, fly ash, or bottom ash, requiring treatment to avoid environmental problems. Coal gasification and liquefaction, oil shale and tar sand development, magnetohydrodynamics, geothermal and ocean thermal energy, fission and fusion - all will call for special property materials.

Table 1. Selected 1980 Data
from "Mineral Commodity Summaries - 1981"
by U.S. Bureau of Mines.
(see Appendix A for more details)

COBALT

World Mine Production 29,800 ST
(0% U.S., 50% Zaire, 11% Zambia)

U.S. Use 8,800 ST
(45% superalloys, 15% electrical, 15% cutting tools)

U.S. Stockpile Inventory 20,402 ST (48% of goal)

U.S. "Reserve Base" 350,000 ST

NICKEL

World Mine Production 721,000 ST
(2% U.S., 18% Canada, 11% New Caledonia, 28% Central Economy)

U.S. Use 197,000 ST
(45% stainless and alloy steel, 40% nonferrous alloys)

U.S. Stockpile Inventory 0 (Goal is 200,000 ST)

U.S. "Reserve Base" 2,700,000 ST

TITANIUM METAL (see also Rutile)

World Sponge Production 92,000 ST
(27% U.S., 49% Central Economy, 22% Japan)

U.S. Use 27,000 ST
(60% aerospace, 20% alloys, 20% chemical etc.)

U.S. Stockpile Inventory 32,331 ST (17% of goal)

RUTILE

World Mine Production 472,000 ST
(few % U.S., 69% Australia, 12% Sierra Leone, 10% South Africa)

U.S. Use 250,000 ST
(79% TiO_2 pigment, 18% metal and glass)

U.S. Stockpile Inventory 39,000 ST (37% of goal)

U.S. "Reserve Base" 2,000,000 ST
(more common Ilmenite, $FeTiO_3$, could also be used)

COLUMBIUM

World Mine Production 24,500,000 lb
(0% U.S., 80% Brazil, 17% Canada, 2% Nigeria)

U.S. Use 7,400,000 lb

U.S. Stockpile Inventory 2,511,000 lb (52% of goal)

U.S. "Reserve Base" 0
(U.S. "Resources" 800,000,000 lb)

TANTALUM

World Mine Production 995,000 lb
(0% U.S., 34% Canada, 23% Brazil, 15% Australia)

U.S. Use 1,700,000 lb
(66% electronics, 26% machinery)

U.S. Stockpile Inventory 2,392,000 lb (33% of goal)

U.S. "Reserve Base" 0
(U.S. "Resources" 3,400,000 lb)

PLATINUM GROUP METALS

World Mine Production 6,740,000 tr. oz.
(0% U.S., 48% South Africa, 48% U.S.S.R.)

U.S. Use 2,962,000 tr. oz.
(35% automotive, 24% electrical, 14% dental)

U.S. Stockpile Inventory:
Iridium 17,000 tr. oz. (17% of goal)
Platinum 453,000 tr. oz. (35% of goal)
Palladium 1,255,000 tr. oz. (42% of goal)

U.S. "Reserve Base" 1,000,000 tr. oz.
(U.S. "Resources" 300,000,000 tr. oz., most in Mont. and Minn.)

CHROMIUM

World Mine Production - Chromite - 9,900,000 ST
(0% U.S., 37% Central Economy, 35% South Africa, 6% Philippines, 6% Zimbabwe)
(Chromite runs 22% to 38% chromium content)

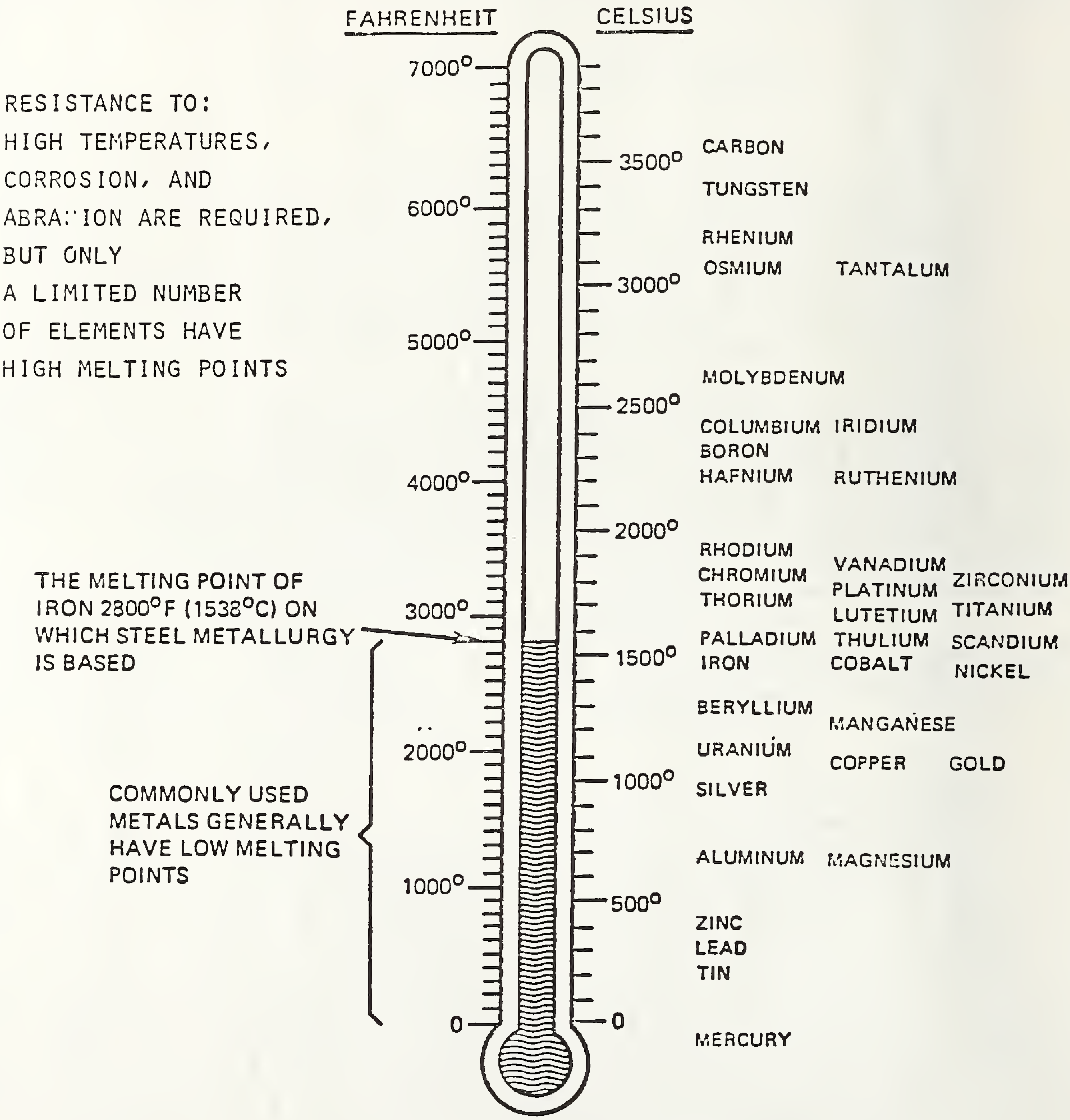
U.S. Use - Chromium - 530,000 ST
(62% metals, 22% chemicals, 16% refractories)

U.S. Stockpile Inventory:
Chemical & metallurgical 1,173,000 ST chromium (87% of goal)
Refractory ore 391,000 ST (46% of goal)

U.S. "Reserve Base" 0
(some "Resources" in Stillwater Complex, Mont., and beach sands in Ore.)

Fig. 1

NEW AND IMPROVED MINERAL-BASED MATERIALS ARE NEEDED FOR A WIDE VARIETY OF DEFENSE, AEROSPACE, AND ENERGY PROGRAMS SUCH AS: JET ENGINES, TURBINES, COAL GASIFICATION AND LIQUEFACTION, MAGNETOHYDRODYNAMICS, FISSION, FUSION AND POLLUTION CONTROL.



(THIS CHART SHOWS ALL KNOWN ELEMENTS WITH MELTING POINTS ABOVE IRON AND MAJOR METALS MELTING AT LOWER TEMPERATURES)

STRATEGIC VULNERABILITY

Assessments of strategic vulnerability must consider not only the position of the United States, but also that of its Allies. Nations and supranational groups with which we are closely allied are even more dependent upon imports for many strategic materials than is the United States (Fig. 2). In contrast, the COMECON bloc is largely self-sufficient - the result of a long-pursued policy of autarky on the part of the USSR, which, with an area of 8 1/2 million square miles is ideally situated for such a policy. Further, not just import dependence but also many other factors must be considered. Materials on hand in strategic stockpiles, other government stocks, and industry stocks are often significant. For example: the U.S. posture in several important materials such as tin, tungsten, manganese, and chromium would be quite different were it not for the strategic stockpile, which, however can only be called upon for defense purposes. Not part of the strategic stockpiles per se, large gold reserves held by the Treasury and large helium reserves held by the U.S. Bureau of Mines assure supplies in an emergency. Possibilities of substitutes and alternates must also be considered, as must the possible use of low-grade presently non-commercial domestic mineral deposits. For example: chromium has been recognized as an important strategic material ever since World War I. Over many years the U.S. Geological Survey and the U.S. Bureau of Mines helped to discover and to assess numerous domestic deposits. The Bureau produced chrome concentrates from domestic deposits as well as ferrochromium, chromite refractories, chromium metal, and chromium chemicals. Consequently, submarginal deposits could become sources of supply at some future time. Current Bureau research includes recovering chromium, nickel, and cobalt from laterite deposits and also from flue dusts, plating wastes, and other residues.

DEFENSE PRODUCTION ACT

The Defense Production Act of 1950, as amended, currently in effect through September 30, 1981, provides the basis for defense mobilization efforts. Title I of the DPAct provides specific authority for priorities and allocations, and Title III provides broad authority for expanding supplies of materials - making specific provisions for exploration, development, and mining of strategic and critical minerals and metals, and the development of substitutes for strategic and critical materials. In 1980 $3 billion was made available under the DPAct for synfuels, but no funding for nonfuel minerals is presently available. The creation or enlargement of domestic productive capacity, if it can be done at reasonable prices should in most cases provide greater flexibility than stockpiles. In fact, <u>one ton of domestic productive capacity is equal to three tons of stockpiled material under current stockpile planning.</u> During the Korean War DPAct supply expansion programs as of June 30, 1956, reached $8.4 billion in gross transactions with probable ultimate net cost of $0.9 billion. Major materials programs included:

Aluminum	$1.5 billion	Manganese	0.4 "	Cobalt	0.1 "
Titanium	0.9 "	Tungsten	0.4 "	Columbium-Tantalum	0.1 "
Rubber	0.9 "	Tin	0.2 "	Other materials (more than 50)	0.4 "
Nickel	0.9 "	Molybdenum	0.2 "		
Copper	0.7 "	Magnesium	0.1 "	($ 1 billion of machine tools was also covered)	

In a few years these programs doubled U.S. aluminum production, increased U.S. copper mine capacity by a quarter, initiated U.S. nickel mining, created the titanium industry, quadrupled U.S. tungsten mining, and greatly expanded the world columbium-tantalum mining and processing industries, as well as expanding supplies of many other materials for production needs and stockpiles. The latest major non-fuel use of the DPAct was an $83 million loan in 1967 in the Vietnam War period to facilitate the Duval Sierrita copper mine development.

Fig. 2

IMPORTS (NET) — % OF CONSUMPTION — 1977

(The 12 nonfuel minerals of the Nonfuel Mineral Policy Study)

6 STOCKPILING

Strategic stockpiles have played a major role in U.S. defense planning ever since World War II. The Strategic and Critical Materials Stock Piling Revision Act of 1979, PL 96-41, reaffirmed the need for stockpiling, conservation, and development of domestic sources. It specified that "the purpose of the stockpile is to serve the interest of national defense only and is not to be used for economic or budgetary purposes," and that "the quantities of the materials stockpiled should be sufficient to sustain the United States for a period of not less than three years in the event of a national emergency." The Act also reaffirmed the need to develop domestic resources. At current prices the overall stockpile status as of mid-1980 was about as follows:

$20 billion	-	cost of all goals
$ 8	"	- value of inventories toward goals
$12	"	- cost to complete all goals
$ 6	"	- value of excess materials that could be sold
$ 6	"	- additional financing needed

Table 2 lists the 93 materials singled out by the U.S. Government as "basic stockpile materials," largely on the basis of import vulnerability. Several of the 93 materials have been recognized as stockpile candidates ever since World War I, while newer ones have been added to the list only after research and development have proved their utility, such as titanium. 80 of the stockpile materials are of mineral origin and 13 are of agricultural origin. However, it would be fallacious to conclude that only the 93 are strategic. For example, neither steel, nor iron ore, nor coke, nor coking coal, nor limestone is on the stockpile list, yet steel is considered a highly strategic material in every modern economy. Despite the large domestic synthetic rubber industry developed in World War II, natural rubber, a major stockpile item, is still a preferred material for tires for aircraft and many off-the-road vehicles because it resists high temperatures and abrasion. Materials have been removed from the stockpile list because substitutes or alternates have been found. For example, hog bristles for paint brushes have been replaced by tapered nylon, and Egyptian extra long-staple cotten by domestic sea island cotton and/or synthetic fibers. The Federal Emergency Management Agency (FEMA) oversees stockpile management, while the General Services Administration (GSA) buys, sells, rotates, and stores stockpile materials.

TAX RELIEF

Also in the Korean War period accelerated amortization ("rapid write-offs" of capital expenditures), authorized by Sec. 168 of the Internal Revenue Code, was a powerful device to encourage capital investment in areas of national concern. This incentive alone was sufficient to add nearly one-quarter to U.S. steel capacity. In the period from October 1950 through December 1956, industrial expansion valued at $37 billion was certified, of which 61%, or $22 billion, was eligible for rapid amortization. The total amount then certified in materials-related industries was as follows:

Mining	$2.2 billion	
Primary metal industries	$5.7 "	
Chemical and allied products	$2.9 "	(Aircraft, machine tools,
Products of petroleum and coal	$3.0 "	presses and forges, etc.,
Pipeline transportation	$1.4 "	were also certified)

Use of the tax laws to encourage domestic production of strategic minerals is not limited to periods of war or national emergency. As a general rule, minerals considered more strategic are allowed higher percentage depletion rates. Exploration for minerals is also specifically encouraged by the tax laws.

Table 2. FEMA's STOCKPILE GOALS, (DESIRED INVENTORY MIX), AND INVENTORIES
AS OF JANUARY 1, 1981

Less-than-100% items are underlined,
and for these the % on hand is also shown

		Goal		Inventory
luminum Metal Group	48	7,150,000	ST Al	3,444,064
(Alumina)		0		0
(Aluminum)	0	700,000	ST	1,733
(Bauxite, Metal Grade, Jamaica Type)	42	21,000,000	LDT	8,858,881
(Bauxite, Metal Grade, Surinam Type)	87	6,100,000	LDT	5,299,596
luminum Oxide, Abrasive Grain Group	41	638,000	ST Abrasive Grain	259,124
(Aluminum Oxide, Abrasive Grain)		0	ST	50,904
(Aluminum Oxide, Fused, Crude)		0	ST	249,867
(Bauxite, Abrasive Grade)	0	1,000,000	LCT	0
ntimony		36,000	ST	40,730
sbestos, Amosite		17,000	ST	42,534
sbestos, Chrysotile		3,000	ST	9,958
auxite, Refractory	12	1,400,000	LCT	174,599
eryllium Metal Group	87	1,220	ST Be Metal	1,061
(Beryl Ore 11% BeO)		18,000	ST	17,987
(Beryllium Copper Master Alloy)	94	7,900	ST	7,387
(Beryllium Metal)	57	400	ST	229
ismuth	95	2,200,000	LB	2,081,298
admium	54	11,700,000	LB	6,328,809
astor Oil (Sebacic Acid)	23	22,000,000	LB	5,009,697
hromium, Chemical & Metallurgical Group	87	1,353,000	ST Cr Metal	1,173,230
(Chromite, Chemical Grade Ore)	36	675,000	SDT	242,414
(Chromite, Metallurgical Grade Ore)	78	3,200,000	SDT	2,488,043
(Chromium, Ferro, High Carbon)		185,000	ST	402,696
(Chromium; Ferro, Low Carbon)		75,000	ST	318,892
(Chromium, Ferro, Silicon)	65	90,000	ST	58,355
(Chromium, Metal)	19	20,000	ST	3,763
hromite, Refractory Grade Ore	46	850,000	SDT	391,414
obalt	48	85,400,000	LB Co	40,802,393
olumbium Group	52	4,850,000	LB Cb Metal	2,510,528
(Columbium Carbide Powder)	21	100,000	LB Cb	21,372
(Columbium Concentrates)	32	5,600,000	LB Cb	1,780,463
(Columbium, Ferro)		0	LB Cb	930,911
(Columbium, Metal)		0	LB Cb	44,851
opper	3	1,000,000	ST	29,048
ordage Fibers, Abaca	0	155,000,000	LB	0
ordage Fibers, Sisal	0	60,000,000	LB	0
iamond, Industrial Group		29,700,000	KT	42,929,316
(Diamond Dies, Small)	42	60,000	PC	25,473
(Diamond, Industrial, Crushing Bort)		22,000,000	KT	23,692,782
(Diamond, Industrial, Stones)		7,700,000	KT	19,223,798
eathers & Down	0	1,500,000	LB	0
luorspar, Acid Grade	64	1,400,000	SDT	895,983
luorspar, Metallurgical Grade	24	1,700,000	SDT	411,738
raphite, Natural - Ceylon, Amorphous Lump	87	6,300	ST	5,498
raphite, Natural - Malagasy, Crystalline	90	20,000	ST	17,911
raphite, Natural - Other than Ceylon & Malagasy		2,800	ST	2,802
odine		5,800,000	LB	8,013,074
Jewel Bearings	57	120,000,000	PC	68,772,719
ead	55	1,100,000	ST	601,036
anganese Dioxide, Battery Grade Group		87,000	SDT	247,827
(Manganese, Battery Grade, Natural One)		62,000	SDT	244,816
(Manganese, Battery Grade, Synthetic Dioxide)	12	25,000	SDT	3,011

		Goal		Inventory
Manganese, Chemical & Metallurgical Group		1,500,000	ST Mn Metal	1,586,581
(Manganese Ore, Chemical Grade)		170,000	SDT	221,044
(Manganese Ore, Metallurgical Grade)		2,700,000	SDT	3,378,713
(Manganese, Ferro, High Carbon)		439,000	ST	599,978
(Manganese, Ferro, Low Carbon)		0	ST	0
(Manganese, Ferro, Medium Carbon)		0	ST	28,920
(Manganese, Ferro, Silicon)		0	ST	23,574
(Manganese, Metal, Electrolytic)		0	ST	14,172
Mercury		10,500	Flasks	191,391
Mica, Muscovite, Block, Stained & Better	84	6,200,000	LB	5,212,444
Mica, Muscovite Film, 1st & 2nd Qualities		90,000	LB	1,274,495
Mica, Muscovite Splittings		12,630,000	LB	19,498,277
Mica, Phlogopite Block	62	210,000	LB	130,745
Mica, Phlogopite Splittings		930,000	LB	2,019,294
Molybdenum Group		0		0
(Molybdenum Disulphide)		0		0
(Molybdenum, Ferro)		0		0
Nickel	0	200,000	ST Ni + Co	0
Opium Group	55	130,000	AMA LB	71,303
(Opium Gum)		0	AMA LB	31,795
(Opium, Salt)	30	130,000	AMA LB	39,508
Platinum Group Metals, Iridium	17	98,000	TrOz	16,991
Platinum Group Metals, Palladium	42	3,000,000	TrOz	1,255,003
Platinum Group Metals, Platinum	35	1,310,000	TrOz	452,640
Pyrethrum	0	500,000	LB	0
Quartz Crystals		600,000	LB	2,423,036
Quinidine	18	10,100,000	Av Oz	1,800,462
Quinine	72	4,500,000	Av Oz	3,246,164
Rubber	14	850,000	LT	119,208
Rutile	37	106,000	SDT	39,186
Sapphire & Ruby		0	KT	16,305,502
Silicon Carbide, Crude		29,000	ST	80,548
Silver (fine)		0	TrOz	139,500,000
Talc, Steatite Block & Lump		28	ST	1,092
Tantalum Group	33	7,160,000	LB Ta Metal	2,391,940
(Tantalum Carbide Powder)		0	LB Ta	28,688
(Tantalum Metal)		0	LB Ta	201,133
(Tantalum Minerals)	30	8,400,000	LB Ta	2,551,302
Thorium Nitrate		600,000	LB	7,145,112
Tin		42,000	LT	200,452
Titanium Sponge	17	195,000	ST	32,331
Tungsten Group		50,666,000	LB W Metal	81,216,792
(Tungsten Carbide Powder)		2,000,000	LB W	2,032,942
(Tungsten, Ferro)		0	LB W	2,025,361
(Tungsten Metal Powder)		1,600,000	LB W	1,898,911
(Tungsten Ores & Concentrates)		55,450,000	LB W	88,436,637
Vanadium Group	6	8,700	ST V Metal	541
(Vanadium, Ferro)	0	1,000	ST V	0
(Vanadium Pentoxide)	7	7,700	ST V	541
Vegetable Tannin Extract, Chesnut		5,000	LT	16,835
Vegetable Tannin Extract, Quebracho		28,000	LT	143,541
Vegetable Tannin Extract, Wattle		15,000	LT	16,398
Zinc	26	1,425,000	ST	375,970

Source: FEMA

The use of flywheels to deliver power to offset sudden increases in load is accepted practice in machinery design, and the use of surge bins is standard practice in materials handling. Expanding such analogies to national economies points to the desirability of maintaining larger than normal working inventories to deal with unexpected interferences with normal supplies such as may be occasioned by politicoeconomic disruptions or such natural disasters as earthquakes, landslides, hurricanes, and floods. However, escalating costs and higher interest rates in recent years have tended to discourage the private sector from maintaining large inventories. Tax incentives for the maintenance of larger than normal working inventories have been in effect in Sweden for a number of years. In the Swedish system a large proportion of the acquisition costs of raw materials can be written off in computing taxable income for the year in which materials are acquired, in contrast to current U.S. practice, which limits deduction of raw material costs to the year in which materials are actually used. Such an incentive can cover the wide variety of materials in everyday use (for example, "chromium" can be metallurgical, chemical, or refractory ores from many sources; high-, medium-, or low-carbon ferrochromium, exothermic or electrolytic chromium metal; sodium bichromate; or even the chromium content of standard stainless steels as used in motor vehicle manufacture). Moreover, such an incentive permits informed judgments by numerous buyers and sellers, rather than requiring direct market intervention by government entities. Prudent materials users should base upon reliable sources of supply, and, if some materials supplies are deemed unreliable, they should have either alternative materials or alternative designs in hand, or they should build up larger than normal working inventories.

Extract from:
Morgan paper 800113 in
Society of Automotive Engineers
"Materials Availability for
Automotive Applications"
SP 462, Feb 1980

Sweden's tax provisions governing the valuation of inventories are designed to eliminate the taxation of merely inflationary profits and to permit the strengthening of corporate resources against the possibility of inventory price declines. Although provisions exist in other countries to accomplish the same purposes, none takes the same form as Sweden's.

The basic rule in Sweden is that the valuation of the inventory entered by the taxpayer in his books of account shall govern for tax purposes. However, the right to value inventories in the taxpayer's sound business discretion is subject to certain limitations established by the tax laws.

The main rule provides that a taxpayer, after first writing off all obsolete or unsaleable items in full, may write down the balance of the inventory by 60 per cent to a floor of 40 per cent of cost or market value, whichever is lower. Cost is determined on a first-in first-out basis.

The amount of this inventory write-down is deductible from taxable income.

Example:

A corporation has an inventory with a cost of SKr 1,100,000. Of this sum, items with a cost of SKr 100,000 are obsolete or unsaleable. This amount of SKr 100,000 may be written off for tax purposes. The cost of the remainder of the inventory is then SKr 1,000,000. Market value of the inventory is SKr 1,500,000. The corporation may take the lower of cost or market value—in this case, cost, or SKr 1,000,000—and write it down by 60 per cent, or SKr 600,000, to a book value of SKr 400,000. In addition to the sum of SKr 100,000 written off for obsolescence, the difference of SKr 600,000 is deductible from income for tax purposes. Thus it is available as a reserve or cushion in future years in the event of inventory price declines or recession.

The main rule governing inventory valuation is complemented by two supplementary rules. The first of these is the rule of "comparable value." If the value of the inventory at the end of a corporation's fiscal year, at cost or market and after deducting obsolete or unsaleable items, is less than the average of the value of the inventory at the close of the two prior years (this average value is called the "comparable value"), the corporation may write its inventory down by 60 per cent of that comparable value, rather than by 60 per cent of the value at the end of the income year in question.

The second supplementary rule relates to the valuation of raw materials or staple commodities in the inventory. The corporation has an option to value these inventory assets at the lowest market price in effect during the income year or in any of the nine previous years, and then to reduce that figure by 30 per cent to give an inventory valuation equal to 70 per cent of the ten-year low. If the corporation chooses to value raw materials or staple commodities in this way, it may not also take advantage of the rule of "comparable value" outlined above.

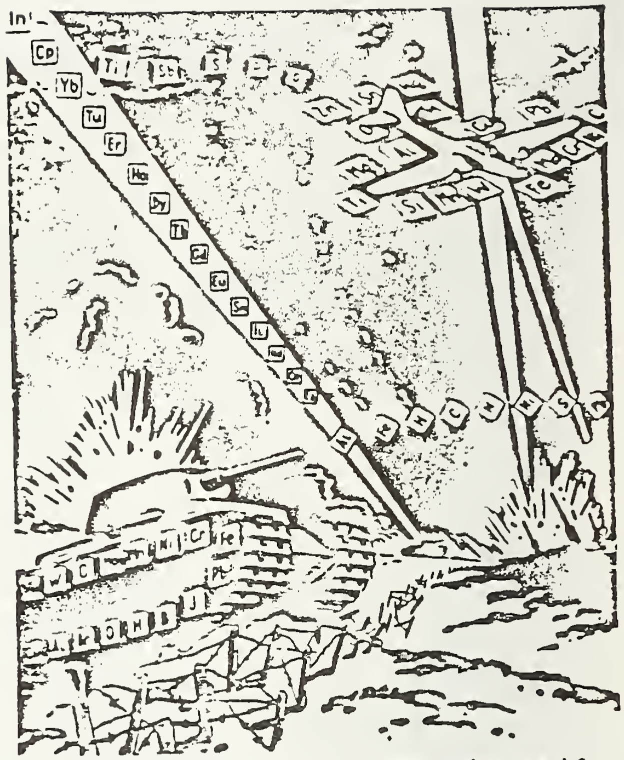
In any event, a corporation may always write its inventory down to its actual value despite the foregoing rules and take appropriate deductions from taxable income.

So far as the company's books are concerned, it is immaterial whether the amount of an authorized write-down is deducted directly from the cost or market value of the inventory on the asset side, or is set up instead as a reserve for inventory price decline on the liability side. The latter method is ordinarily used, however, when the use of the "comparable value" rule results in a negative inventory value.

A special provision, enacted in 1964, permits a Swedish parent company, selling inventory assets to a foreign subsidiary for further resale on the foreign market, to defer tax on profits attributable to goods which remain unsold in the hands of the subsidiary at the end of the parent's fiscal year. The parent may take a deduction from taxable income, by allocation to an "intercompany profit account", of an amount not exceeding the difference between (1) the price at which the parent sold these goods to the subsidiary (minus any amount of inventory write-down deducted by the subsidiary), and (2) the parent's cost of these goods. The allocation must be restored to taxable income during the following fiscal year; at the end of that year the question of a deduction for a renewed allocation is considered in view of the then existing circumstances.

"Section 4.2 - Inventory Valuation"
from
"The Tax System in Sweden"
published by
Skandinaviska Enskilda Banken,
Stockholm, Sweden Feb. 1972

REGULATION OF METALS AND MINERALS IN DEFENSE EMERGENCIES



Soviet chemistry textbook illustration, 1948

Pursuant to Executive Orders 10480 and 11490 under the Defense Production Act as amplified by Federal Register Document 67-1313, and Executive Order 12155 under the Stock Piling Act, the Department of the Interior is responsible for emergency readiness plans and programs for all non-fuel minerals. As set forth in detail in FR 67-1313, the Department of the Interior is, in general, responsible for mines, concentrating plants, and refineries, and for the ores, concentrates, and other materials treated in such facilities. The Department of Commerce is responsible for facilities and materials that are further along in the chain of processing and utilization, and it maintains the Defense Materials System to channel materials to defense and defense-related production. Steel, copper, aluminum, and nickel have long been designated as "controlled materials" and they are the basis for the "Defense Materials System" through which the Department of Commerce channels materials to defense rated orders. The Department of the Interior has chartered the Emergency Minerals Administration to carry out actual operations in the event of a major emergency, and the Emergency Minerals Administration is based upon the Bureau of Mines, with support as needed from the U.S. Geological Survey and other Interior units. In emergencies, the Department of the Interior operates under the direction of the Federal Emergency Management Agency (FEMA). FEMA, an independent agency, was created in 1979 to consolidate the emergency planning, civil defense, and disaster relief functions of the government.

The Bureau of Mines continuously monitors domestic production, imports, exports, stocks, and consumption of all major nonfuel minerals. Detailed reports are received monthly, quarterly, and/or annually from domestic mines, smelters, refineries, recyclers, and major users. Monthly import and export data are obtained from the U.S. Customs Service via the Bureau of the Census of the Department of Commerce. Bureau of Mines' experts continuously monitor developments in foreign supply areas. Every month the Bureau of Mines publishes for the guidance of government and industry its "Mineral Industry Surveys" which give up-to-date detailed statistics, and for several major important mineral materials monthly data are also summarized in the Bureau's "Minerals and Materials." A detailed review of U.S. and world production for more than 100 commodities is provided in the annual "Mineral Commodity Summaries," and special mineral commodity profiles giving details of world production, technology, reserves, resources, and outlook to the year 2000 are published as appropriate. As a result of its continual monitoring of mineral supply/demand and its technological competence, the Bureau of Mines has the framework needed to discharge priorities, allocations, and supply expansion responsibilities under the legislation cited earlier. The Bureau would also act as the claimant agency for the mineral sector of the economy to assure needed fuel, power, transportation, personnel, supplies, and equipment. To facilitate coordinated government action in the event of an emergency, the Bureau in 1975 organized nearly 100 interagency mineral commodity committees. These committees include experts from the Bureau of Mines, the U.S. Geological Survey, and one or more areas of State, Commerce, Defense, CIA, FEMA, GSA, Treasury, U.S. Trade Representative, Council of Economic Advisors, International Trade Commission, Commodity Futures Trading Commission, Council on Wage and Price Stability, and for certain commodities, Agriculture and Transportation. These committees would be promptly called upon in the event of any emergency.

In the event of a supply disruption, the first action to be taken would be to monitor exports, followed, if necessary, by export controls. The Export Administration Act of 1979 authorizes use of export controls to restrict exports detrimental to U.S. national security, to further U.S. foreign policy, or to protect the domestic economy from the excessive drain of scarce materials and to reduce the serious inflationary impact of foreign demand. The Secretary of Commerce is charged with monitoring exports and contracts for exports, of any nonagricultural good "when the volume of such exports in relation to domestic supply contributes, or may contribute, to an increase in domestic prices or a domestic shortage, and such price increase or shortage has, or may have, a serious adverse impact on the economy or any sector thereof."

A worsening supply situation would require imposition of a system of priorities, under Title I of the Defense Production Act, whereby rated orders would have to be filled first. If priorities proved to be inadequate, they would be followed by a system of allocations, also authorized by Title I. The Bureau of Mines and the Department of Commerce would implement priorities and allocations in their respective areas of responsibility.

At some point in a serious shortage situation recourse to the strategic stockpile might be required. The Stock Piling Act provides for release "(1) on the order of the President, at any time the President determines the release of such materials is required for purposes of the national defense; and (2) in time of war declared by the Congress or during a national emergency, on the order of any officer or employee of the United States designated by the President to have authority to issue disposal orders . . . if . . . required for purposes of the national defense." To release stockpiled materials, FEMA, in consultation with other agencies including the Bureau of Mines, would prepare a justification and recommendation for the President's signature. On receipt of the President's authorization, the Office of Stockpile Disposal of GSA would release the material to specified recipients.

Export controls, priorities and allocations, and stockpile releases, however, are only temporary measures of limited effectiveness. Any long-lasting supply disruption would call for supply expansion programs under Title III of the Defense Production Act. These would cover not only domestic deposits but also deposits in reliable foreign sources. The Bureau of Mines would recommend needed mineral supply expansion programs to FEMA, which would then direct GSA to make the necessary contractual arrangements.

CHROMIUM

(Data in thousand short tons gross weight, unless noted)

Domestic Production and Use: Although there was no domestic mine production of chromite in 1980, the United States continued to be one of the world's leading consumers. Chromite was consumed by seven firms producing chromium ferroalloys and metal; seven firms producing refractories; and three firms producing chromium chemicals. Most of these were in the Eastern United States. The metallurgical industry used 62%, chemical industry 22%, and the refractory industry 16%. Consumption of chromium by end use was as follows: Construction, 20%; machinery and equipment, 18%; transportation, 12%; refractories, 11%; and all other uses, 39%.

Salient Statistics--United States:	1976	1977	1978	1979	1980 e/
Production: - Chromite 1/	W	-	-	-	-
Imports for consumption: Chromite	1,275	1,336	1,013	1,024	990
Chromium ferroalloys 2/	259	228	322	243	350
Exports and reexports: Chromite	209	248	52	55	50
Chromium ferroalloys	14	12	19	15	20
Shipments from Govt. stockpile excesses: Chromite	311	517	-	-	-
Consumption (reported): Chromite	1,006	1,000	1,010	1,208	1,040
Chromium ferroalloys	417	453	500	543	410
Consumption of chromium (apparent) 3/	529	570	590	610	530
Price (yearend)					
Chromite - Turkish, per long ton, Turkey	$137	$137	$105	$110	$110
Chromite - South African, per metric ton, South Africa	$39	$59	$56	$56	$55
Consumer stocks: Chromite, yearend	1,009	1,339	1,300	907	750
Net import reliance 4/ as a percent of apparent consumption	89	91	91	90	91

1. Recycling: In 1980, estimated recycled chromium contained in purchased stainless steel scrap amounted to 9% of total chromium demand.

4. Import Sources (1976-79): Chromite: Republic of South Africa 40%, Philippines 15%, U.S.S.R. 16%, Turkey 10%, Other 19%. Ferrochromium: Republic of South Africa 62%, Yugoslavia 11%, Zimbabwe 9%, Japan 5%, Other 13%.

5. Tariff:

Item	Number	Most Favored Nation (MFN) 1/1/81	Most Favored Nation (MFN) 1/1/87	Non-MFN 1/1/81
Ore and concentrate	601.15	Free	Free	Free
Low-carbon ferrochromium	606.22	4% ad val.	3.1% ad val.	30% ad val.
High-carbon ferrochromium	606.24	.625¢/lb. chromium*	.625¢/lb. chromium	25% ad val.

*Until 11/15/81, 4.625¢/lb. on material valued less than 38¢/lb. of chromium.

6. Depletion Allowance: 22% (Domestic), 14% (Foreign).

7. Government Programs: Bureau of Mines research was being conducted on recovery of chromium from laterites and low-grade ores. Other Bureau studies concerned reclamation of chromium from stainless steel, recovery of chromium values from metallurgical and mining wastes, and conservation of chromium through surface alloying techniques.

Stockpile Status--11-30-80

Material	Goal	Total Inventory	Authorized For Disposal	Sales, 11 Months
Chromite:				
Metallurgical-grade	3,200	1,957	-	-
Chemical-grade	675	242	-	-
Refractory-grade	850	391	-	-
Chromium ferroalloys	350	759	-	-
Chromium metal	20	4	-	-

In addition to data shown, the stockpile contained the following nonstockpile-grade materials: 531,219 tons of metallurgical-grade chromite and 20,762 tons of chromium ferroalloys.

e/ Estimate. W Withheld to avoid disclosing company proprietary data. 1/ Chromite ore is typically from 22% to 38% chromium content. 2/ Chromium ferroalloys are typically from 36% to 70% chromium content. 3/ Calculated total demand for chromium. 4/ Net import reliance = imports - exports + adjustments for Government and industry stock changes.

Prepared by E. C. Peterson, telephone number (202) 634-1020.

T3-11

CHROMIUM

APPENDIX - CHROMIUM -

8. Events, Trends and Issues: Demand for chromium in 1980 dropped to about the same level as that of 1976 after a near record high in 1979, reflecting reduced demand in the steel industry, the major consumer of chromium. All three chromite-consuming industries were affected as consumption fell on an average of nearly 15% compared with that of 1979.

The published price of Turkish high-chromium chromite remained at $110 per metric ton while the price of Russian chromite continued to be suspended. South African high-iron chromite price in 1980 was $51 - $55 per metric ton, slightly less than the listed 1979 price. Ferrochromium prices moved somewhat higher. Along with other major consuming countries, the United States will continue to rely on imports of chromium. From a 1978 base, demand for chromium is expected to increase at an annual rate of about 3.2% through 1990.

International relationships in the future may influence the United States supply-demand position, as they have in the past. Increasing ferrochromium imports of the last few years compete with the domestic ferrochromium industry.

Environmental requirements for cleaner air impose economic problems for some processors. Disposal of reclaimed dust and slag remains a problem.

9. World Chromite Mine Production and Reserve Base:

	Mine Production 1979	Mine Production 1980 e/	Reserve Base*
United States	-	-	-
Finland	-	-	-
Philippines	210	200	28,000
South Africa, Republic of	620	590	3,300
Turkey	3,634	3,450	2,500,000
Zimbabwe (Rhodesia)	500	450	5,500
Other Market Economy Countries	597	550	1,100,000
Central Economy Countries	1,065	1,010	14,300
World Total	3,872	3,650	22,500
	10,498	9,900	3,700,000

10. World Resources: World resources total about 36 billion tons of shipping-grade chromite, sufficient to meet conceivable demand for centuries. Over 99% of these resources are in southern Africa; nearly 25 billion tons in the Republic of South Africa and over 11 billion tons in Zimbabwe. Although the rest of the world's resources are measured in millions of tons, they are small in comparison with those in Africa. Most of the United States chromium resources are in the Stillwater Complex in Montana and beach sands of Oregon. Renewal of substantial domestic chromite mining in the near future is doubtful.

11. Substitutes and Alternates: Some elements or materials may substitute for chromium in various end use applications, but cost consideration, performance standards, and customer appeal are major determining factors in use of chromium. Typical substitute possibilities are: Nickel, zinc, or cadmium for corrosion protection of iron and steel; aluminum and plastics for automotive decorative trim; nickel, cobalt, molybdenum, or vanadium for alloying iron and steel; titanium for chemical processing equipment; cadmium yellow pigment for protective coatings; and magnesite and zircon refractories for some refractory products.

* Pending establishment of criteria for the reserve base, classification of data is based on a judgmental appraisal of current knowledge and assumptions - See page 184 for definition.

January 1981

(Data in short tons of metal, unless noted)

1. Domestic Production and Use: Domestic mine production ceased at the end of 1979. Cobalt usually was recovered as a byproduct of either copper or nickel. Most secondary cobalt is derived from recycled superalloy or cemented carbide scrap. At midyear one foreign company started operation of a plant, located in Laurinburg, North Carolina, to produce extra fine cobalt powder. The single domestic refiner of cobalt was located in Louisiana. About 15 processors were active in the production of cobalt compounds in 1980. Industrial consumers totaled about 250, with the largest in New Jersey, Pennsylvania, New York, Ohio, Indiana, Illinois, and Michigan. Demand for cobalt declined; superalloys, mainly for industrial and aircraft gas turbine engines, accounted for about 45%; magnetic materials for various electrical applications about 15%; metal cutting and mining tool bits about 15%; catalysts 10%; driers 10%; and other 5% of reported consumption. Total estimated value of cobalt consumed in 1980 was $400 million.

2. Salient Statistics--United States:

	1976	1977	1978	1979	1980 e/
Production: Mine			N o n e		
Secondary	165	254	518	585	600
Imports for consumption	8,244	8,744	9,515	9,999	8,000
Exports e/	876	446	774	363	400
Shipments from Govt. stockpile excesses	3,349	74	—	—	—
Consumption: Reported	8,241	8,289	9,997	8,701	8,000
Apparent	9,920	9,155	10,128	9,403	8,800
Price (range, per lb.)	$4.00-5.40	$5.20-6.40	$6.40-20.00	$20.00-25.00	$25.00
Stocks: Industry, yearend	4,342	3,933	3,010	3,828	3,200
Employment: Mine			N o n e		
Net import reliance 1/ as a percent of apparent consumption	98	97	95	94	93

3. Recycling: About 600 tons of cobalt was recycled from purchased scrap in 1980. This represented about 8% of estimated reported consumption for the year.

4. Import Sources (1976-79): Zaire 42%, Belgium-Luxembourg 16%, Zambia 13%, Finland 6%, and Other 23%.

5. Tariff:

Item	Number	Most Favored Nation (MFN) 1/1/81	Most Favored Nation (MFN) 1/1/87	Non-MFN 1/1/81
Ore and concentrate	601.18	Free	Free	Free
Unwrought metal, waste and scrap	632.20	Free	Free	Free
Alloys, unwrought	632.86	9% ad val.	9% ad val.	45% ad val.
Chemical compounds:				
Oxide	418.60	1.2¢/lb.	1.2¢/lb.	20¢/lb.
Sulfate	418.62	1.4% ad val.	1.4% ad val.	6.5% ad val.
Other	418.68	5.8% ad val.	4.2% ad val.	20% ad val.

6. Depletion Allowance: 22% (Domestic), 14% (Foreign).

7. Government Programs: Bureau of Mines research was conducted on extraction of cobalt from laterites in Oregon, the Duluth gabbro in Minnesota, lead ores in Missouri, and high-arsenic sulfides in Idaho.

Stockpile Status--11/30/80

Material	Goal	Total Inventory	Authorized for Disposal	Sales, 11 Months
Cobalt	42,700	20,402	--	--

e/ Estimate.
1/ Net import reliance = imports - exports + adjustments for Government and industry stock changes.
2/ Data may not add to totals shown because of independent rounding.

Prepared by S. F. Sibley, telephone number (202) 634-1025.

8. Events, Trends, and Issues: The cobalt market remained in a relatively stabilized condition as producer prices stayed constant and demand softened considerably. Superalloys gained a greatly increased share of the cobalt market. The 70% allocation implemented by the major U.S. dealer on May 1, 1978, was lifted July 3, 1980. Producer stocks swelled with the decline in consumption, while consumer stocks dropped to relatively low levels. From a 1978 base, demand for primary cobalt is expected to increase at an average annual rate of 2.5% through 1990.

Development activity took place worldwide. A French mining company awarded a contract to an independent firm for engineering design of a nickel-cobalt plant to be built near Koumac, New Caledonia. A French government-owned company became the major shareholder in the dormant Tenke Fungurume copper-cobalt project in Zaire. The major Canadian nickel producer announced that it planned to build a plant to produce 2 million pounds per year of electrolytic cobalt to be on stream by early 1983. Additional expansions were announced in South Africa.

In June, a Belgian company's subsidiary in Laurinburg, N.C. opened a new facility to produce extra fine cobalt powder. Capacity of the plant is about 1 million pounds per year of cobalt.

The Ninth Session of the Third United Nations Conference on the Law of the Sea was held in Geneva in August, but no final treaty emerged from the conference. On June 28, the Deep Seabed Hard Mineral Resources Act (PL 96-283), allowing U.S. companies to begin commercial mining after January 1, 1988 for cobalt-bearing manganese nodules, was signed into law.

The producer price of cobalt remained at $25.00 per pound throughout the year. The spot price for cobalt fluctuated between $18 and $23 per pound.

The relatively low grade of resources was the principal impediment to development of domestic minerals. Since cobalt is a byproduct, environmental considerations are generally derived from the mining and processing of copper and nickel ores.

9. World Mine Production and Reserve Base:

	Mine Production 1979	Mine Production 1980 e/	Reserve Base* Quantity	Reserve Base* Grade of ore %
United States	—	—	350,000	0.01-0.8
Australia	1,700	1,700	50,000	0.08-0.12
Botswana	300	300	30,000	0.06
Canada	1,522	1,500	30,000	0.03-0.11
Finland	1,320	1,300	20,000	0.2
Morocco	1,000	1,000	50,000	1.2
New Caledonia	230	200	100,000	0.05
Philippines	1,430	1,400	200,000	0.03-0.12
Zaire	16,535	15,000	1,300,000	0.25-1.45
Zambia	3,500	3,400	400,000	0.09-0.4
Other Market Economy Countries	3,500	300	400,000	0.01-1.4
Central Economy Countries	3,900	3,700	450,000	0.05-0.15
World Total 2/	32,000	29,800	3,400,000	

10. World Resources: The identified cobalt resources of the United States are more than 700,000 tons, chiefly in the Midwest and Far West. The identified cobalt resources of the world are about 6 million tons. In addition, the world's hypothetical and speculative resources of cobalt in manganese nodules on the sea floor and in lateritic iron-nickel deposits of tropical regions amount to millions of additional tons.

11. Substitutes and Alternates: Nickel may be substituted for cobalt in several applications but only with a loss of effectiveness. Various potential substitutes include nickel, platinum, barium or strontium ferrite and iron in magnets; tungsten, molybdenum carbide, ceramics, and nickel in machinery; nickel and ceramics in jet engines; nickel in catalysts; and copper, chromium, and manganese in paints.

*Pending establishment of criteria for the reserve base, classification of data is based on a judgmental appraisal of current knowledge and assumptions - See page 184 for definition.

January 1981

COLUMBIUM

(Data in thousand pounds columbium content, unless noted)

1. Domestic Production and Use: There has been no domestic columbium mining industry since 1959. Metal, ferrocolumbium, other alloys, and compounds were produced by eight companies with nine plants. The basic raw material feed for these plants was imported concentrates and tin slags. Consumption was mainly as ferrocolumbium by the steel and aerospace industries located in the Eastern United States, California, and Washington. Total estimated value of shipments of domestically produced ferrocolumbium, nickel columbium, and metal was about $70 million. End uses as metal and alloys in fabricated form were: Construction, 33%; oil and gas industries, 14%; transportation, 32%; machinery, 13%; other, 8%.

2. Salient Statistics--United States:

	1976	1977	1978	1979	1980 e/
Mine production			None		
Imports for consumption:					
Concentrates, tin slags, and other 1/	2,497	2,433	2,418	2,827	3,200
Ferrocolumbium e/	2,221	2,676	4.159	5,515	5,100
Exports: Metal, alloys, waste, and scrap e/	34	38	48	50	60
Shipments from Government stockpile excesses	70	-	2/1	-	-
Consumption, reported:					
Raw material	2,722	2,427	2,673	2,402	2,400
Ferrocolumbium 3/	3,389	4,389	5,694	6,337	6,550
Consumption, apparent	6,003	4,777	6,585	6,997	7,400
Prices: Columbite 4/	$2.55	$3.18	$3.18	$5.34	$11.00
Pyrochlore 5/	$1.85	$2.42	$2.55	$2.55	$2.55
Industry stocks: Processor, dealer, and consumer, yearend	5,221	5,514	5,459	5,897	6,737
Employment: Processor e/	700	700	700	700	700
Net import reliance 6/ as a percent of apparent consumption	100	100	100	100	100

3. Recycling: Recycling of prompt industrial and obsolete scrap was insignificant.

4. Import Sources (1976-79): Brazil 66%, Canada 9%, Thailand 7%, Other 18%.

5. Tariff:

Item	Number	Most Favored Nation (MFN) 1/1/81	Most Favored Nation (MFN) 1/1/87	Non-MFN 1/1/81
Columbium oxide	423.0050 7/	4.7% ad val.	3.7% ad val.	25% ad val.
Columbium carbide	423.0094 7/	4.7% ad val.	3.7% ad val.	25% ad val.
Columbium concentrate	601.2100	Free	Free	Free
Ferrocolumbium	606.5300	5.0% ad val.	5.0% ad val.	25% ad val.
Columbium, unwrought:				
Metal, waste, and scrap 8/	628.1500	4.7% ad val.	3.7% ad val.	25% ad val.
Alloys	628.1700	6.9% ad val.	4.9% ad val.	25% ad val.
Columbium, wrought	628.2000	8.1% ad val.	5.5% ad val.	45% ad val.

6. Depletion Allowance: 22% (Domestic), 14% (Foreign).

e/ Estimate. NA Not available.
1/ Metal, alloys, and synthetic concentrates.
2/ Inventory adjustment.
3/ Includes nickel columbium and a small quantity of other columbium materials.
4/ Average price per pound of contained pentoxides for material having a Cb_2O_5 to Ta_2O_5 ratio of 10 to 1.
5/ Average price per pound of contained pentoxide in Brazilian pyrochlore.
6/ Net import reliance = imports - exports + adjustments for Government and industry stock changes.
7/ Non-specific class.
8/ Duty on waste and scrap suspended until July 1, 1981.
9/ Rounded.

Prepared by T. S. Jones, telephone number (202) 634-7091.

7. Government Programs:

Stockpile Status--11-30-80

Material	Goal	Total Inventory	Authorized For Disposal	Sales, 11 Months
Columbium:				
Carbide Powder	100	21	-	-
Concentrate	5,600	911	-	-
Ferrocolumbium	-	598	-	-
Metal	-	45	-	-

In addition to data shown, the stockpile contains 869 thousand pounds in nonstockpile grade columbium concentrate and 333 thousand pounds in nonstockpile grade ferrocolumbium.

8. Events, Trends, and Issues: Overall consumption of columbium continued to advance, but at a slackened pace. Leading the advance was a further increase in consumption of nickel columbium by the aerospace industry. About the same quantity of ferrocolumbium was consumed in steelmaking as in the previous year. Brazil, the main source of ferrocolumbium, added another dimension to its role as the foremost world source of columbium materials by initiating large-scale production of columbium oxide. Significant amounts of Brazilian oxide were among imported materials used in domestic production of ferrocolumbium and columbium metal and compounds. Using a proprietary process and nontraditional feedstocks, a fourth U.S. firm became a large-scale domestic source of columbium oxide. Imports of columbium concentrates rose, chiefly because of much greater shipments from Canada, where the sole producer was expanding capacity for pyrochlore concentrates. The price of regular grade ferrocolumbium was increased by about 14% beginning the second quarter of the year. However, prices were lowered by about 13% shortly thereafter for high-purity ferrocolumbium and nickel columbium, at least partly because of the expanded availability of columbium oxide. From a 1978 base, demand for columbium is expected to increase at an annual rate of about 6% through 1990.

There are no known uncontrollable health hazards connected with production or fabrication of columbium metals and compounds. Fumes, gases, dust, and low-level radiation generated by columbium-processing plants can be controlled by modern technology.

9. World Mine Production and Reserves:

	Mine Production 1979 e/	Mine Production 1980 e/	Reserve Base*
United States	-	-	-
Brazil	18,300	19,500	7,100,000
Canada	3,700	4,200	270,000
Nigeria	500	550	140,000
Zaire	20	20	70,000
Other Market Economy Countries	200	200	-
Central Economy Countries	NA	NA	NA
World Total (Excluding Central Economy Countries) 9/	22,700	24,500	7,600,000

10. World Resources: Most of the world's identified resources of columbium lie outside the United States and occur mainly as pyrochlore in carbonatite deposits. On a worldwide basis, resources are more than adequate to supply projected needs. The United States has approximately 800 million pounds of columbium located in identified deposits, which were considered uneconomic at 1980 prices for columbium.

11. Substitutes and Alternates: The following materials can be substituted for columbium: Vanadium and molybdenum in high-strength low-alloy steels; tantalum and titanium in stainless and high-strength steel and superalloys; molybdenum, tungsten, tantalum, and ceramics in high-temperature applications.

*Pending establishment of criteria for the reserve base, classification of data is based on a judgmental appraisal of current knowledge and assumptions - See page 184 for definition.

January 1981

NICKEL

(Data in short tons of metal, unless noted)

1. Domestic Production and Use: One firm in Oregon mined nickel and produced ferronickel. A second firm in Louisiana produced nickel metal from imported intermediate (matte) materials. Nickel was also produced as a byproduct of copper refining and from secondary sources. Secondary nickel was recovered from nickel-bearing alloys, stainless and alloy steel, and residues at copper smelters and refineries, foundries, and steel mills. A new facility converted stainless steel plant particulate wastes to stainless pig. The principal forms of primary nickel consumed were: Pure nickel metal, ferronickel, nickel oxide, and nickel salts. Major industrial consumers totaled about 200 with the largest ones in Pennsylvania, West Virginia, Ohio, Illinois, Michigan, Maryland, and New York. Major consumption occurred in the production of stainless and alloy steel, 45%; nonferrous alloys, 40%; and electroplating, 10%. Ultimate major end uses were: Transportation, 25%; chemical industry, 15%; electrical equipment, 15%; construction and fabricated metal products, 10% each; household appliances, 5%; other, 20%. The estimated value of primary nickel consumed in 1980 was $563 million.

2. Salient Statistics--United States:

	1976	1977	1978	1979	1980 e/
Production: Mine	16,469	14,347	14,485	15,065	16,000
Plant: Refined metal:					
From domestic ore 1/	13,869	12,897	11,298	11,691	12,500
From foreign matte	20,070	25,000	26,000	32,500	32,500
Secondary	52,199	50,491	44,182	57,400	40,000
Imports for consumption r/	188,147	194.770	240,032	183,742	170,000
Exports (primary forms)	15,372	16,618	16,599	23,949	20,000
Consumption: Reported (excludes most secondary)	162,927	155,260	180,723	196,293	165,000
Apparent (includes secondary) r/	243,000	255,000	278,000	232,000	197,000
Price range: Metal f. o. b. Port Colborne, Ont. (per lb.)	$2.20-2.41	$2.41-2.08	$2.08-2.03	$1.93-3.20	$3.20-3.45
Stocks: Consumer, yearend 2/	72,320	58,856	59,507	56,143	48,345
Producer, yearend 3/	NA	NA	NA	28,500	42,000
Employment: Mine e/	170	170	160	160	160
Smelter e/	250	230	230	230	230
Net import reliance 4/ as a percent of apparent consumption	72	71	80	69	73

3. Recycling: Recovery of secondary nickel from old and prompt industrial scrap was estimated at 40,000 tons in 1980 and accounted for 20% of total nickel demand. Of the scrap consumed, 50% was estimated as prompt industrial and 50% as obsolete.

4. Import Sources (1976-79): Canada, 52%; Norway, 10%; New Caledonia, 7%; Dominican Republic, 6%; Other, 25%. Norway's raw material was nickel-copper matte of Canadian origin.

5. Tariff:

Item	Number	Most Favored Nation (MFN) 1/1/81	Most Favored Nation (MFN) 1/1/87	Non-MFN 1/1/81
Nickel ore and concentrates	601.36	Free	Free	Free
Nickel oxide	419.72	Free	Free	Free
Ferronickel	607.25	Free	Free	3¢/lb.
Unwrought nickel	620.03	Free	Free	3¢/lb.
Waste and scrap	620.04	Free	Free	3¢/lb.
Nickel powders	620.32	Free	Free	3¢/lb.
Nickel flakes	620.30	4.4¢/lb.	Free	14¢/lb.
Other, over 10% nickel	603.60	Free	Free	Free

6. Depletion Allowance: 22% (Domestic), 14% (Foreign).

e/ Estimate. r/ Revised (1/30/81).
1/ Includes byproduct nickel from primary copper operations.
2/ Includes stocks held by the U.S. Mint.
3/ Stocks of producers or producers' representatives held in the United States only.
4/ Net import reliance = imports - exports + adjustments for Government and industry stock changes

Prepared by S. F. Sibley, telephone (202) 634-1025.

NICKEL

7. Government Programs: The cost-sharing contract placed by the Bureau in 1978 continued, with demonstration plant-scale processing tests on Western laterites. Research continued on the extraction of nickel from the Duluth gabbro in Minnesota, with emphasis on process waste control, and the extraction of nickel and cobalt from Missouri lead ores.

Stockpile Status—11-30-80

Material	Goal	Total Inventory	Authorized For Disposal	Sales, 11 Months
Nickel	200,000	-	-	-

8. Events, Trends, and Issues: Domestic primary nickel consumption in 1980 was estimated to have decreased about 15% from that consumed in 1979. Consumer stocks also declined substantially. Domestic and foreign producer stocks increased above relatively normal level. Some foreign operations cut back production or temporarily shut down facilities in order to keep stocks down. Consumption of unwrought nickel and ferronickel decreased substantially, as significant reductions occurred in consumption of nickel in stainless steel, other nickel alloys and electroplating.

From a 1978 base, total demand for nickel is expected to increase at an annual rate of about 4% through 1990. Domestic mine production of nickel should remain at a level about the average for the last 5 years and supply approximately 7% of the primary nickel demand. The price for nickel cathode was raised from $3.20 to $3.45 per pound on February 28. It remained at that level through yearend. A 6% discount was applied to nickel cathode by the major producers early in November and was expected to continue in effect at least through yearend.

A Canadian government control order was issued in September, setting limits on sulfur dioxide emissions at the nickel smelter of a Canadian company at Sudbury, Ontario. Under the order, emissions of sulfur dioxide were to be reduced to 2,500 tons per day effective immediately, thereby restricting production capacity to 280 million pounds per year. The Ninth Session of the Third United Nations Conference on the Law of the Sea was held in Geneva in August, but ended without a final treaty emerging from the meeting. Further sessions were scheduled for 1981. On June 28, the Deep Seabed Hard Mineral Resources Act (PL96-283) allowing U.S. companies to begin commercial mining after January 1, 1988, for cobalt-bearing manganese nodules, was signed into law.

9. World Mine Production and Reserve Base:

	Mine Production 1979	Mine Production 1980 e/	Reserve Base* Quantity	Reserve Base* Grade of ore %
United States	15,065	16,000	2,700,000	0.2-1.3
Canada	145,040	130,000	8,600,000	1.5-3
New Caledonia	89,550	80,000	15,000,000	1-3
Other Market Economy Countries	318,061	290,000	22,000,000	0.2-4.0
Cuba e/	40,800	40,000	3,400,000	1.4
Other Central Economy Countries	168,000	165,000	8,100,000	0.4-4.0
World Total	776,516	721,000	59,800,000	

10. World Resources: Identified world resources in deposits averaging approximately 1% nickel or greater are 143 million tons of nickel. Of this, 80% (115 million tons) is in laterites and 20% (28 million tons) is in sulfide deposits. World resources from lower grade nickel deposits are very large. The United States, for example, has sulfide deposits containing more than 7 billion tons of material averaging 0.2% nickel. Peridotites and serpentinites containing 0.2 to 0.4% nickel in less concentratable form are widely distributed throughout the world. In addition, there are extensive deep-sea resources of nickel in the form of manganese nodules covering large areas of ocean floors, particularly in the Pacific Ocean.

11. Substitutes and Alternates: With few exceptions, substitutes for nickel would require increased cost or some sacrifice in the economy or performance of the product. Potential nickel substitutes include aluminum, coated steel, and plastics in the construction and transportation industries; nickel-free specialty steels in power, petrochemical, and petroleum industries; titanium and plastics in severe corrosion service applications; and platinum, cobalt, and copper in some catalytic uses.

Pending establishment of criteria for the reserve base, classification of data is based on a judgmental appraisal of current knowledge and assumptions - See page 184 for definition.

January 1981

PLATINUM-GROUP METALS

(Platinum, Palladium, Iridium, Osmium, Rhodium, Ruthenium)
(Data in thousand troy ounces, unless noted)

1. Domestic Production and Use: Domestic primary production was a byproduct of copper refining by three firms; output was valued at about $1.5 million. Secondary metal was refined by about 30 firms, mostly in the East and Midwest. The platinum-group metals were sold by at least 90 processors and retailers, largely in the Northeast, and were distributed among using industries as follows: Automotive, 35%; electrical, 24%; chemical, 14%; dental, 10%; and other, 17%. The automotive, chemical, and petroleum refining industries used the platinum-group metals mainly as catalysts; other industries used the metals in a variety of ways that took advantage of their chemical inertness and refractoriness.

2. Salient Statistics--United States:

	1976	1977	1978	1979	1980 e/
Production: Mine	6	6	8	7	6
Refinery: New	7	5	10	9	6
Secondary	215	195	257	309	345
Imports for consumption	2,667	2,510	2,921	3,479	3,370
Exports	512	427	703	900	750
Shipments from Govt. stockpile excesses			None		
Consumption (reported sales to industry)	1,603	1,592	2,260	2,756	2,200
Apparent consumption	2,140	2,357	2,635	2,995	2,962
Price: (dollars per ounce) 1/					
Platinum (average)	162	162	237	352	439
Palladium (average)	51	60	71	113	216
Stocks, yearend (refiner, importer & dealer)	1,086	1,013	861	761	950
Employment: Refinery e/	350	350	350	375	400
Net import reliance 2/ as a percent of apparent consumption	90	91	90	89	87

3. Recycling: In 1980, about 345,000 ounces of platinum-group metals were refined from scrap, an amount equivalent to 16% of sales to industry. The quantity of toll-refined secondary was much larger, amounting to more than 1 million ounces.

4. Import Sources (1976-79): Republic of South Africa 53%, U.S.S.R. 22%, United Kingdom 12%, Other 13%.

5. Tariff:

Item	Number	Most Favored Nation (MFN) 1/1/81	Most Favored Nation (MFN) 1/1/87	Non-MFN 1/1/81
Ore	601.39	Free	Free	Free
Plat.-group metals	605.02,605.07	Free	Free	Free
Alloys	605.03,605.08	17.1% ad valorem	8.2% ad valorem	65% ad valorem
Scrap	605.70	Free	Free	Free

6. Depletion Allowance: 22% (Domestic), 14% (Foreign).

7. Government Programs: The Bureau of Mines conducted research on the processing of domestic platinum-group metals ores, on recovery from electronic scrap, and on electrodeposition of platinum-group metal coatings. More stringent automobile emission standards for 1981 models, which increased the demand for platinum-group metals in exhaust systems, were required by the Environmental Protection Agency.

Stockpile Status--11-30-80

Material	Goal	Total Inventory	Authorized For Disposal	Sales, 11 Months
Platinum	1,310	453	-	-
Palladium	3,000	1,255	-	-
Iridium	98	17	-	-

e/ Estimate. NA Not available. 1/ Producer price.
2/ Net import reliance = imports - exports + adjustment for Government and industry stock changes.

Prepared by W. C. Butterman, telephone number (202) 634-1071.

8. Events, Trends, and Issues: In 1980, world production of platinum-group metals was about 6.7 million troy ounces, up about 1% from 1979. The Republic of South Africa increased output slightly during the year and, together with the U.S.S.R., accounted for more than 95% of the world total. Canadian production, which is a byproduct of copper/nickel mining, remained low for the second year because of curtailed nickel production. U.S. output continued to be derived solely as a byproduct of copper refining.

Sales of platinum-group metals to U.S. industries dropped 20% in 1980 to about 2.2 million ounces. Use as catalysts in automobile exhaust converters was again the largest single end use. From a 1978 base, demand in the U.S. is expected to increase at an annual rate of about 3.1% through 1990.

Imports, which account for essentially all of the annual U.S. requirement for primary platinum-group metals, dropped 3%, to about 3.4 million ounces. The Republic of South Africa was the most important source, followed by the United Kingdom (which has no mine production, but is an important processor of concentrates imported from the Republic of South Africa and Canada), and the U.S.S.R.

Dealers' prices for the platinum-group metals, as reported in Metals Week, climbed steeply in the first weeks of 1980. Dealers' prices for platinum and palladium peaked once in the third week of January, and then reached record highs in the first week of March (platinum $985 per ounce, palladium $300 per ounce), after which the palladium dealers' price quickly dropped below the producers' price, while the platinum dealers' price remained substantially above the producers' price. The platinum producers' price was $420 until August 28, when it went to $475; the palladium producers' price changed from $150 to $175 on January 29, and then to $225 on February 28.

Exploration and evaluation of the platinum-group metal resources in the Stillwater Complex, Montana, currently the only U.S. deposit where significant production of these metals is possible, continued. Although U.S. deposits may be developed, it is unlikely that domestic production could satisfy domestic demand. Environmental factors concerning domestic production are those associated with copper production.

9. World Mine Production and Reserve Base:

	Mine Production 1979	Mine Production 1980 e/	Reserve Base*
United States	7	6	1,000
Canada	185	220	9,000
South Africa, Republic of	3,200	3,250	970,000
Other Market Economy Countries	68	64	NA
U.S.S.R.	3,200	3,200	200,000
World Total	6,660	6,740	1,180,000

10. World Resources: World resources of the platinum-group metals are estimated to be about 3.2 billion troy ounces, 2.7 times the estimated reserves, and 20 times the forecast demand for primary metal in the period 1980-2000. Total U.S. resources are estimated at about 300 million troy ounces, most of which occur in Montana and Minnesota.

11. Substitutes and Alternates: Potential substitutes: Gold, silver, and tungsten in electrical/electronic uses; gold in dental uses; metals, such as the rare-earth elements, nickel, vanadium, and titanium, and molecular sieves, in catalytic uses. New and/or improved engines and fuels, and electric automobiles, could reduce or eliminate the use of platinum-group metals in emission control catalysts in automobiles.

* Pending establishment of criteria for the reserve base, classification of data is based on a judgmental appraisal of current knowledge and assumptions - See page 184 for definition.

TANTALUM

(Data in thousand pounds tantalum content, unless noted)

1. Domestic Production and Use: There has been no domestic tantalum mining industry since 1959. Metal, alloys, and compounds were produced by seven companies with eight plants; tantalum units were obtained from imported concentrates and tin slags, and from both foreign and domestic scrap. Consumption in the form of metal, powder, ingot, fabricated forms, and compounds and alloys, had the following end uses: Electronic components, 66%; machinery, 26%; and transportation, 8%. Total estimated value of domestic shipments of metal, alloys, and compounds was $320 million.

2. Salient Statistics--United States:

	1976	1977	1978	1979	1980 e/
Mine production			None		
Imports for consumption: Concentrate, tin slags, and other 1/	1,310	2,058	1,409	1,914	2,500
Exports: Concentrate, metal, alloys, waste, and scrap e/	443	539	607	721	750
Shipments from Government stockpile excesses	8	2/-4	2/1	-	-
Consumption, reported: Raw material	1,485	1,448	1,571	1,740	1,700
Consumption, apparent	1,328	1,476	1,114	1,439	1,480
Price: Tantalite 3/	$16.63	$21.00	$28.00	$65.50	$104.00
Industry stocks: Processor and dealer, yearend	4,188	4,096	3,841	2,753	3,073
Employment: Processor e/	600	600	600	600	600
Net import reliance 4/ as a percent of apparent consumption	96	97	97	96	97

3. Recycling: Prompt industrial and old (obsolete) scrap consumed totaled about 50,000 pounds, which was about 3% of total raw materials consumed. Production of new scrap was estimated at more than 400,000 pounds, most of which was consumed by processors.

4. Import Sources (1976-79): Thailand 35%, Canada 13%, Malaysia 10%, Brazil 4%, Other 38%.

5. Tariff:

Item	Number	Most Favored Nation (MFN) 1/1/81	Most Favored Nation (MFN) 1/1/87	Non-MFN 1/1/81
Potassium fluotantalate	420.3620	3.8% ad val.	3.1% ad val.	25% ad val.
Tantalum concentrate	601.4200	Free	Free	Free
Synthetic tantalum/columbium concentrate	603.6700	Free	Free	30% ad val.
Tantalum, unwrought:				
Waste and scrap 5/	629.0520	4.7% ad val.	3.7% ad val.	25% ad val.
Metal	629.0540	4.7% ad val.	3.7% ad val.	25% ad val.
Alloys	629.0700	6.9% ad val.	4.9% ad val.	25% ad val.
Tantalum, wrought	629.1000	8.1% ad val.	5.5% ad val.	45% ad val.

6. Depletion Allowance: 22% (Domestic), 14% (Foreign).

7. Government Programs: Stockpile Status--11-30-80

Material	Goal	Total Inventory	Authorized For Disposal	Sales, 11 Months
Carbide powder	-	29	-	-
Metal	-	201	-	-
Minerals	8,400	1,399	-	-

In addition to data shown, the stockpile contains a negligible quantity in nonstockpile grade metal and 1,152 thousand pounds in nonstockpile grade minerals.

e/ Estimate. NA Not available.
1/ Metal, alloys, and synthetic concentrates.
2/ Inventory adjustment.
3/ Average price per pound of contained tantalum pentoxide, 60% basis.
4/ Net import reliance = imports - exports + adjustments for Government and industry stock changes.
5/ Suspended until July 1, 1981.
6/ Tin slags production not available.

Prepared by T. S. Jones, telephone number (202) 634-7091.

TANTALUM

8. Events, Trends, and Issues: Price and the question of price stability continued as central issues for tantalum. The year-average spot price for tantalite was over 50% higher than that for 1979; the price of domestic mill products advanced to over $200 per pound. These developments were accompanied by further reports of substitution away from tantalum in capacitors, especially by aluminum, and of reduction of tantalum usage in cemented carbides, at least partly because of wider use of coatings for cutting tools. Tantalum source materials continued to be of foreign origin. Concentrate imports were up significantly, especially those from Brazil. Developments affecting world tantalum supply included mine expansions underway or announced in Canada and Australia. An emerging trend toward upgrading of raw materials by the host country, at least to intermediates, was evident both in Thailand and Australia. From a 1978 base, demand for tantalum is expected to increase at an annual rate of about 4% through 1990.

There are no known health hazards connected with production or fabrication of tantalum metals and compounds. Fumes, gases, dust, and low-level radiation generated by extracti[on] plants can be easily controlled by modern technology.

9. World Mine Production and Reserve Base:

	Mine Production (Concentrate only 6/) 1979 e/	1980 e/	Reserve Base*
United States	-	-	-
Australia	120	150	5,000
Brazil	200	230	7,000
Canada	285	340	2,000
Malaysia	10	15	8,000
Mozambique	67	70	NA
Nigeria	71	80	16,000
Thailand	35	40	10,000
Zaire	15	15	82,000
Other Market Economy Countries	52	55	4,000
Central Economy Countries	NA	NA	NA
World Total (Excluding Central Economy Countries)	855	995	134,000

10. World Resources: Most of the world's resources of tantalum occur outside the United States. On a worldwide basis, identified resources of tantalum are considered adequate to meet projected needs. These resources are largely located in Zaire, Rwanda, Nigeria, Brazil, Canada, Thailand, Malaysia, and Australia. The United States has about 3.4 million pounds of tantalum located in identified deposits, which were considered uneconomic at 1980 prices.

11. Substitutes and Alternates: The following materials can be substituted for tantalum: Columbium in superalloys and carbides; aluminum and ceramics in electronic capacitors; silicon, germanium, and selenium in electrical rectifiers; glass, titanium, zirconium, columbium, and platinum in corrosion-resistant equipment; tungsten, rhenium, molybdenum, iridium, hafnium, and columbium in high-temperature applications.

* Pending establishment of criteria for the reserve base, classification of data is based on a judgmental appraisal of current knowledge and assumptions - See page 184 for definition.

January 1981

1. Domestic Production and Use: Sponge metal was produced by three firms at plants in Ohio, Oregon, and Nevada. Ingot was made by the three sponge makers and by five firms located in California, Michigan, North Carolina, and Pennsylvania. Eighteen companies produced titanium mill products; 12 of them were located in the east-central region and the others in California, Oregon, and Nevada. In 1980, about 60% of the titanium metal was used in jet engines, airframes, and space and missile applications. Of the remainder, about half was used in the chemical processing industry, power generation, and in marine and ordnance applications, and half in steel and other alloys. The value of sponge metal consumption in 1980 was about $300 million.

Titanium dioxide pigment was produced by six companies at 12 plants in eight States. In 1980, uses of titanium dioxide were in paints, varnishes, and lacquers, 50%; paper 23%; plastics 12%; rubber 3%; ceramics 2%; and other uses 10%. The value of titanium dioxide consumption in 1980 was about $900 million.

2. Salient Statistics--United States:

	1976	1977	1978	1979	1980 e/
Metal:					
Production	W	W	W	W	W
Imports for consumption, sponge	1,778	2,387	1,476	2,488	4,500
Exports (mainly scrap)	7,209	4,444	7,789	8,602	8,800
Shipments from Govt. stockpile excesses	-	-	-	-	-
Consumption of primary metal, reported	13,[illegible]	16,236	19,854	23,937	27,000
Price: Sponge, per pound, yearend	$2.70	$2.98	$3.28	$3.98	$7.02
Stocks: Sponge, industry, yearend	3,617	3,546	2,642	2,155	2,000
Employment: Reduction plants	900	1,100	1,400	1,700	1,900
Net import reliance 2/ as a percent of apparent consumption	W	W	W	W	W
Titanium Dioxide:					
Production	712,940	687,103	700,755	724,887	727,000
Imports for consumption	68,497	114,810	117,708	104,968	106,000
Exports	20,580	16,336	37,812	49,369	49,500
Apparent consumption	753,947	785,003	801,728	810,218	757,000
Price: Rutile, per pound, yearend	0.465	0.485	0.510	0.590	0.630
Stocks: Producer, yearend	113,873	114,447	93,370	63,638	90,000
Employment	4,900	4,900	4,200	4,800	4,600
Net import reliance 2/ as a percent of apparent consumption	5	12	12	13	14

3. Recycling: New scrap metal recycled was 19,000 short tons in 1980, including estimated use of scrap and ferrotitanium by the steel industry, 3,000 short tons; by the aluminum industry, 700 short tons; and in miscellaneous alloying uses, 400 short tons. Old scrap reclaimed was about 100 to 400 tons. There was no known recycling of titanium dioxide.

4. Import Sources (1976-79): Sponge metal: Japan 72%, U.S.S.R. 21%, United Kingdom 6%, China 1%.
Titanium dioxide pigment: Federal Republic of Germany 35%, Canada 16%, United Kingdom 15%, Belgium 7%, Other 27%.

5. Tariff:

	Number	Most Favored Nation (MFN) 1/1/81	Most Favored Nation (MFN) 1/1/87	Non-MFN 1/1/81
Waste and scrap metal	629.12	15.3% ad val.	7.2% ad val.	25% ad val.
Unwrought metal	629.14	18% ad val.	15% ad val.	25% ad val.
Wrought metal	629.20	18% ad val.	15% ad val.	45% ad val.
Titanium dioxide	473.70	7.1% ad val.	6% ad val.	30% ad val.

e/ Estimate. W Withheld to avoid disclosing company proprietary data.
1/ See also Ilmenite and Rutile.
2/ Net import reliance = imports - exports + adjustments for Government and industry stock changes.
3/ The suspension of duty on waste and scrap was extended until June 30, 1981, as provided by P. L. 95-508.
4/ Excludes U.S. production.

Prepared by L. E. Lynd, telephone number (202) 634-1073.

6. Depletion Allowance: Not applicable.

7. Government Programs:

Stockpile Status--11-30-80

Material	Goal	Total Inventory	Authorized For Disposal	Sales, 11 Months
Specification sponge metal	195,000	21,465	-	-

In addition to data shown, the stockpile contains 10,866 tons of nonstockpile grade sponge metal.

8. Events, Trends, and Issues: Production of titanium sponge increased 12% from that of 1979, with a 7% reduction in industry inventories. The market for titanium sponge remained strong, mainly because of continued heavy demand for commercial aircraft production. The supply of sponge eased as production capacities were increased 13% in the United States and 53% in Japan. U.S. imports were about 80% higher than in 1979. From a 1979 base, demand for titanium sponge is expected to increase at an average annual rate of about 5% through 1990.

Announced plans for expansion or new construction of sponge metal facilities could bring U.S. annual capacity to 34,000 tons by 1985.

From a 1979 base, demand for titanium dioxide is expected to increase at an annual rate of about 3% through 1990. Production began at the new 150,000-ton-per-year chloride-process pigment plant at DeLisle, Miss., and was to be increased gradually as demand grows. Two other producers announced plans to increase pigment capacity by a total of about 15,000 tons per year in 1981.

A major problem area in the titanium dioxide industry is the disposal of waste acid and ferrous sulfate from the sulfate process which uses ilmenite or slag as feed material. Although some ocean disposal of these wastes is still practiced, two companies now treat their sulfate plant waste effluent with calcium carbonate and lime, producing a gypsum byproduct which they sell to wall board and cement manufacturers. The chloride process, which uses high grade ilmenite, leucoxene, rutile, and synthetic rutile, produces much less waste material than does the sulfate process.

9. Sponge Metal Production and Sponge and Pigment Capacity:

	Sponge Production 1979	Sponge Production 1980 e/	Capacity 1980 Sponge	Capacity 1980 Pigment
United States	W	W	26,500	1,022,000
Germany, Federal Republic of	-	-	-	364,000
United Kingdom	2,600	2,600	3,000	276,000
Japan	14,000	20,000	23,500	237,000
France	-	-	-	88,000
Finland	-	-	-	88,000
Other Market Economy Countries e/	-	-	-	521,000
Central Economy Countries e/	43,000	45,000	47,000	200,000
World Total	4/59,600	67,600	100,000	2,796,000

10. World Resources: The source of titanium for domestic sponge production is rutile and for pigment production is ilmenite, slag, and rutile. The U.S.S.R. reportedly uses a high grade titaniferous slag for sponge metal production.

11. Substitutes and Alternates: For aircraft and space use there is essentially no substitute for titanium. For industrial uses high-nickel steel and to a limited extent the superalloy metals may be substituted. There is no cost-effective substitute for titanium dioxide pigment.

January 1981

APPENDIX - TITANIUM

RUTILE 1/

(Data in thousand short tons of concentrates, unless noted)

1. Domestic Production and Use: Rutile was produced at one Florida mine in 1980. At two other mines in Florida, rutile was included in a bulk concentrate containing mostly ilmenite and/or leucoxene. The major coproduct of these titanium minerals is zircon. Of 31 consuming firms located mainly in the Eastern United States, five companies used 79% of the rutile consumed to make titanium dioxide pigment. Three firms in N. .d, Ohio, and Oregon used titanium tetrachloride made from rutile to manufacture titanium metal. Welding rod coatings consumed 3%; miscellaneous applications, which include titanium metal and glass fibers, 18%.

2. Salient Statistics--United States:

	1976	1977	1978	1979	1980 e/
Production	W	W	W	-	W
Imports for consumption 2/	282	124	290	283	235
Exports	5	1	NA	10	4
Shipments from Gvt. stockpile excesses	-	-	-	-	-
Consumption, reported	238	185	263	314	250
Consumption, apparent	W	W	W	330	W
Price: Per short ton, f.o.b. Atlantic and Great Lakes ports, last quarter (spot)	$510	$360	$340	$390	$440
Stocks: Mine, distributor, and consumer, yearend	152	146	184	127	107
Employment: Mine and mill 3/	550	550	487	455	410
Net import reliance 4/ as a percent of apparent consumption	W	W	W	100	W

3. Recycling: None.

4. Import Sources (1976-79): Australia 84%, India 5%, Other 11%.

5. Tariff:

Item	Number	Most Favored Nation (MFN) 1/1/81	Most Favored Nation (MFN) 1/1/87	Non-MFN 1/1/81
Rutile Ore	601.5140	Free	Free	Free
Synthetic rutile 5/	603.7010	6.9% ad val.	5% ad val.	30% ad val.

6. Depletion Allowance: 22% (Domestic), 14% (Foreign).

7. Government Programs: None.

Stockpile Status—11-30-80

Material	Goal	Total Inventory	Authorized For Disposal	Sales, 11 Months
Rutile	106	39	-	-

8. Events, Trends, and Issues: Production of natural rutile in Australia, which has for years been the source of about 90% of the world's supply, was 6% higher than in 1979. U.S. imports from Australia of natural and synthetic rutile totaled 62% of those of 1979. Total synthetic rutile imports in 1980 were about 74,000 tons compared with 142,000 tons in 1979, and came from Australia, 87%; and Japan, 13%. The need for rutile imports in 1980 decreased because of reopening of a synthetic rutile plant in Alabama with a capacity of 110,000 tons per year. Dependence on foreign sources in 1976-79 was over 90%. From a 1979 base year, demand for natural and synthetic rutile is expected to increase at an annual rate of about 3% through 1990.

The heavy minerals operation at Green Cove Springs, Fla., which had been partially shut down since 1978, was purchased by an Australian firm, and production was resumed in June 1980. The annual production rate was to be 50,000 tons of ilmenite, 25,000 tons of rutile, and 25,000 tons of zircon.

The major impediment to more extensive use of natural rutile is the limited supply. On the east coast of Australia, reserves of rutile are about 6 million tons but because of environmental concerns, only about 4 million tons can be mined. Deposits on Australia's west coast may contain 4 million tons of rutile. Exploitation of the deposits in Sierra Leone has presented major engineering problems, but production began again in early 1979, and is expected to approach planned capacity of 110,000 tons per year during 1981 or 1982.

Production from the Republic of South Africa in 1980 was about 80% of capacity.

Mining of rutile is entirely from sand deposits which contain only a few percent of rutile and coproduct minerals. While the discarded sand can be readily returned to the mined area, regraded and seeded to aid restoration of the original environment, there is increasing pressure to curtail sand mining in some areas.

Fewer environmental problems are encountered when pigment is made from rutile rather than ilmenite. The chloride process, using a rutile feed, generates 0.3 tons of waste per ton of product, while the alternate sulfate process, using ilmenite, generates about 3.5 tons of waste per ton of product.

9. World Mine Production and Reserve Ba·

	Mine Production 1979	Mine Production 1980 e/	Reserve Base*
United States	-	W	2,000
Australia	306	325	10,000
Brazil e/	(6/)	(6/)	100,000
India e/	10	12	8,000
Sierra Leone e/	11	55	3,000
South Africa, Republic of e/	46	48	6,000
Other Market Economy Countries e/	15	17	5,000
Central Economy Countries e/	10	15	3,000
World Total	7/398	7/472	133,000

10. World Resources: Identified world resources of rutile (including anatase) total about 280 million short tons of contained TiO_2. The Brazilian resources are mainly anatase, and are reportedly being developed. Other major resources occur in Australia, India, Italy, Mexico, the United States, Sierra Leone, the Republic of South Africa, the U.S.S.R., and China.

11. Substitutes and Alternates: Ilmenite, titaniferous slag, and synthetic rutile made from ilmenite may be used instead of natural rutile for making pigment or welding rod coatings.

* Pending establishment of criteria for the reserve base, classification of data is based on a judgmental appraisal of current knowledge and assumptions - See page 184 for definition.

e/ Estimate. NA Not available. W Withheld to avoid disclosing company proprietary data.
1/ See also Ilmenite and Titanium.
2/ Includes synthetic rutile.
3/ Employment at three sand deposit operations in Florida, which produce either rutile concentrate or a titanium mineral concentrate, where ilmenite and zircon are major coproducts, and where employees are not assigned to specific commodities.
4/ Net import reliance = imports - exports + adjustments for Government and industry stock changes.
5/ The suspension of duty on synthetic rutile was extended until June 30, 1982, as provided by P.L. 96-467.
6/ Less than 1/2 unit.
7/ Excludes U.S. production.

Prepared by L. F. Lynd, telephone number (202) 634-1073.

REMARKS ON CRITICAL RAW MATERIALS

Russell Babcock
Bear Creek Mining

(no manuscript submitted)

WORKSHOP ON CRITICAL MATERIAL NEEDS OF THE AEROSPACE INDUSTRY

Robin Brumwell
Cabot Mineral Resources

February 9-10, 1981

WORKSHOP ON CRITICAL MATERIAL NEEDS OF THE AEROSPACE INDUSTRY

Good morning. My name is Robin Brumwell. I am the Executive Vice President of Cabot Mineral Resources, a division of Cabot Corporaiton.

Cabot Corporation -- Supplier to the Aerospace Industry

Under the brand names of Stellite, Haynes and Hastelloy, the Cabot Corporation is one of the world's leading suppliers of super alloys essential for the manufacture of jet engines.

Cabot is also the leading producer of tantalum in the United States and is one of two manufacturers of beryllium alloys in the Western World. These two latter materials have particular relevance in advanced electronic applications and, therefore, play an important, although indirect, role in support of the aerospace industry.

Five major raw materials (and a host of minor ones) are required to manufacture alloys for the flying gas turbine market -- nickel, cobalt, chromium, molybdenum and tungsten.

Concerns over Raw Material Supply

Nickel, molybdenum and tungsten are not regarded as serious problems as far as security of supply is concerned. North America is more than self-sufficient in nickel and molybdenum. While tungsten is approximately 50% imported, supplies are sufficiently diverse throughout the rest of the world not to cause great concern should disruption from one or two sources occur.

Supply security of cobalt and chromium are of the utmost concern to Cabot. Both metals are essentially 100% import dependent and are primarily from areas of actual or potential political instability. Furthermore, substitution possibilities are either non existant or limited in the high temperature applications for which these metals are required.

The same points are true of tantalum bearing materials and beryl ore. Both are 100% imported, significant quantities originate in areas of potential supply concern and, in both cases, substitution would for many applications be painstaking, time consuming or extremely undesirable from a quality standpoint.

Cabot's concern is increased by current moves to expand eventual capacity of super alloy manufacture three fold at its midwest plant with the installation of a new 4-Hi mill which will come on stream later this year. Cabot will use some of this additional capacity to greatly develop its titanium wrought product position thereby further increasing general anxiety over the continuity of critical material supply.

In a nutshell therefore, the five elements of cobalt, chromium titanium, tantalum and beryllium are items of great significance to Cabot and which could either directly or indirectly impact upon the production capability of the U.S. aerospace industry should a major supply disruption occur.

None of this will come as any surprise to any member of the audience. Both the criticality and problematic nature of these elements are well known and I will risk sounding like a broken record if I do not rapidly progress to what we are doing to protect our supply lines and what the U.S. government may also do to assist industry.

Cabot's Response

Cabot Mineral Resources has been established as a new division of the company to concentrate purely upon questions of metals and mineral supply to Cabot's operating divisions.

CMR's mandate is extremely broad. We will do everything necessary to ensure the short and long term availability of critical materials. This means traditional procurement at one end of the spectrum to exploration, and mine ownership at the other. Between these two points there are numerous options such as investment in processing facilities, scrap reclamation, R&D on substitute materials, long term producer contracts and of course stockpiling. Every critical material we have identified has its own peculiar set of characteristics and problems and we are developing a custom tailored strategy of supply line protection for each one.

However much we organize to be masters of our own destiny in this regard there are clearly a number of areas where governmental involvement in support of the national interest is as necessary as it is desirable. In other areas the converse may be equally true.

Government Involvement

Within the confines of a ten minute address, the following issues can only be listed in extreme summary. I should also emphasise that these comments and opinions are my own and do not necessarily represent the official view of Cabot Corporation.

A) <u>Stockpiles</u>

The concept is undoubted. The practicality is fraught with a number of well publicized drawbacks:

- Funding	-	Inadequate or non existant.
- Quantity	-	Too much? Too little?
- Quality	-	Adequate for immediate usage by processors?
- Form	-	Proper balance between ores, intermediates and refined metals?

Form is as important as quantity. There is little point in emphasizing chromite in a stockpile when the country's ability to convert to ferro chrome is extremely limited. By the same token with only one facility in the Western World capable of processing beryl ore, it would possibly be safer to give greater emphasis to beryllium inventories in their end use form.

Quality is more important than anything. Anything that cannot be used in the stockpile is worse than it being absent altogether. It provides a false sense of security which may take valuable time to discover -- perhaps in those very circumstances when time cannot be wasted and replacement materials cannot be obtained.

There is little that needs to be said about having goals and no funds to achieve them -- or funds so small as to be piteously inadequate.

I know it is easy to take pot shots -- and these comments are not meant to be distructive or negative to those who have had the impossible task of managing the FEMA stockpile.

It is not unreasonable to regard a strategic material stockpile as a direct adjunct of the nation's defense program -- to be managed and funded accordingly. There is no alternative view if the U.S. recognizes its foreign dependence of certain materials and also recognizes that all supply lines cannot always be protected. I think it goes without saying that the stockpile should be subject to regular review and action on quantities, quality and form.

B) <u>Production Incentives</u>

Title III of the Defense Production Act of 1950 exists to provide fiscal incentives and financial support to expand capacity, develop new technology and generally provide government stimulation of production of strategic metals and minerals. Techniques available include:

- Production loans
- Exploration loans.
- Accelerated depreciation of capital equipment.
- Purchase contracts with guaranteed floor price on material produced.

This law helped develop much of the copper and molybdenum mining industry in Arizona. It is a statute that is still on the books and which might have a very real application, for example, to cobalt mining in the U.S. The old Blackbird mine in Idaho and the old Madison mine in Missouri have the potential to supply a useful proportion of U.S. needs and they might well come to fruition under the price umbrella held aloft by Zaire and Zambia since early 1979. If, however, the price of cobalt retreats from $25/lb. to say $10/lb., then it may well be in the nation's strategic interest to extend provisions to the act to the mining companies concerned.

C. Tariffs

Tariffs exist to protect domestic business against foreign competition. However, are these artifical barriers sufficient to stimulate the domestic production and capacity expansion of those strategic metals where a strong U.S. industry is required?

Titanium is an interesting case in point. Although exact data is not available, Russia is reputedly the world's largest manufacturer of titanium sponge. In spite of the fact that Russia does not possess most favored nation status, the USSR has, for many years, exported significant but highly variable quantities to the West. Together with the cyclical nature of demand, these imports have contributed to a basic instability in the price structure -- which, in turn, has been an undeniable factor in discouraging domestic capacity expansion.

The ideals of trade liberalization notwithstanding, it might well be argued that it is a strategic error to allow the production of strategic materials to be too strongly influenced by countries whom the U.S. could not reasonably regard as an ally in an emergency situation.

I suggest that there may well be a good case for selective and punitive tariff imposition or other such barriers to protect strategic materials.

D. Other Issues

This is not the forum for a detailed review of any issue. Suffice it to say that a balanced view of environmental protection and mineral development is necessary -- although, obviously subjective and endlessly debatable. Suffice it to say that a realistic view of embargoes is also necessary if the U.S. is to avoid damaging its own material position as much as that of the nation it seeks to punish. Rhodesian chrome is an excellent example.

Finally, and at the risk of stating the obvious, it is clearly the ultimate responsibility of government to recognize external dangers and guard against them. There must be a continuing government awareness not only of domestic metal deficiency but also of those nations where U.S. dependence lies and the prognosis for supply reliability or disruption for whatever reason, from these areas in the short and long term.

Although industry will do much to captain its own fate it is, again obviously, the responsibility of government to provide the incentive and environment to allow the strength of industry to make it happen -- a broad responsibility to inspire mining, enhance innovation and develop production.

The organization of this workshop is, I believe a refreshing piece of evidence of the recognition of a number of these issues.

CRITICAL MATERIAL NEEDS OF THE AEROSPACE INDUSTRY

David Swan
Kennecott Copper

DEPARTMENT OF COMMERCE WORKSHOP

ON

CRITICAL MATERIAL NEEDS OF THE AEROSPACE INDUSTRY

February 9 - 10, 1981
Gaithersburg, Maryland

COMMENTS

My comments are on behalf of the American Mining Congress, a trade association representing more than 200 American companies involved in the minerals industries.

In dealing with questions of supply of critical materials, I would like to propose a methodology for identifying and characterising critical materials issues, particularly those involving interaction of the public and private sectors and which views those issues in an international framework.

In developing this, I would suggest we visualize supplying raw materials as a four (4) step process, consisting of:

- discovery of mineral resources;
- development of ore bodies into mines;
- mining and beneficiation; and finally
- extraction of desired material in sufficiently pure form to permit subsequent fabrication into useful articles.

For those mineral resources which the United States has adequate competitive grade reserves, the entire process can and is carried out domestically. Imports and exports at any stage of the process become almost purely economic decisions based on such considerations as freight costs, location of facilities and short-run market conditions. Even for such minerals, however,

/imposition....

imposition of unilateral U.S. policies can significantly and adversely alter the competitiveness of the U.S. mining industry in the international marketplace.

Unfortunately, this desirable state of affairs does not exist with many minerals, therefore, the interface between the U.S. industry consumer and offshore supplier is moved towards the fabrication/end use part of the process. From a policy point of view, the consuming country has a strong incentive to purchase supplies of the material as early in the cycle as possible, i.e., as ores and concentrates rather than alloys or metals. Conversely, the raw material owner has an equally strong incentive towards integration toward end uses as far as possible. At this stage, various government policies come into play, designed to maximize the self-interests of the producing and consuming countries. Generally speaking, such arrangements are considered to be a part of trade policy development and are aimed at directly supporting the mineral policy goals of sovereign nations.

Inevitably, however, other national policies also impinge on the location of the interface, but less directly. These include tax policies, environmental health and safety policies, employment and labor policies, energy policies, etc.

/In the.......

In the more advanced countries, very often application of these types of policies have a larger impact on mineral availability than do trade policies and it is this area which I propose that we concentrate on. In order to analyze the economic impact of these policies, it is necessary to identify the policy asymmetries between the U.S. and producing countries and to determine whether these inhibit or enhance the availability of a specific mineral resource.

I have extracted a number of these examples from the excellent GAO report, "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications:" to illustrate how they impact the availability of resources in the real world.

In its testimony in support of the National Materials and Minerals R&D Act to Congress, the American Mining Congress recommended that specific responsibility for identifying these policy asymmetries be assigned in the President's Office with the requirement that policy changes be proposed which would support the national objectives of assuring adequate supplies of critical raw materials.

I would suggest that our examination of critical resource needs for the aerospace industry follow this method of analysis. This conference can provide an important input by contributing useful data to carry out the charges of the Congress in enacting the National Materials & Minerals Policy Research & Development Act.

*****

A NATIONAL MATERIALS POLICY FOR A DESTABILIZED WORLD

E. F. Andrews
Allegheny Ludlam

·14-Point Outline
A NATIONAL MATERIALS POLICY FOR A DESTABILIZED WORLD

1. Growing import dependence for strategic materials is now an established fact.

2. From the Paley Commission through the interagency study, we still do not have a national policy. It is time to stop studying and start implementing.

3. Research and technological development will play a major role, but they cannot be relied upon for short-term emergencies.

4. Four metals are of primary concern: chromium, platinum, manganese, and cobalt, in that order. I pick these because of their pervasive use in defense, basic industry, quality of life.

5. We need to form a National Non-Fuel Minerals Board with the power of the Presidency to coordinate this broad policy.

6. This board should be backed up with an advisory board from the private sector, such as the President's Resource Advisory Board.

7. We need to reexamine our land use policies.

8. We need to internationalize the Bureau of Mines.

9. We need a total reexamination of the stockpile and the stockpile laws, including an examination of the parameters for economic use of the stockpile.

10. We need to reexamine our tax and depreciation laws so that they will be stimulators rather than disincentives.

11. We need a nationwide, coordinated research and development program.

12. We need to reexamine and effect better balance between the pragmatic consideration of our national needs and the advancement of social justice throughout the world -- a reordering of our priorities.

13. We need a reexamination of our business laws, including the Foreign Corrupt Practice Act so as not to render American business uncompetitive as it tries to deal in the world market.

14. I believe that Public Law 96-479 contains all the necessary legislation to finally put into practice a national materials policy.

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.A.

A NATIONAL MATERIALS POLICY FOR A DESTABILIZED WORLD

I have devoted most of the last 30 years working in and being concerned about the materials supply problems of my company and my country. For many years, I have been calling for a national materials policy and a higher profile on this general subject. I believe it is finally beginning to move to the top of the national agenda, and I am very pleased to have it do so. In the past decade, we have gone through the National Materials Policy Commission, National Commission on Supplies and Shortages, and the interagency study of the materials problem. But nothing much occurred to change the collision course of which the Paley Report gave timely warning. Nothing much, that is, until what can be milestone legislation cleared Congress last October.

Chromium presents a good example of why such a policy is needed. The United States has virtually no chromium indigenous to this country. But at the same time, we were in an accelerating, high level of consumption, we passed a group of environmental laws that virtually mandated an additional increase in the consumption of chrome to make the clean air and clean stream equipment and converters on our automobiles. After we had mandated this increase in the consumption of chrome, we then unilaterally, in another part of government, placed an embargo on the importation of chromium from what was then our largest supplier, Rhodesia. At the same time, we applied stricter environmental enforcement on the antiquated ferrochrome industry, reducing its productive capabilities. Also at the same time, we allowed unlimited export of stainless steel scrap, each ton of which contained 400 pounds of chrome. Truly, a good example of the need for a coordinated materials policy.

A brief look at history, and particularly at some events and developments that occurred in the lifetimes of most of us here, will help explain and in part define our present national predicament in this matter.

America had all the resources it needed from the outset of its nationhood and through its first 150 years or so. It was singularly blessed with timber, water, iron, coal, copper, petroleum, and much more---adequate for the American economy of those days.

That happy condition began to change markedly after the First World War. It was not that we exhausted our resources but that new materials were required by our industrial society: rubber, for instance, as we realized with a shock when, in the Second World War, the Japanese overran southeast Asia.

The explosion in technological development during and after that last global war has meant unprecedented advances in the quality of our national life and has wondrously transformed older industries and brought new industries unimagined only decades ago. But that explosion also put an end to our historic self-sufficiency.

We are import-dependent, in whole or in part, on a long list of minerals without whose assured and long-term supply we cannot function in the industrial sense. I am not speaking here of oil, for that is a topic which has not wanted for attention, but of non-fuel minerals: chrome, cobalt, manganese, platinum-group metals, nickel, tin, tungsten, and a score or so more.

Beyond technological development at a constantly accelerating rate of sophistication, the minerals predicament was enormously complicated by vast world-wide political changes. these included "decolonization" by the old Western imperial powers and the emergence of Third World nations. And it so happened that Providence chose to endow a number of the Third-World nations, particularly those in southern Africa, with minerals on which we are most dependent.

However salutary certain global political changes may be in the historical annals of self-determination, they have meant, to say the least, a destabilization of minerals access.

Now, as we venture further into the topic of non-fuel minerals, it would be well to avoid two extremes of mental attitude.

First, there's the attitude of blind faith in technological miracles. We solved the World War II rubber crisis in short order, didn't we? We put a man on the moon, didn't we? Surely we can make cobalt or chromium out of straw or who-knows-what when the crunch comes!

The fallacy of such gee-whizery lies not in any essential deficiency of technological research and development. Lord knows we've seen astonishing developments that have altered dependence on minerals. Consider what frozen foods have meant in respect to tin cans. Or the laser and satellite communications in respect to copper wire. Yes, there will surely be technological developments at some unforeseen time that will reduce or perhaps eliminate our present dependence on one or more strategic minerals.

But the point is precisely that the time is unforeseen. Time is at the heart of the problem. What presses for immediate attention and coordinated action is getting America from now to, say, 1990 or 1995. Wonderful indeed if we are mining the moon in the next century. But what can be done to mine the earth and have assured access to its mineral treasures in the next five, ten, fifteen years?

Secondly, I recognize that there some authorities who are concerned that we may be consuming basic resources of this world at a faster rate than we should. I do not wish to get into that argument.

however, I am one who believes that the world is not really running out of raw materials. It has been said that the first pound of copper ever discovered in this world is probably still here somewhere. Of course, all and everything are finite. If somehow or other, we consume or destroy until there is no place to stand on this planet, then I guess we could say the raw materials are gone. But I do not believe that is within our time frame of thinking. I do not anticipate that we are likely to encounter any serious natural constraints on the existence of raw material, at least in the next 25 to 50 years and possibly 25 decades. In the case of those raw materials that may run out, if there are any, we will merely let the system work as we reach deeper into the bowels of the earth for less yielding ores. Costs will rise. As the cost to extract these materials rises, the price to the consumer will rise. As the price rises, consumers will be forced to design away; and by the time the supply is exhausted, the need for the product will be gone also. It really is a self-correcting system, if we will just let it alone and let it happen.

Avoiding then either extreme -- the one of blind trust in instant technology, the other of resource-despair -- let's look at the situation in four just basic minerals.

First off, there's chrome, indispensable to the manufacture of stainless steel, ball bearings, and surgical equipment. This country has virtually no indigenous chrome. The world's reserves of it lie almost entirely in southern Africa -- in the Republic of South Africa and in Zimbabwe, the former Rhodesia.

Then there's cobalt, essential to jet-aircraft engines, machine-tool bits, and permanent magnets, to name some broad categories. We import 98 percent of our cobalt, the bulk of it from Zaire, the former Belgian Congo. Guess which nations account for a big share of the world's reserves, after one totals Zaire's and Zambia's? Our not-so-well-wishers, the Soviet Union and Cuba.

Next, there's manganese, without which you can't have steel, period; and for which we are almost wholly import-dependent. Of the world's present reserves of manganese, the U. S. Bureau of Mines estimates that southern Africa accounts for some 40 percent and the Soviet Union for 50 percent.

Finally, there's the platinum group of metals, on which we are more than 85 percent import-dependent for the manufacture of catalytic converters and a variety of electronic and chemical products. Roughly three-quarters of platinum-group reserves are in South Africa and about one-quarter in the Soviet Union.

This recital indicates why the four I have chosen out of a much longer list surely quality as "strategic" and why the reliability of their supply is less than reassuring. You also see why the Soviet Union already holds a powerful position from which to conduct a "resource war" and why southern Africa has been aptly called the "Persian Gulf of Metals."

The hallmark of such strategic minerals is their pervasive use throughout a modern industrial economy. Let us suppose, for a moment, that somebody in Detroit or any other American city were to say, well, in a pinch we could make do without chrome or cobalt.

Make do? Without these you couldn't build a jet engine or an automobile, run a train, build an oil refinery or a power plant. You couldn't process food, under present laws, or run a sanitary restaurant or a hospital operating room. You couldn't build a computer, clean up the air and water, and on and on.

The four minerals I've mentioned, plus others which we must import, impact intensely on our national defense -- for what defense could there be without planes and tanks and missiles? They impact intensely on our basic industry and on our quality of life, as shown by some of the specifics I've cited, and on the employment of our work force. With regard to jobs and national output, listen to what Helmut Schmidt, Chancellor of West Germany, has said about his country of some 60 million people. If you cut off West Germany's chrome for a year, according to Schmidt, there would be two-and-a-half million people unemployed and a drop in the GNP of 25 percent. Translate this in terms of the American economy and you have a "crises" by the most conservative definition of that term.

Such are the broad outlines of our mineral dependence. What can we do to alleviate it or at least render it less precarious?

One thing we can and must do is stop commissioning studies that come to nothing. What we need are studies upon which we are determined to act. Happily, a solid start in that constructive direction was made in the closing weeks of the last Congress. It was then that the lawmakers passed, and the outgoing President signed, what is formally known as the National Materials and Minerals Policy, Research and Development Act of 1980.

The Act declares, and I quote, "that it is the continuing policy of the United States to promote an adequate and stable supply of materials necessary to maintain national security, economic well-being and industrial production with appropriate attention to a long-term balance between resource production, energy use, a healthy environment, natural resources conservation, and social needs." It sets forth a comprehensive list of steps to be undertaken by Executive departments and agencies in line with the Act's objectives and calls on the President to submit to Congress within a year of the law's enactment a "program plan" -- including budget proposals and organizational structures.

Against the background of this promising start, some general comments and recommendations on certain aspects of a future program may be in order.

1. We need a coordinating mechanism, operating immediately under the President. Let us call it, for the sake of hypothesis, a National Non-Fuel Minerals Board. It should have full authority to cut across departmental jurisdictions in the interest of designing and carrying out a total and consistent minerals policy.

As part of the Executive Office of the President, the N.N.M.B. would coordinate and mitigate programs, tasks and analyses among the various agencies relating to the security of strategic minerals supplies. It would also recommend actions for the President, Congress and other Executive agencies.

It would add no new bureau or department but would combine the <u>in-place</u> functions of one each from State, Treasury, Defense, Commerce, Interior, Transportation, Labor and Energy.

2. To facilitate <u>private sector advice</u>, I would establish the President's Resource Advisory Board (PRAB) -- modeled after the structure of the former "President's Foreign Intelligence Advisory Board," i.e. limited term membership of distinguished experts from relevant fields, in this case from the mining, minerals production and end user industries; plus the fields of labor, environmental studies, regulation impact, investment banking and geopolitical/national security affairs.

3. We need a thorough inventory of our nation's reserves and resources in strategic and other minerals -- a reliable data base, in other words. Specifically, this need concerns what is or may be available as reserves in America's public lands.

The Federal Government owns about one-third of the U. S. land area, mostly in the West and Alaska. In 1968, the amount of this land withdrawn from mining and exploration -- and my own concern at this point is with exploration -- came to 17 percent. Eight years later, the figure was almost 70 percent!

As an Interior Department official noted at the time, the withdrawal for conservationist purposes "is being done too often without detailed knowledge of the existing mineral potential of these lands." At the very least, I would add, Americans have a right to know what resources of theirs have been locked away and are being locked away and why!

4. We need to internationalize the capabilities of the U. S. Bureau of Mines to assess supplies of minerals. The data base provided by the Bureau in this country -- with respect to those areas where it may freely operate -- is the best in the world. But the minerals problem is worldwide in scope, and so the data base should be as worldwide in scope as international political conditions allow.

The new public law recognizes this need by directing the Secretary of the Interior to promptly initiate actions aimed at improving the Bureau's capacity in an international sense. A decided improvement, it should be noted, could be effected by stationing a total of 20 to 30 Bureau experts in a few select countries.

5. We need a total reassessment of our present <u>defense</u> stockpile -- amounting, at today's inflated prices, to about $12 billion -- and we need new policies concerning it.

The reassessment should be made in the light of such considerations as quantity, quality, and mix. Are we too short on this and too long on that? What have time and weather done to the quality of, say, cobalt that was laid down 25 years ago? Should we not, for example, change the ratio of imported ferrochrome to chrome ore, now that a series of misguided actions in the past has virtually destroyed our former capacity to smelt chrome ore into ferrochrome?

Questions like these and remedial measures based on answers to them can help bring about a viable stockpile, appropriate to current realities.

A new program will then be required for, among other things, buying and selling relatively small quantities each year so as to maintain the quality of stockpile materials on the one hand and to make sure that markets are not dislocated on the other.

Further, Congress should establish parameters for certain limited <u>economic</u> uses of the stockpile. This statement must not be taken as implying there should be an economic stockpile, distinct from the established one for defense. Rather, it means that in the case of certain stockpile items which are essential to national well-being and on which we are import-dependent, Congress should allow for carefully circumscribed conditions under which they can be drawn on for <u>economic</u> purposes.

Economic use of the stockpile could have value in providing the <u>time</u> required for the United States to implement such long-term and more permanent solutions as substitution, conservation, and the development of alternate sources would provide. The United States must consider this alternative in its domestic and foreign supply policy.

The present policy of using the strategic stockpile as a de facto economic stockpile, subject only to the vaguest guidance and controls, we believe, is unwise and should be discouraged.

The legislators should explore to establish guidelines under which the stockpile could be so used. Among these should be:

(a) A certain percentage of import dependency before an item would be considered for stockpiling -- example, 75%.

(b) The geographic location of the supplying countries should be considered. In other words, the urgency would be quite different perhaps on an item from Canada, as opposed to an item from China or Africa.

(c) The number of supplying countries would be heavily considered. If only two or three countries supplied the item, it would be considered with a great deal more concern than if twenty or twenty-five countries could supply the item.

(d) The ease of substitutibility of the material would be an additional criterion and the essentiality to the domestic economy and to our security would also be weighed.

(e) We should take into account the economic or non-economic leverage that we might have on the supplying country. In other words, are they more dependent upon us than we are upon them?

(f) The political stability of the supplying country would be a major consideration as would be the cartelability of the item.

Congress should also provide in the enabling legislation the parameters under which items would be taken out of the stockpile. Stockpile disposal for price stabilization purposes I consider would be unwise and an inadvisable intrusion in the free market; however, certain other parameters for disposal should be made quite clear so that all concerned would know when a disposal time was near; for example:

(a) Never dispose of stockpile for export purposes.

(b) Never dispose at a higher rate than the difference between consumption and production in this country.

(c) Never sell from the stockpile when the material is available through normal channels.

(d) Replace materials in the stockpile only at times of low market activity.

(e) Insofar as possible, sell only to domestic consumers.

The most difficult problem is providing for the management of the stockpile within the parameters set forth by Congress. How can economic use of the stockpile be designed and operated so that it will not be misused for financial advantage of special interest groups? How can it be sufficiently insulated from the political process to prevent its misuse yet insure it will achieve the public benefit for which it was established? It must be sufficiently insulated from the political process that it may act in the public interest and yet remain responsive to Congressional scrutiny.

One final word on stockpiling. It is not and cannot be a long-term solution to our import-dependence on strategic minerals. It can only serve as a buffer in case of crisis, tide us over in case of war, give us options and maneuvering room in case of civil disruption at a source of overseas supply. In short it is a limited hedge against risk in a highly disturbed world.

6. We must, as the new law states, "promote a vigorous, comprehensive, and coordinated program of materials research and development." At the same time, we must overhaul tax policies towards the mining and metallurgical industries. Ironically enough, these policies have been a disincentive, not only to research, but to the capital formation needed to develop the fruits of research as well as the resources available to us.

7. But even as we press on with R&D, we must avoid fantasies of a quick technological fix. Substitution -- the use of a new or modified substance for another -- can readily become a voodoo incantation to exorcise the demons of mineral dependence. If one remembers in this context that a substitute -- for chrome say -- has to be of as good a performance quality as the material for which it substitutes and also that it has to be reasonably price-competitive, then fantasy will give way to reality. And reality is, for example, one considered estimate that it would take us 10 years to design away from chrome and might cost as much as a billion dollars; meanwhile, there is more than a thousand-year supply of chrome in southern Africa that might well be sold for something like 50 cents a pound.

These comments should not be taken as depreciating purposeful R&D across the spectrum of materials and minerals, but rather as putting the problem of dependence in focus. The one key element of that problem is diplomatic -- which leads to the next point.

8. We must reconsider the balance -- some would call it imbalance -- we have struck in recent years between the requirements of national security and the advancement of social justice throughout the world. The Washington Star put the issue well in an editorial some months ago, entitled "Bulletin from the Resource War."

> ". . .While the Kremlin (wrote the Star) has been trying to advance its interests via build-ups of well-positioned bases and client states in such areas as Africa, the United States has concentrated on human rights and hopes of coming out 'on the right side of history' by forbearing to press material or geopolitical interests against revolutionary regimes.
>
> "There is still time for us to protect ourselves in the area of strategic materials. But it will take a rethinking of priorities in the way we define allies and adversaries abroad as well as in domestic stockpiling policies."

Keep in mind that at the heart of our predicament is fair access to sources. Put another way, the problem is not sufficiency of the strategic minerals on which we depend, but rather the peculiar nature of their geographic distribution. Given that nature, disruption of some supply is a very real possibility. And the power to disrupt is, in this matter, the power to deny.

I would briefly note, however, with respect to what the Washington Star called "rethinking of priorities in the way we define allies and adversaries abroad," the phenomenon of selective indignation. This phenomenon has characterized much of our diplomacy towards mineral-rich areas of southern Africa. For instance, at one time we embargoed the importation of chrome from the then state of Rhodesia while at the same time we were buying chrome from that citadel of human liberty, the Soviet Union.

What is the answer to such inconsistency and, more specifically, to the need for looking after our security interests no less than our moral ones? At the least, it seems to me, we should tilt to the principle that our conducting trade with another nation carries no implication whatsoever that we either approve or disapprove of that nation's internal policies.

9. Further, in the diplomatic arena, we should try, in international forums and with individual Third-World countries, to shore up contract law and equity in financial and commercial transactions. The essence of such law and equity is common benefit to all parties concerned, as we have to make clear more forcibly than we have done. To accomplish that will take, among other things, persistence and a stockpile of patience.

It has been nearly 30 years since the Paley Report warned us of the predicament that lay ahead for us in strategic minerals. The warning was by and large ignored. The predicament is upon us. But it need not become a crisis if we rally ourselves now to act steadfastly and with purpose.

The materials and minerals law adopted last fall is a good start. But it is only a start. Nothing guarantees that we will proceed with appropriate speed to make the most of it -- nothing, that is, except the initiative and resolve of people like yourselves all across the nation.

Initiative and resolve are each a <u>human</u> resource. And fortunately, America has those qualities in abundance.

If we bring them to bear now on our minerals predicament, we will not and cannot fail.

1/29/81

E. F. Andrews

RMI COMMENTS ON THE U.S. DEPARTMENT OF COMMERCE WORKSHOP

Dom Strollo
RMI Company

RMI COMPANY COMMENTS

U.S. DEPARTMENT OF COMMERCE WORKSHOP

February 9, 1981

RMI Company is an integrated producer of titanium mill products, with sponge facilities in Ashtabula, Ohio, ingot and mill product facilities in Niles, Ohio, and finishing facilities in Washington, Missouri.

In this paper, we would like to review several of the key topics of concern to us in the titanium industry:

(1) The critical nature of the industry
(2) The uses of the metal
(3) A brief history of the industry
(4) The strategic importance of titanium to America's future
(5) The advantages in the applied use of titanium

We will close by suggesting some questions that might be addressed in any study that may be made.

At RMI Company, we reaffirm the belief that the current and future status of titanium mill products production and demand should be the subject of such a study on critical materials needs. History has shown that end products are essential to many facets of American life, not the least of which is our nation's defense preparedness.

General Alton Slay, formerly head of Air Force Systems Command, had identified the titanium industry as one where domestic productive sponge capacity is, and may continue to be, insufficient to meet domestic industrial and defense market demands.[1]

Titanium sponge is the necessary feedstock for the production of titanium metal. The metal is low in density, light in weight, exceptionally strong, and resistant to many forms of corrosion.

[1] The Air Force Systems Command Statement on Defense Industrial Base Issues, Gen. Alton D. Slay, November 13, 1980.

Alloys have been developed that have the strength of steel, at 60% the density. These alloys can be used at temperatures far exceeding 1000°F. Because of this special property, titanium alloys are the most engineeringly efficient materials of construction for critical parts of both defense and commercial airframes, and the power plants used to propel them. Currently, about two-thirds of all titanium mill product shipments are allocated to the aerospace industry.

Of the aerospace purchases, approximately 50% go to America's defense contractors for such programs as the F-14, F-15, F-16, F-18, various types of offensive and defense missiles, and helicopters. These programs utilize titanium to reduce weight and increase operational integrity.

The titanium mill products shipped to commercial aircraft manufacturers are primarily for use in the Boeing family of airliners, Lockheed's L-1011, and the McDonnell Douglas DC-10 (KC-10) and DC-9 series. Principally Pratt and Whitney and General Electric, through their subcontractors, consume millions of pounds annually for both defense and commercial aircraft jet engines.

In the evolution of jet engines, the addition of a two-stage titanium fan to a basic straight jet helped produce 42% more takeoff thrust, while reducing fuel consumption by 13% and specific weight by 18%. The current generation of large, high-bypass-ratio engines have substantial amounts of titanium alloys in the fans and compressor sections, as well as other structures. These engines, and the aircraft they propel, could not have been built without titanium alloys.

Despite the obvious engineering advantages of the metal, there has often been a reluctance on the part of industry executives to fund expansions. We believe it valuable to briefly review the history of the industry. This will help us to better understand the position we are in now.

In the 30-year history of the titanium industry, market demand has been extremely erratic. Because of large anticipated government contracts, and private enterprise expectations, a number of companies have, in the past, entered into the supply market. Unfortunately, many of those programs were abruptly terminated, due primarily to the lack of political and economic support (e.g., the B-1, B-70, and SST programs). Thus, several companies withdrew from sponge production. Included are such industry giants as Union Carbide, DuPont, Crane Company, Crucible Steel, and Dow Chemical. (Although Dow has recently reentered in a joint venture with Howmet.)

In the 1960s, with increased defense spending, and a new generation of commercial aircraft coming on stream, capacity was once again developed to meet anticipated demand. But, because of program terminations, and despite exceedingly low domestic sponge prices, the non-integrated producers bought their sponge product from Russian and Japanese sponge producers. These countries were dumping their sponge on American markets, with subsidies from their governments.

Domestic sponge consumption and production fared no better throughout most of the 1970s. But, a recent surge in demand finds the industry producing at capacity levels.

A combination of reasons have led to this surge in demand and resultant capacity constraints. Among them are: (1) the almost complete withdrawal of the Soviets from supplying Western markets, (2) other offshore supply channels being redirected to fulfill internal and other markets, and (3) a spike in demand from both industrial and aerospace users.

When we talk about the first two items just mentioned, it is important to reemphasize the "dumping" practiced by the Russians and Japanese. A suit was won against the Soviets in 1968 for dumping practices, yet the penalties were not enforced. If they had been, it is quite likely that production capacity would have been in place domestically.

The importance of titanium in the defense establishment and in commercial markets, and the susceptibility to disruptive foreign product penetration, make it clear that a strong domestic industry for this strategic metal is advantageous to the United States.

An examination of expanded uses of alternative ore sources may be a valuable addition to any proposed study. America has vast resources -- ilmenite -- which can be process upgraded to a form comparable to rutile, which is then compatible with existing process facilities. With the keen interest being shown in rutile producing countries about developing their own metal reduction plants, domestic integration would assure this important industry of plentiful and totally self-sufficient resources.

Titanium is a cost-effective material of construction, especially when one considers elements beyond initial cost; elements like: lifespan, cost of construction, cost of maintenance, etc. This can be most accurately measured by comparing titanium to other materials of construction, like zirconium, inconels, hastelloys, and nickel alloys. In 1980, the following relative prices have been demonstrated[2] (where titanium = 1.00).

Zirconium	2.8
Hastelloy C276	2.8
Inconel 625	2.1
Hastelloy G	1.5
Nickel 200	1.3
Inconel 600	1.2
Incoloy 825	1.1
Monel	1.1
Carpenter 20	1.0
Titanium	1.0
Alloy Steel	0.1

Compared to other metals, the discrepancy can be seen even further:

Tantalum	53.5
Columbium	26.7
Titanium	1.0

[2]Relative costs of plate product

There are a number of reasons why a strong domestic industry is extremely important to the United States. We have previously discussed the strategic importance of the industry, and, the United States could be in the enviable position of self-sufficiency in at least one strategic metal.

It is our hope that any proposed study would consider this crucial fact. There are a number of avenues that might be examined when we consider this potential. Included are: (1) improvements in productive capabilities, (2) additional R&D into the potentials for material conservation and wise application, and (3) fulfillment of the stated goals of the national stockpile.

Taking the last item first, there are currently only 32,331 tons of titanium in the stockpile. Of this, 10,836 tons are considered <u>not</u> to be of stockpile grade.[3] The objective is 195,000 tons. Thus we really have only 11% of our goal attained.

The strategic importance of the metal is acknowledged by being placed on the list of materials in the Strategic and Critical Materials Stockpiling Act. This act requires the acquisition of materials determined to be "deficient or insufficiently developed to supply industrial, military, and naval needs of the country for common defense," and necessary to "prevent wherever possible a dangerous and costly dependence of the United States upon foreign nations for supplies of these materials in times of national emergency." U.S. Code, Section 98 (1951)

In this sense, titanium is comparable to cobalt. Both metals are vital to the country. Both are especially important in the development of cost-effective and fuel efficient jet engines.

With any surge in defense preparedness requirements, the United States would not have enough titanium stockpiled to last the aerospace industry one year. This is true -- even assuming we devote all current production capabilities to aerospace. New and current aerospace systems production would be slowed severely, especially in essential engine production.

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[3] Mineral Commodity Summaries 1980, U.S. Bureau of Mines, U.S. Department of Interior.

Long-term contracts for replenishment and rebuilding of the stockpile would be one means to give domestic industry the incentive to go even further in current expansion plans and programs. It would insure both a complete stockpile, and the productive capacity to respond to critical or surge requirements. The United States would indeed be capable of self-sufficiency in one strategic metal. As this indicates, we would then have developed a significant improvement in our materials production base.

The rebuilding of American industrial strength should not rely solely on defensive weapons procurement. The strength of the United States depends on a totally strong industrial economic base. And, part of a strong economic base in America is energy development and energy conservation. Titanium is the preferred application material in many energy-related applications, including: auxiliary heat exchangers, condensers for liquefied natural gas, steam turbine blades, geothermal power, and instrumentation and piping for oil exploration.

One of our common objectives in this meeting today is to illustrate the crucial issues facing our country. We believe our discussions, to this point, have demonstrated the importance of the titanium industry, and its critical applications.

Securing a strong economic and defense capable industrial base is imperative in the United States today!! To do this, we must adopt intelligent, rational policies with which to act most propitiously. To develop these policies, we need to initiate aggressive and insightful studies which will lay the foundation for policy formulation.

We are hopeful that this discussion will assist you in defining our nation's needs. And, we would respectfully suggest that titanium be included in the initial studies, so that a comprehensive titanium policy can be developed to the benefit of everyone.

In a proposed study of titanium production capacity and demand requirements, there are a number of questions that might be asked. These may provide the basis for policy initiatives. Though the following list is certainly not all-inclusive, it may be representative of other issues that might be covered in a study of this nature.

(1) Would it not be advantageous to U.S. policy-makers to be made totally aware that the defense concerns of the United States today imply that critically needed materials be examined completely? As previously suggested, America would easily become self-sufficient in titanium metals production if the incentives to do so were present.

(2) Might it not be of concern to U.S. policy-makers to understand how our balance of payments can be affected by the redevelopment of a strong domestic industry? Rather than a reliance on imports which may be suddenly cut off, for economic or defensive reasons, it may be better to be in a position where value added production can be sent out of the United States instead of into the United States. One way for America to fight the awesome effect of payments out of the United States, due to the huge deficit from OPEC accounts, is to increase exports. Many aerospace contractors are running surplus accounts now (most notably Boeing), and strong domestic subcontractors could help maintain or build, this payment flow into America.

(3) Might we not look at the current U.S. policy initiatives concerning redeveloping America through applied R&D? Research and development on improved alloys has been a way of life at RMI Company. As new areas of application grow, R&D becomes an even more essential element in the total equation. As demand for the metal grows, industry

feels an obligation to put its first priority on facility expansion. Inasmuch as the titanium industry is extremely capital intensive, this does not always allow for congruent growth in R&D for the future. It is suggested then that careful thought be given to the possible benefits of legislation to encourage R&D funding -- be it through grants or tax benefits.

(4) One element of policy in government today is to understand the problems of strategically important industries. Government can be very beneficial by encouraging communications that enhance predictability. Thus, study of the titanium industry may include a comprehensive analysis of long-term market demand. The recent, and temporary, shortfall in capacity versus demand requirements was partially due to the lack of communication of true demand. Would industry have added capacity to prevent this problem if we had an accurate picture? The answer is yes. In fact, RMI Company recently did add to capacity -- an increment of over 25%. Past history has made the industry shy about expansion. Long-term contracting might be examined as potential methods of building a sense of economic security in this strategically important industry.

(5) It might be worthwhile to examine the federal emergency allocation policies and procedures. Included in these laws are the potential for assisting American industry in capacity expansions, economic production practices, and other incentives for domestic industry to produce at levels not only to support defense requirements, but also allow commercial development not to be restricted or impinged upon.

In 1950, the Congress passed the Defense Production Act. This act, in its present form, is used:

> To establish a system of priorities and allocations for materials and facilities, authorize the requisitioning thereof, provide financial assistance for expansion of productive capacity and supply, provide for price and wage stabilization, provide for the settlement of labor disputes, strengthen control over credit, and by these means facilitate the production of goods and services necessary for the national security and for other purposes.

Specifically, the act provides for the implementation of a system -- the Defense Priorities System -- which permits the President to accelerate the production of critical defense items by causing the manufacturer to place these items at the front of the production line; guaranteed loans to expedite deliveries of national defense systems; and direct government loans to industry to expand plants and facilities in order to develop or produce essential material.

(6) The Department of Commerce could act as a synthesizer of the needs of the titanium industry. With the two previous topics in mind, is it not worthwhile to have the assistance of a central body who can recognize both commercial and defense requirements, and recognize both classified and unclassified demands?

Might we not also look into the question of materials substitution capabilities as an element of U.S. policy? For example, titanium is an excellent candidate for substitution among many nickel-based alloys.

To carry this one step further, might not U.S. policy place even greater emphasis on more extensive applications in energy and environmental areas? These are areas where titanium metal is constantly being demonstrated to be the most engineeringly efficient and cost-effective material of construction.

In conclusion, we would like to suggest that it may be beneficial to use titanium as a vehicle of policy analysis. Though it is an atypical metal, it is one where there is a definite domestic solution.

The life of the titanium industry has been very short, only three decades; yet, the potential for critical applications which will be immensely beneficial to the United States is tremendous. And, the developed technologies put titanium on the threshold of fantastic growth.

With an integrated effort on the part of the producers, users and other members of private industry, hand-in-hand with our military and other government agencies, solutions may be readily obtained.

KEYNOTE ADDRESS

William A. O'Donnell
Sperry Corporation

I am pleased to have the opportunity to address the Department of Commerce Workshop on Critical Materials Needs of the Aerospace Industry. The Workshop has been planned to establish a framework and lay out essential ideas for the Department of Commerce report due to the Congress in October of 1981. The report is required under Public Law 96-479, entitled Materials and Minerals Policy, Research and Development Act of 1980.

The Congress has taken steps to establish a National Policy to deal with those materials, including minerals of current or potential use, that will be needed to supply the military, industrial and essential civilian needs of the United States in the production of goods or services. Of particular interest are those materials or minerals which are primarily imported. The continued availability of these materials is of concern to the United States. The Aerospace Industry also shares the concern.

The U.S. is more than 50 percent dependent on foreign sources for over half of the approximately 40 minerals which have been described as most essential to our $2.3 trillion dollar economy. Many of these essential minerals come exclusively from foreign sources and some of the most critical of them from highly unstable areas of the world.

Last year the U.S. had to import over $25 billion worth of non-fuel minerals. This dependence on foreign sources for raw materials vital to our industries has been increasing for many years.

Aerospace Industries Association reported estimated 1980 aerospace sales of $50.5 billion, up from $45 billion in 1979. The increase is slightly above the rate of inflation and marks continuance of the Industry's upward climbing activity curve initiated in 1978. Backlog at year-end 1980 was expected to top $97 billion, up 30 percent over the $75 billion on the books at the end of 1979.

Aerospace exports increased substantially, from $11.7 billion in 1979 to $14.6 billion in 1980 --- an increase of almost 25 percent. The net export balance is estimated at $11.3 billion and Aerospace continues as the nation's number one manufacturing exporter.

Profits, after taxes, as a percentage of sales are estimated at 4.4 percent, down from 5 percent in 1979. For 1981, AIA forecasts total sales of $57 billion, or almost 13 percent over the 1980 level.

Our industry has a lot at stake should there be an interruption in its vital supply of critical materials and minerals.

The Aerospace Industry has been selected by the Department of Commerce as a focus for the first study in connection with P.L. 96-479 and has begun to examine anticipated materials used in the Aerospace Industry. I have been asked to deliver a keynote address on the general topic "Critical Engineering Materials" used by the Aerospace Industry. As an Industry Chairman of the Materiel Management Committee of the Aerospace Industries Association, I chair a group made up of approximately 40 Procurement executives of member Aerospace companies. We are concerned with:

- Availability of supply
- Lead times
- Escalation
- Critical materials
- Federal regulations common to our buying practices

and

- Other non-proprietary matters related to Procurement.

Within our companies we are the individuals charged with obtaining the materials required by our manufacturing locations. We seek sources of supply, worldwide, that will assure quality delivery at a price we can afford to pay. You are being addressed by a professional Buyer. We buy materials for developmental work -- engineers, for production work -- manufacturing and quality departments, for plant and equipment -- buildings and machine tools. All, but with the possible exception of the brick and mortar, involve materials or components using critical materials and minerals.

Following my keynote address, there will be a series of presentations specifically covering critical materials and minerals as they are used in:

- Electronics
- Engines
- Airframes

  and

- Machine Tools

I believe you will find them pinpointing the vital materials and minerals used in each category.

My talk will:

<u>FIRST</u>

Summarize the key critical materials "<u>issues</u>" with respect to the Aerospace Industry as I see them and offer alternatives

and

<u>SECOND</u>

Suggest a particular material or two that would provide the most useful focus for a Departmental report designed to bring out these key issues and recommended action.

In our business planning cycle at my corporation, Sperry, we annually develop business planning for one year and for five years, in the product areas. We start with an appraisal and under that heading include such elements as a summary of current performance, environmental assumptions, markets, strengths and weaknesses, opportunities and threats and an evaluation of previous strategies. That is the first step. Again, we call it an appraisal. I believe the fact that P.L. 96-479 is on the books attests to the fact that, as a nation, an appraisal has been made and that the evaluation of our previous strategies concludes that if we continue on the same non-action oriented path as we have pursued in the past 20 years, we are headed for a profit loss and a possible negative growth. This appraisal has been made on the basis of potential non-availability of critical materials and minerals. In the National Security sector, we can foresee diminishing sources or extremely high prices to be paid for essential materials. In the Industrial sector we, and our allies, are headed for the possible strangulation of economy without a strategic plan to combat the diminishing availability of key materials. So, the appraisal has been made. We have identified weaknesses and threats and made our appraisal and now move on to a Strategic Plan.

The Strategic Plan includes a statement of business areas, key issues, strategies, development programs, manpower, facilities, management for results objectives and financial goals. We have stated our business area, and for the purpose of this meeting have restricted it to the Aerospace business. It is a $50 billion dollar industry and it consists of both military and commercial products. Aerospace continues as the nation's number one manufacturing exporter - $14.6 billion in 1980. In a logical progression, that brings us to key issues. Our strategies and development programs will be the output of this workshop and subsequent task groups. A completed plan will be ready by October, 1981.

Are there any key issues facing the Aerospace Industry? I believe there are. Aerospace Industries Association President, Karl Harr, delivered his annual address providing a review of the Industry's status in December 1980. Many of the statistics I have used were included in that address. In partial summary, Mr. Harr called for:

- Multi-year procurement funding
- More realistic projections of inflation rates in estimating program costs
- Reduction in excessive controls in the procurement process.

Mr. Harr summed up his address with this advice to the new administration:

> "In space, concentrate on making the utilization of that domain so feasible as to make it a commonplace option for businesses and governments to take full advantage of the economic and social gains that space offers.

In commercial aircraft, concentrate on maintaining U.S. leadership in the world marketplace.

In defense -- most important of all -- concentrate on getting new systems into the inventory, even at the risk of passing up the last increment of technological advance in the name of sufficient quantity and timely delivery."

Certainly some of these goals include key issues to the Aerospace Industry as an entity.

Let me present 9 key issues to Aerospace, specifically related to Public Law 96-479, National Materials and Minerals Policy, Research and Development Act of 1980.

Key Issue #1

Can the Aerospace Industry, or the Government, identify and quantify critical materials as included in P.L. 96-479? Can we identify current usage, predicted usage, by material or mineral, with a degree of accuracy for the next decade?

Alternative 1 -- the data accumulated to date which identifies critical materials and minerals, its current usage and predicted usage, is adequate and correct. We may accept this data. A National Materials Policy utilizing this data will provide a realistic basis for Industry business planning over the next 5 to 10 years.

Alternative 2 -- an intensive effort is required to accumulate accurate data and develop forecasts of usage in both the military Aerospace business and the commercial business areas. The meager data that does exist is simply a regurgitation of past data, myth and postulation. The entire spectrum of materials and minerals used by Aerospace must be reassessed by both industry and government working together: industry through its Trade Associations; government through the Department of Commerce, Defense and other agencies to identify and quantify the critical materials and minerals. To accept existing data will be misleading. To generate new data will require the allocation of industry resources in terms of manpower and costs. The same will apply to governmental agencies.

Alternative 3 -- rather than attempt to eat the whole elephant in one bite, accept some data and thoroughly examine only minimal, key materials or minerals to develop a model program and policy. There is sufficient time to permit this approach. Three (3) to 5 minerals could be identified and quantified in this manner in 4 to 6 months and the balance at the rate of 8 to 10 per year thereafter.

Key Issue #2

The Congress passed the Strategic Materials Act in 1939 followed by the Strategic and Critical Materials Stockpile Act of 1946, to create a strategic and critical materials stockpile for emergency use in times of war. The stockpile, as originally planned, was to be used solely for defense materials purposes; however, since 1946 there have been frequent, and severe, shifts in stockpile objectives having little to do with defense.

The consequences of materials stockpile sales to balance the national budget and sales to try to control prices or reduce inflation have severely hindered the system. Today there are many shortages and imbalances in the stockpile.

Of the 62 family groups and individual materials that are stockpiled, approximately 60 percent do not meet the established goals. We currently stockpile only 17% of titanium sponge against our goal, 33% tantalum in all forms, 48% of cobalt, 52% of columbium and 86% of chromium. Clearly, our stockpile is in a dangerous position. Should there be only one stockpile, for military use in times of emergency or should there be one for military, one for industrial commercial use by industries such as Aerospace or should there be one stockpile for use by both?

Alternative 1 -- there is sufficient data to increase the national stockpile to required levels and it should be done immediately. The stockpile should be available for

Critical military emergency use. Congress must support the full FY '81 FEMA (Federal Emergency Management Agency) stockpile request of $100 million to increase the stockpile.

Alternate 2 -- we should wait until the picture is more definitive and then increase the stockpile.

Alternate 3 -- the stockpile should be built up to cover emergency military usage and should cover the commercial sector of our Aerospace business as well. The economic strength this industry furnishes the nation, both domestically and for export, requires that we make the stockpile available to the Aerospace industry. This will require additional stockpiling and may be used in times of economic uncertainty related to drastic price increases possibly due to cartel type actions or the shutdown of supply due to geopolitical reasons. There is not sufficient time to develop substitutes or develop sources for items such as cobalt, titanium, nickel, tungsten, aluminum and others.

Alternate 4 -- if the government wants to stockpile for emergency military use, that is fine. But, the commercial Aerospace sector considers that it can effectively do the job itself, provided adequate tax incentives are made available through legislation to permit it to handle the cost of preventing critical material stock-outs.

Key Issue #3

In Defense contracting, the current one-year procurement method of buying to an annual authorization bill causes Industry to be loath to make capital investment for programs funded for only one year. Both business and government planning are largely affected. We could achieve significant economies by buying materials and components in larger quantities. We could even procure more critical materials at today's prices and availability if we had the mechanism to procure shapes and components containing critical materials and the incentive to do so, beyond one year or contract limitation, even in multi-year contracts in effect. Current multi-year contracts have a cancellation ceiling of $5 million. We have advance procurement funding for long-lead but as prices escalate, particularly in the critical materials area, we need more advance procurement dollars. Short supplies will lengthen lead time. Do we have any possible way out of the growing dilemma and the possible future undesirable effects on our industry?

Alternate 1 -- the Congress can increase the present $5 million cancellation ceiling limit on multi-year contracts to a higher, more enabling figure of $100 million. This will assist the Aerospace military segment as an industry. It will permit added capital investment. It will permit better planning. It will lower costs. More critical items can be procurred at today's prices and availability. This could help us over the next 4 year period.

Alternate 2 -- advance Procurement funding can be increased. Many critical materials and minerals are included in our long-lead parts. We now have aircraft with 4 year lead times. While long-lead procurement appropriations have increased from $650 million in FY '76 to over a billion dollars in Fiscal Year 1980, the alternative is costly schedule slippages. Advance procurement to termination liability, rather than full funding, is a way to minimize the dollar impact. Funding to termination liability means that we only pay for the contractor's actual expenditures plus termination liability for the advance procurement contract. Application in the area of materials, shapes and components requiring critical materials will help solve the problem of growing shortages, escalating prices and potential eventual supply disruption.

Alternate 3 -- the current methods of contracting are acceptable and, besides, we can't afford to invest in long term multi-year contracting (4 or more years) even though there may be a cost savings, as much as 30%, according to General Slay and we also are okay in the area of Advance Procurements. After all, we've gotten by so far. We are currently paying through the nose in escalating costs and lead times for items containing critical materials but that's just a fact of life.

Key Issue #4

The same key issue exists in the commercial Aerospace sector.

Other than government stockpile and substitution, are there other means available to the commercial Aerospace sector to beat the critical materials problem? Advance funding and multi-year contracts are not available in this sector.

Alternate 1 -- long term contracts are sought and acquired in the commercial sector. Excellence of product and continued good planning techniques will be adhered to.

Alternate 2 -- Congressional actions to enhance capital formation, through realistic tax incentives, will be sought. Awareness of the industry needs will be made known to the Congress.

Alternate 3 -- the by-products of P.L. 96-479 will be available and, as such, utilized.

I will mention other key issues as I see them but do nothing more than list them:

Key Issue #5

Substitutes for unobtainable or uneconomically priced materials and minerals will be required. Since this is a topic to be covered in subsequent presentations, I will not dwell on it. I only hope we do embark on substitution programs rather than tend to live with the problem as we have in many cases, like gold.

Key Issue #6

Cartel actions are likely to form in the mineral areas. Can we and our allies survive resulting price increases?

Key Issue #7

The United States Aerospace Industry faces fierce competition from Europe in the commercial aviation arena and to a lesser degree in the military. Industry, in general, faces industrial competition from Japan. Can we get a competitive edge in the area of "critical engineering materials"? Are they formulating national policies and, if so, what can be learned?

Key Issue #8

Will current government regulations permit the development of alternate sources within the continental United States?

Key Issue #9

What timetable can we expect for our resulting task force proposals to be turned into desirable legislation?

So much for key issues. There are probably more. It is up to us to help to develop the necessary strategies and development plans to complete the entire planning cycle.

I have also been asked to select a critical material or two that would provide the most useful focus for a Departmental report designed to bring out these key issues and recommend action.

The key materials I would select are:

Titanium

Cobalt

Tantalum

I have selected these materials since one essentially represents airframe -- titanium; engines -- cobalt; electronics -- tantalum. Each is extensively imported and at least one, cobalt, has a potential source of domestic supply. Substitution is difficult, particularly in cobalt and titanium, and predictably easy in the case of tantalum, at least as it is used in the production of electronic capacitors. Prices have escalated in all three. Between 1978 and 1980, titanium sponge has increased 80%, refined cobalt 117%, and tantalum ore 300%. It has been pointed out by General Slay that the price rise in cobalt alone caused, for example, price increases for the F-100 engine of almost $18,000; the J-79 engine, $21,000; and the TF-39 engine, $21,000. Our domestic capacity to shape forgings containing titanium and cobalt is limited. Each of the key issues I have listed and the alternates listed apply to these three materials. The recommended actions I shall leave to the output of this workshop and those persons involved in the area of "critical engineering materials".

I am pleased to note that not only are we in the Government and Aerospace Industry concerned with critical materials, but so is the general population of the United States. The new issue of the Readers' Digest, and you simply can't get any more "general population" oriented than that monthly, carries a boldface title on its cover titled "Strategic Minerals, The Invisible War". It devotes 5 pages to our topic. I would comment that the Invisible War is becoming Visible and Vocal. The time has come! Thank you.

MATERIALS CRITICALITY IN JET ENGINES

William A. Owczarski
Pratt & Whitney Aircraft Group

THE HEART OF MODERN AIRCRAFT IS ITS JET ENGINE (FIG. 1). A JET ENGINE IS MADE OF MANY SOPHISTICATED METAL ALLOYS, CHOSEN FOR LIGHTNESS, HEAT RESISTANCE, STRENGTH AND DURABILITY. TITANIUM ALLOYS AND HEAT-RESISTANT "SUPERALLOYS" CONSTITUTE MORE THAN 85% OF THE ENGINE'S WEIGHT. THESE TWO CLASSES OF ENGINEERED ALLOYS ARE INDISPENSABLE TO THE PRODUCTION OF A JET ENGINE WITH THE POWER, DURABILITY AND EFFICIENCY REQUIRED BY OUR NATION'S MILITARY AND COMMERCIAL AIRCRAFT. THESE ALLOYS ARE FORMULATED FROM A VARIETY OF BASIC METALLIC INGREDIENTS. TO BUILD AN F100 ENGINE (FIG. 2), WHICH POWERS OUR NATION'S FRONT LINE DEFENSE AIRCRAFT, THE F-15 AND F-16, REQUIRES AN INPUT WEIGHT OF 5204 LBS. OF NICKEL, 1656 LBS. OF CHROMIUM, 910 LBS. OF COBALT, 5366 LBS OF TITANIUM, 720 LBS. OF ALUMINUM, 3 LBS. OF TANTALUM, AND 171 LBS. OF COLUMBIUM. EACH OF THESE METALS IS IMPORTED FROM SOME OVERSEAS SOURCE. SOME FOREIGN SOURCES LIKE CANADA OR AUSTRALIA ARE SECURE, STABLE AND FRIENDLY; OTHERS SUCH AS THE SOVIET UNION OR ZAIRE ARE LESS RELIABLE FOR DIFFERENT REASONS. WE ALL KNOW THAT IN 1978 CIVIL WAR ERUPTED IN ZAIRE, CAUSING THE COBALT MINES TO CLOSE. MORE THAN 50% OF THE WORLD'S COBALT COMES FROM ZAIRE AND THE DISRUPTION IN PRODUCTION CAUSED WORLD-WIDE SHORTAGES. BY 1978 COBALT WAS ALLOCATED TO USERS AT 70% OF 1977 CONSUMPTION AND WELL BELOW ACTUAL REQUIREMENTS. THE SHORTAGES CAUSED PRICE JUMPS FROM $6.85/LB. TO ABOUT $50.00/LB. IN THE SPOT MARKET AND CAUSED LARGE INCREASES IN LEAD TIME FOR OBTAINING BASIC MATERIALS TO PRODUCE ENGINE PARTS. TODAY, THE MINES ARE PRODUCING AGAIN BUT ECONOMIC PROBLEMS BESIEGE ZAIRE AND THE RISK OF DISRUPTION REMAINS.

TO ILLUSTRATE THE NATURE OF OUR CONCERN, LET'S EXAMINE THE IMPACT OF A LONG-TERM COBALT SUPPLY CUT-OFF ON U.S. AIRLINES BY LOOKING AT ONE PART IN ONE ENGINE TYPE. IN 1979, SOME 83% OF THE COMMERCIAL FLIGHTS

IN THE UNITED STATES WERE IN AIRCRAFT EQUIPPED WITH OUR JT8D ENGINE. ON THE AVERAGE, THESE ENGINES OPERATE ABOUT 2,500 HOURS PER YEAR AND THE FIRST TURBINE VANE (FIG. 3), WHICH IS A 60% COBALT ALLOY, HAS A USEFUL LIFE OF 10,000 HOURS BEFORE IT IS REPLACED. THE PIPELINE FOR REPLACEMENT PARTS IS ABOUT TWELVE MONTHS LONG FROM OUR MELTING SUPPLIERS TO DELIVERY OF SPARE VANES TO THE AIRLINES. FROM THE TIME COBALT SHOULD BE CUT OFF FROM OUR MELTING SUPPLIERS, WE COULD SUPPLY SPARE PARTS TO OUR AIRLINE CUSTOMERS FOR ONLY A YEAR. AT THE END OF THAT TIME, THE JT8D-POWERED FLEET WOULD START TO BE GROUNDED AT THE RATE OF ABOUT 25% PER YEAR.

ALTHOUGH THE ILLUSTRATION HAS BEEN LIMITED TO ONLY JT8D PARTS (FIG. 4), ALL ENGINES, FROM ALL MANUFACTURERS, USE COBALT-CONTAINING ALLOYS FOR FIRST TURBINE VANES. IN THE REAL CASE, TO AVERT GROUNDINGS, LESS SATISFACTORY ALTERNATIVE MATERIALS WOULD BE USED, BUT SIGNIFICANT PENALTIES WOULD RESULT. THE IMPACT ON OUR DEFENSE AND COMMERCIAL AVIATION SYSTEMS WOULD BE EXTREMELY SERIOUS.

CHROMIUM, WHICH IS ALSO USED IN TURBINE VANES, TURBINE BLADES AND TURBINE DISKS, SHAFTS, BEARINGS, CASES, SEALS AND COATINGS, IS ANOTHER METAL IMPORTED FROM SOUTH AFRICA AND THE SOVIET UNION. THE UNITED STATES IS 90% IMPORT-DEPENDENT ON CHROMIUM, AND THE REMAINDER COMES FROM RECYCLED SCRAP, NOT DOMESTIC MINERAL SOURCES. JET ENGINE NEEDS FOR CHROMIUM CANNOT BE SATISFIED FROM COMMERCIAL SCRAP BECAUSE OF PURITY REQUIREMENTS. A STUDY BY THE NATIONAL MATERIALS ADVISORY BOARD IN 1978 STATED: "WHILE (CHROMIUM) IS AN IMPORTANT INGREDIENT IN MANY COMMODITIES, IT IS IRREPLACEABLE IN STAINLESS STEELS AND HIGH TEMPERATURE-

RESISTING SUPERALLOYS, TWO CLASSES OF MATERIALS THAT ARE VITAL TO THE TECHNOLOGICAL WELL-BEING OF THE NATION. CURRENTLY THERE IS NO CHROMIUM-FREE SUBSTITUTES THAT CAN BE USED IN THESE CRITICAL APPLICATIONS, NOR ARE ANY SUCH SUBSTITUTES LIKELY TO BE DEVELOPED IN THE FORESEEABLE FUTURE." ALTHOUGH THE CURRENT SUPPLY SITUATION IS STABLE, THERE REMAINS A RISK TO BE ADDRESSED FOR THE LONG-TERM FUTURE.

TITANIUM ALLOYS ARE USED FOR NEARLY 30% OF THE ENGINE BY WEIGHT IN FAN AND COMPRESSOR BLADES, DISKS AND CASES. TITANIUM COMPONENTS ARE ONE-THIRD LIGHTER THAN EQUIVALENT STEEL PARTS AND MAKE POSSIBLE THE WEIGHT ADVANTAGE WHICH GIVES THE ENGINE AND AIRCRAFT FUEL EFFICIENCY AND SUPERIOR PERFORMANCE. TITANIUM SHORTAGES OCCURRED IN 1979 AND 1980, NOT BECAUSE OF RAW MATERIAL SUPPLY INTERRUPTIONS FROM AUSTRALIA, WHERE 85% OF THE WORLD'S RUTILE IS, BUT BECAUSE OF DOMESTIC AND WORLD SPONGE-MAKING CAPACITY. SPONGE IS THE INITIAL METALLIC FORM OF TITANIUM WHEN IT IS REFINED FROM THE RUTILE ORE. THE SPONGE SHORTAGE WAS INTENSIFIED WHEN THE SOVIET UNION, A MAJOR SUPPLIER, CUT ITS EXPORTS TO THE U.S. SIGNIFICANTLY.

THE OVERALL LIST OF MATERIALS DESCRIBED EARLIER FOR THE F100 ARE USED IN BROADLY SIMILAR QUANTITIES IN ALL JET ENGINES (FIG. 5). BUT BASED ON CRITICALNESS TO PRODUCT, RISK FACTORS AND ACTIONS WHICH CAN BE TAKEN, WE BELIEVE THAT COBALT, CHROMIUM AND TITANIUM ARE MATERIALS WHICH DRAW THE FOCUS OF ATTENTION AT THE DEPARTMENT OF COMMERCE IN THIS STUDY REQUIRED BY THE NATIONAL MATERIALS AND MINERALS POLICY, RESEARCH AND DEVELOPMENT ACT OF 1980.

ACTIONS HAVE ALREADY BEEN TAKEN AT PRATT & WHITNEY AIRCRAFT TO ADDRESS THE CRITICAL MATERIALS ISSUES. SUBSTITUTION (FIG. 6) OF ONE ALLOY BY

ANOTHER AVAILABLE ALLOY HAS BEEN ACCOMPLISHED WHERE POSSIBLE TO REDUCE CRITICAL MATERIAL USE. ALLOY CHANGES IN ONE MILITARY ENGINE VANE RESULTED IN A SAVINGS OF 65,000 LBS. OF COBALT IN 1980. DISK ALLOYS ARE BEING CERTIFIED FOR USE IN COMMERCIAL ENGINES WHICH WILL RESULT IN FURTHER SAVINGS. HOWEVER, THESE ARE THE EASY SUBSTITUTIONS WHICH HAVE BEEN IDENTIFIED, AND ALTHOUGH IMPLEMENTATION IS COSTLY, THEY ARE BEING PURSUED. FURTHER PROGRESS TOWARD SUBSTITUTION WILL COME MORE GRUDGINGLY, INVOLVING HARD DECISIONS ON TRADE-OFFS IN PERFORMANCE OR IN FIELD MAINTAINABILITY. BEYOND THE USE OF AVAILABLE MATERIALS THERE IS THE OPPORTUNITY FOR NEW MATERIALS YET TO BE DISCOVERED. ONE SUCH RESEARCH EFFORT IS BEING FUNDED BY THE DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA) AND THE AIR FORCE IS FOSTERING RAPID SOLIDIFICATION RATE (RSR) POWDER TECHNOLOGY, TO SEEK NEW ALLOYS WHICH CAN PERFORM WITH REDUCED CRITICAL METAL CONTENT.

CONSERVATION EFFORTS ARE ALSO BEING IMPLEMENTED IN THE FORM OF INCREASED EMPHASIS ON MATERIAL RECYCLING. IN ONE CASE, THE CHIPS FROM MACHINING A TURBINE DISK ALLOY WITH HIGH COBALT AND CHROMIUM CONTENT ARE COLLECTED, AND AFTER CLEANING RETURNED TO THE MELTERS TO MAKE THE ALLOY FOR NEW DISKS. WE HAVE REACHED A POINT WHERE UP TO 20% OF THIS DISK MATERIAL USED CONSISTS OF THE RECYCLED MATERIAL. EMPHASIS ON NET-SHAPE MANUFACTURING TECHNOLOGY IS ANOTHER SOURCE OF CONSERVATION. WHEN A PART FORGING CAN BE MADE CLOSER TO NET-SHAPE, LESS INPUT MATERIAL IS REQUIRED. USE OF ADVANCED TECHNOLOGIES SUCH AS GATORIZING[R], AN ISOTHERMAL FORGING PROCESS, ALLOWS REDUCED FORGING ENVELOPES. A PROGRAM IS IN PROCESS TO REDUCE THE INPUT WEIGHT OF NINE KEY F100 PARTS FROM 1200 TO 600 POUNDS BY THIS PROCESS. MORE WORK IS NEEDED AND WILL CONTINUE, BUT THESE EFFORTS DO NOT ELIMINATE THE NEED FOR CRITICAL MATERIALS; THEY JUST REDUCE THEM.

THE CRITICAL MATERIALS PROBLEM IS MULTI-FACETED AND WILL REQUIRE A VARIETY OF SOLUTIONS. THREE SPECIFIC ACTIONS WHICH ARE NEEDED WILL REQUIRE GOVERNMENT, PRODUCER AND CONSUMER COMMITMENT AND COOPERATION (FIG.7). THESE ARE: (1) INCREASE DOMESTIC SUPPLIES OF CRITICAL MATERIALS; (2) IMPROVE THE USE OF OUR NATIONAL STOCKPILE; AND, (3) PROMOTE AND SUPPORT ADDITIONAL CONSERVATION.

WHILE THERE HAS BEEN SOME RECENT PROGRESS IN RECOGNIZING THAT MULTIPLE USE OF THE 760 MILLION ACRES OF FEDERAL LANDS IS NECESSARY, FURTHER ENCOURAGEMENT IS NEEDED TO SEEK, DEVELOP AND PRODUCE DOMESTIC SOURCES OF CRITICAL MATERIALS. THE COBALT, CHROMIUM AND NICKEL DEPOSITS IN IDAHO AND CALIFORNIA ARE EXAMPLES OF POTENTIAL DOMESTIC RESOURCES THAT CAN BE DEVELOPED WHILE RECOGNIZING THE NEED TO PRESERVE THE NATURAL BEAUTY OF THE WILDERNESS IN WHICH THEY EXIST. THANKS TO THE IDAHO WILDERNESS BILL, THE MINERALS IN THE BLACKBIRD MINE CAN PROVIDE MUCH NEEDED COBALT METAL IN THE NEAR FUTURE. IT MAY ALSO BE NECESSARY IN THE CONTEXT OF A MATERIALS INSURANCE POLICY TO PROVIDE FINANCIAL INCENTIVES FOR DOMESTIC PRODUCTION. HIGHER PRODUCTION COSTS OF LOW GRADE ORES IN THIS COUNTRY, COUPLED WITH THE ADDITIONAL COSTS OF ENVIRONMENTAL OR REGULATORY RESTRICTIONS, MAY HINDER THE NORMAL ECONOMIC DEVELOPMENT PROCESS OF DOMESTIC MINES. SOME FORM OF TAX AID, DEPLETION ALLOWANCE OR GOVERNMENT PRICE SUPPORT COULD BE NEEDED TO PERMIT DEVELOPMENT OF AN ECONOMICALLY-MARGINAL BUT BADLY-NEEDED SOURCE.

THE TECHNOLOGY FOR MINERAL BENEFICIATION SHOULD RECEIVE FEDERAL SUPPORT AND STIMULATION IN THE FORM OF RESEARCH AT BUREAU OF MINES, AT UNIVERSITIES OR OTHER RESEARCH INSTITUTIONS TO FIND WAYS TO DISCOVER AND PRODUCE MINERALS

NOT PRESENTLY ADAPTABLE TO JET ENGINE PRODUCTION. FINALLY, THE LONGER TERM FUTURE MAY FIND THAT MAJOR MINERAL RESOURCES WILL COME FROM THE SEA. THE CURRENT LAW OF THE SEA TREATY APPEARS TO WORK AGAINST THE KIND OF STRONG GOVERNMENT SUPPORT NECESSARY TO ESTABLISH AN AMERICAN TECHNOLOGY AND SEA MINING INDUSTRY WITH GUARANTEED ACCESS TO THOSE MINERALS WHICH THE OCEAN FLOORS CAN PRODUCE.

NEXT TO INCREASED DOMESTIC SUPPLY, THE USE OF THE NATIONAL STOCKPILE CAN BE THE BEST GUARDIAN AGAINST FUTURE TEMPORARY SUPPLY INTERRUPTIONS. AT LEAST FOR SHORT-TERM EMERGENCIES, OUR STOCKPILE CAN PROVIDE THE MATERIALS TO KEEP GOING. BUT THE PRESENT STATE OF THE STOCKPILE IS INADEQUATE IN QUANTITY AND PROBABLY IN QUALITY. THE STATIC NATURE OF THE STOCKPILE SUGGESTS THAT THE SPECIFICATIONS OF TODAY MIGHT NOT BE MET BY RAW MATERIALS PUT INTO STOCKPILE 20, 30, OR 40 YEARS AGO. THE EXISTING STOCKPILE MUST BE INVENTORIED FOR QUALITY, RESUPPLIED WHERE NEEDED AND THEN KEPT DYNAMIC TO AVOID FURTHER OBSOLESCENCE. THE EXCLUSIVE USE OF THE STOCKPILE AS A DEFENSE STOCKPILE MAKES IT RELATIVELY USELESS IN TIMES WHEN WE ARE NOT AT WAR. IT WOULD BE FAR MORE EFFECTIVE IF ITS USE COULD BE CONSIDERED FOR ECONOMIC EMERGENCIES AS WELL, SUCH AS WOULD HAPPEN IF AFRICAN COBALT OR CHROMIUM WERE NOT AVAILABLE. FURTHERMORE, IF NATURAL DISASTERS PREVENTED PRODUCTION OR SHIPMENT OF A CRITICAL MATERIAL, THE STOCKPILE SHOULD BE AVAILABLE TO AVOID ECONOMIC DISRUPTION WHICH COULD DAMAGE OUR INDUSTRIAL BASE. RECENT TESTIMONY BY GENERAL ALTON D. SLAY, COMMANDER, AIR FORCE SYSTEMS COMMAND, WARNS OF AN ALREADY THIN DEFENSE INDUSTRIAL BASE AND "SPRINT" CAPABILITY. THE STOCKPILE CAN ALSO BE USED TO HELP STIMULATE SOUND CAPITAL INVESTMENT

IN CRITICAL MATERIALS-PRODUCING INDUSTRIES BY BUYING TO FILL THE STOCKPILE DURING THE VALLEYS OF DEMAND AND THEN SUPPLYING DURING THE PEAK "CRUNCH." IT MIGHT BE USED TO STABILIZE SEGMENTS OF INDUSTRY LIKE THAT OF TITANIUM SPONGE PRODUCTION WHICH HAVE BEEN RELUCTANT TO ADD CAPACITY DUE TO THE CYCLIC HISTORY OF THE USE OF TITANIUM IN OUR COUNTRY.

THE THIRD ELEMENT, CONSERVATION, HAS NOT BEEN EXHAUSTED AND COULD BE FURTHER STIMULATED BY GOVERNMENT RESEARCH AND DEVELOPMENT SUPPORT THROUGH AGENCIES LIKE THE DEPARTMENT OF DEFENSE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, DEPARTMENT OF ENERGY, AND NATIONAL SCIENCE FOUNDATION. SUPPORT OF NEW KNOWLEDGE-BUILDING STUDIES CAN HELP INDUSTRY UNDERSTAND WHY MATERIALS HAVE THE PROPERTIES THEY DO AND LEAD TO DEVELOPMENT OF NEW MATERIALS AND METHODS FOR MANUFACTURING THEM.

CONCERTED ACTION TO SOLVE OUR NATIONAL MATERIAL CRISIS IS LONG OVERDUE. PRATT & WHITNEY AIRCRAFT PLANS TO CONTINUE TO DO WHAT IT CAN AND IS PLEASED TO CONTRIBUTE TO THIS CASE STUDY. ONE CANNOT PROVIDE DETAILS IN THE TIME THIS TALK ALLOWS, BUT WE WILL BE AVAILABLE AND ANXIOUS TO EXPAND ON THESE BRIEF COMMENTS DESCRIBING THE PROBLEM AND ITS SOLUTIONS AT ANY TIME.

THANK YOU FOR THE OPPORTUNITY TO PARTICIPATE.

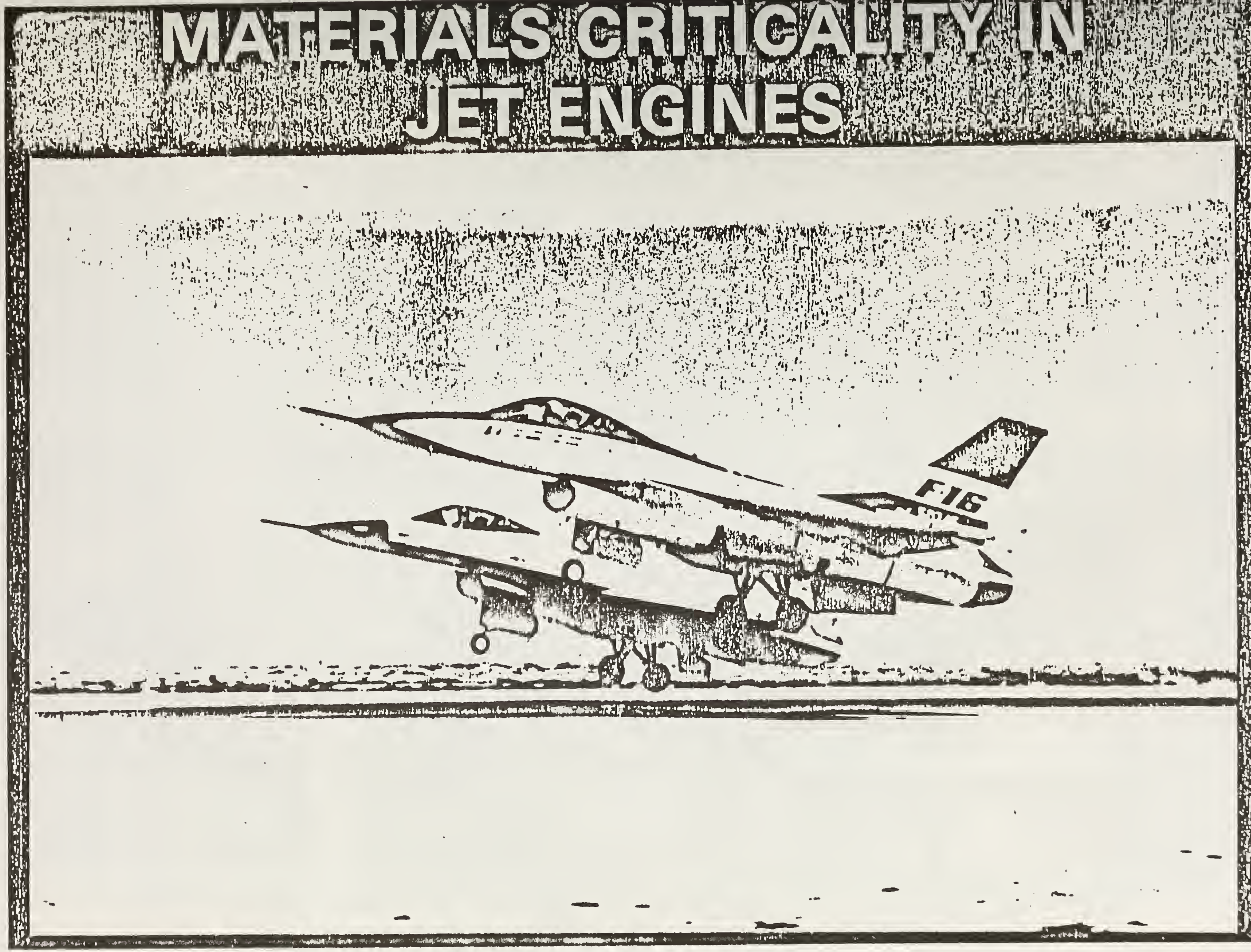
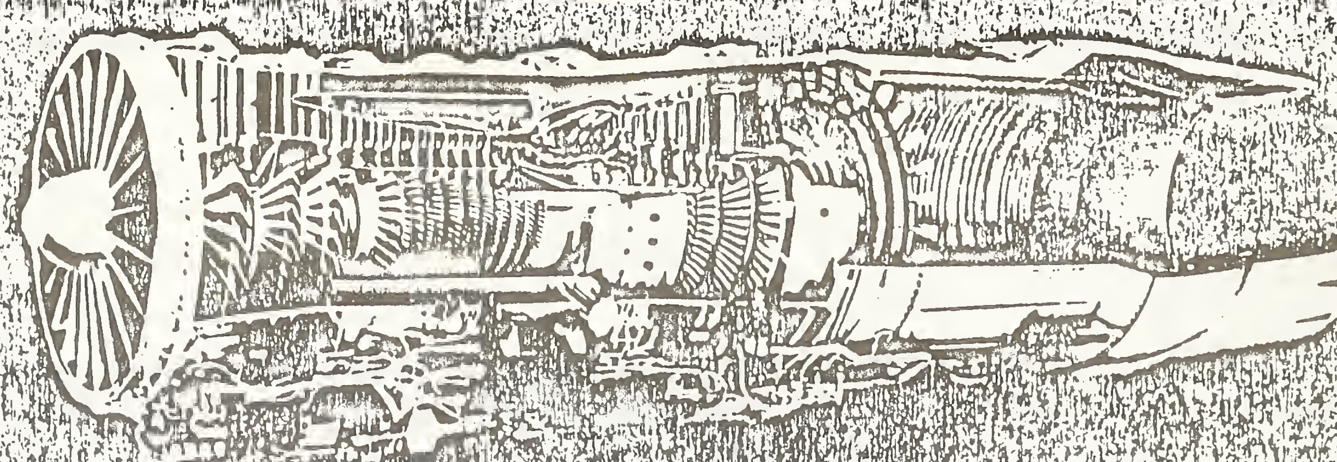


Figure 1



	Pounds	% Dependency	Sources
Nickel	5204	77	Canada, USSR, Australia
Chromium	1656	90	South Africa, USSR
Titanium	5366	100	Australia, Japan
Cobalt	910	90	Zaire, Zambia
Columbium	171	100	Brazil, Canada
Tantalum	3	96	Thailand, Canada

Figure 2

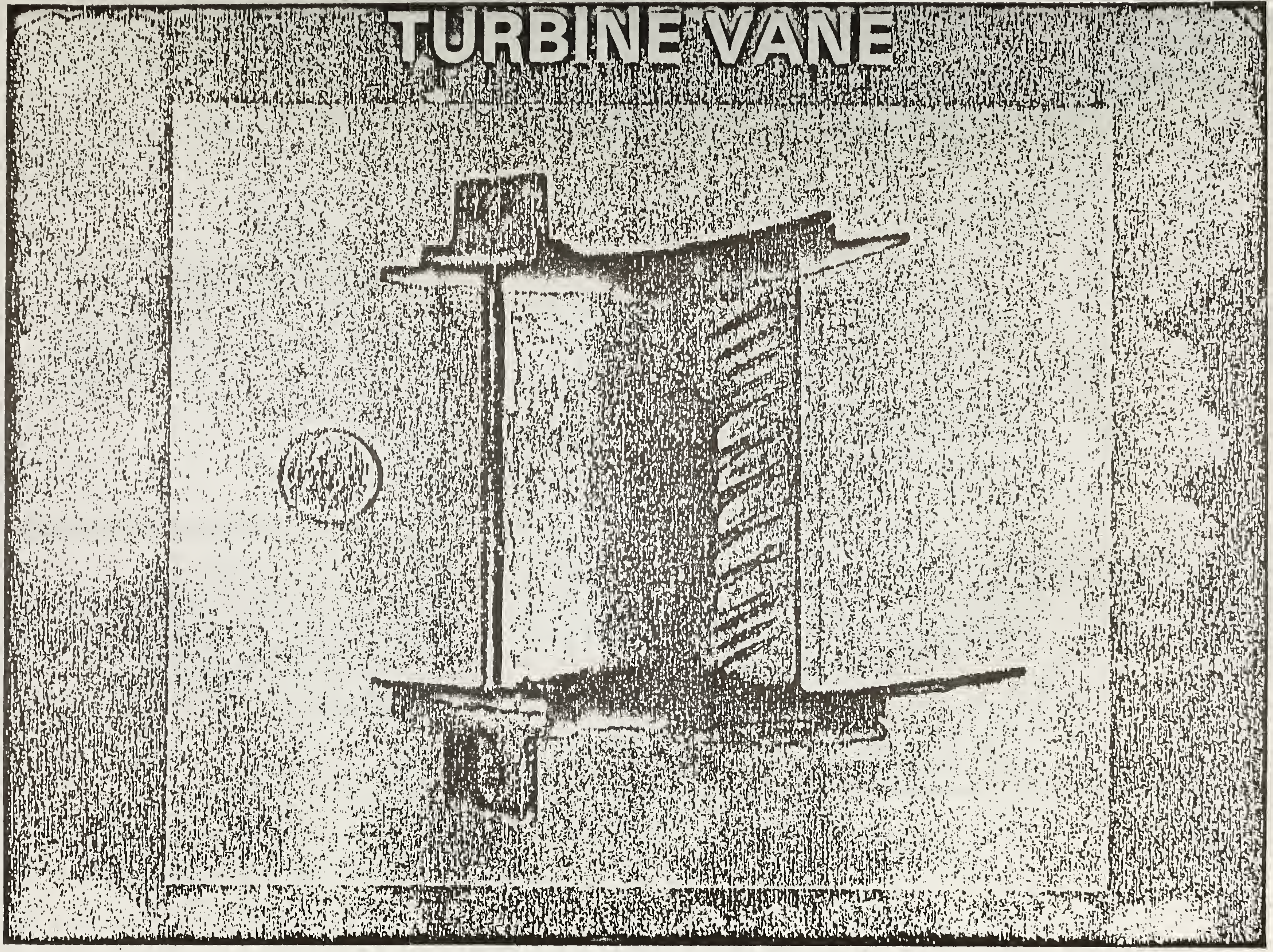


Figure 3

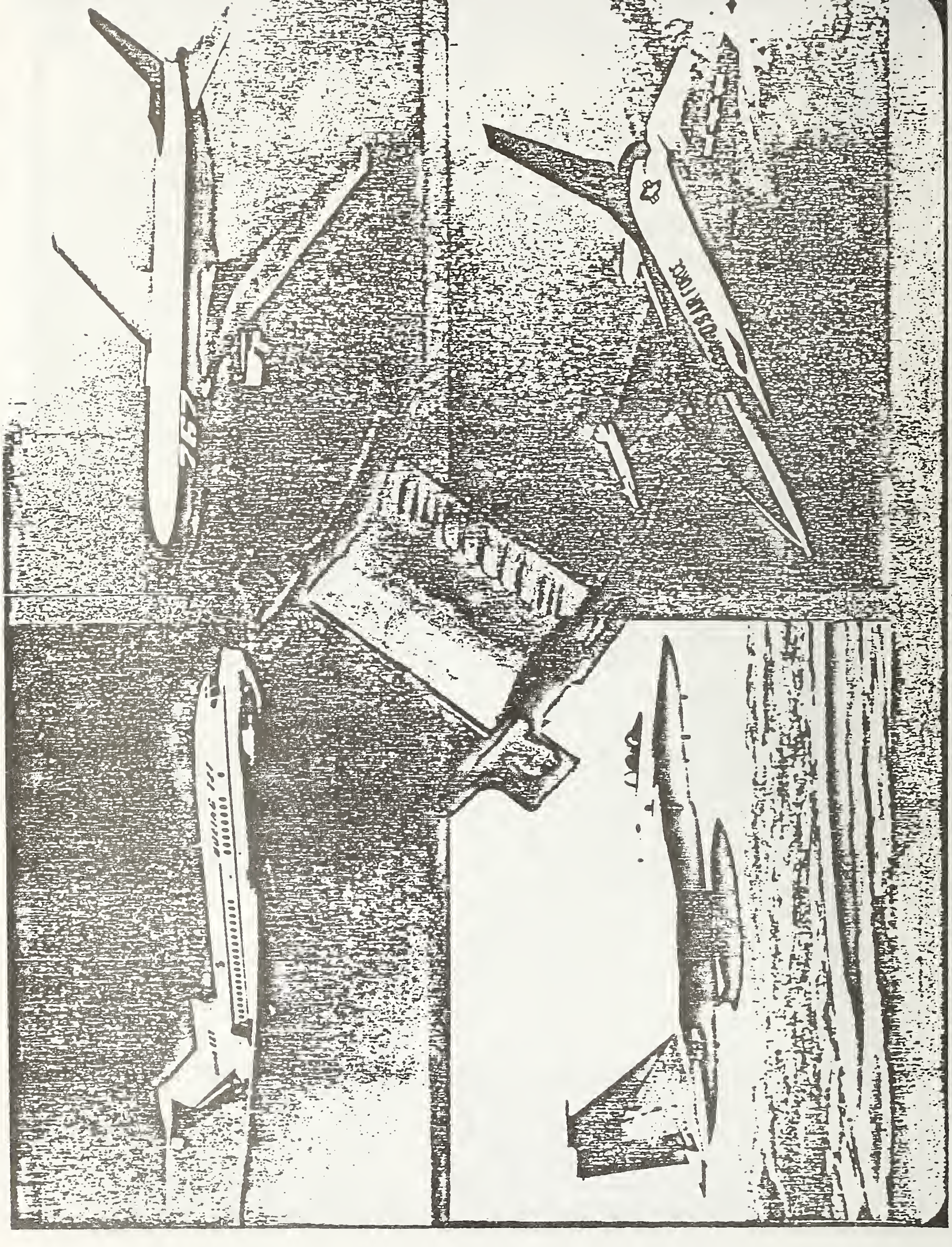


Figure 4

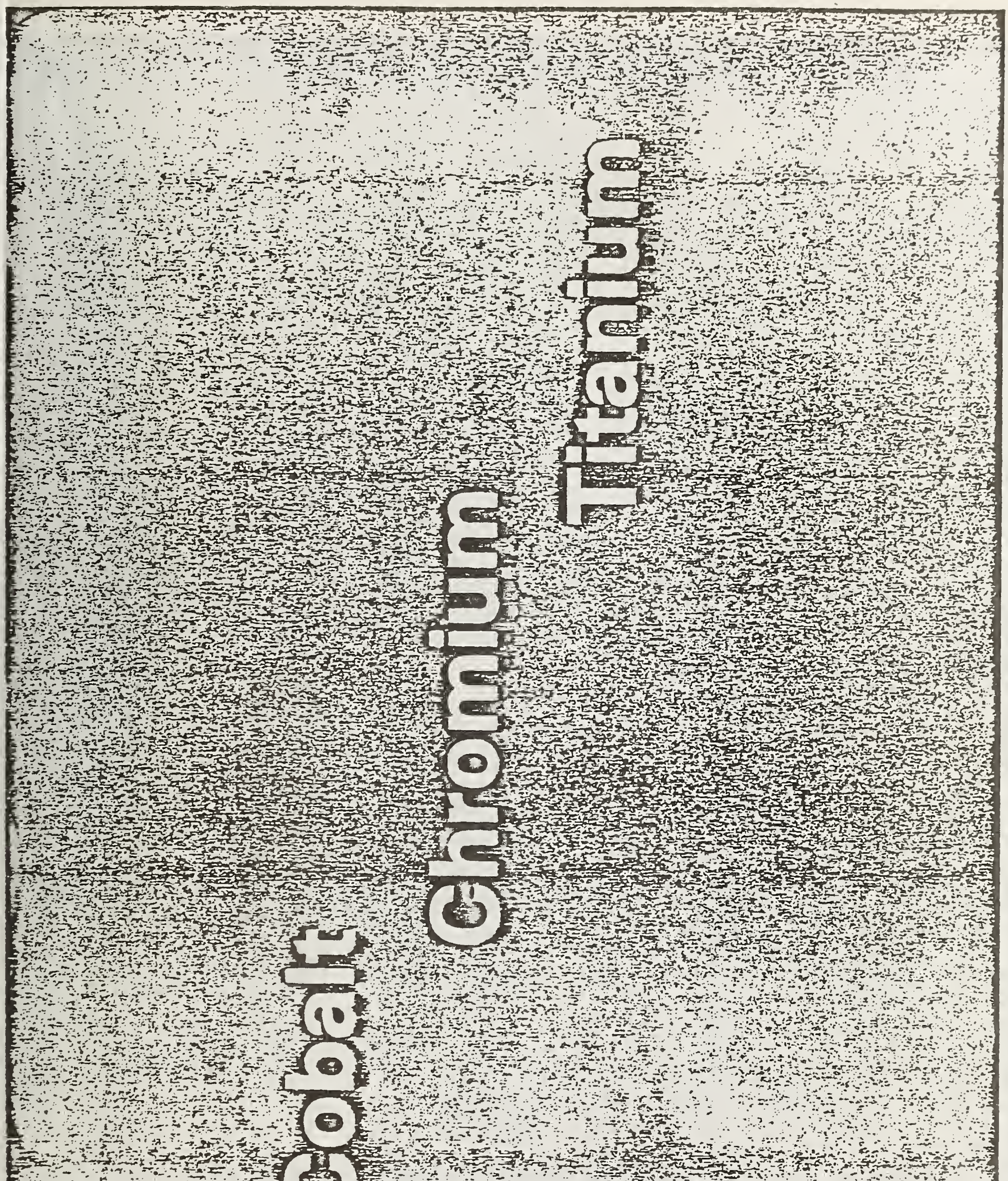


Figure 5

Substitution

Conservation

Figure 7

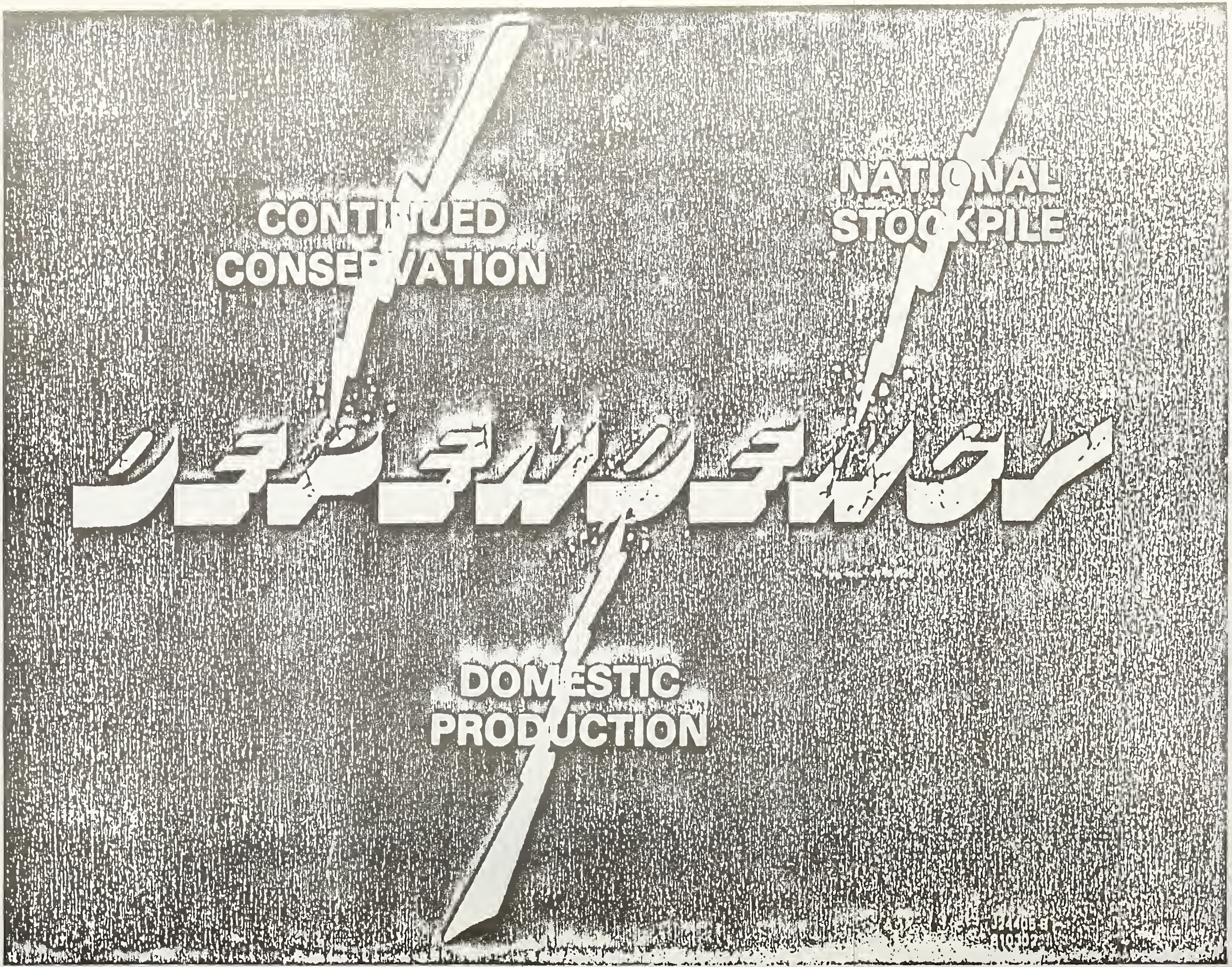

CONTINUED
CONSERVATION
NATIONAL
STOCKPILE
DOMESTIC
PRODUCTION

Figure 8

ELECTRONIC COMPONENTS

John M. Kerr
Rockwell International

ELECTRONIC COMPONENTS

- MATERIAL ECONOMICS
- MATERIAL AVAILABILITY
- PRECIOUS METAL IMPACT

MATERIAL ECONOMICS

THE PAST

IMPACT OF INFLATION

PRODUCER PRICE INDICES

FISCAL YEAR (SEPT 30)	ALL COMMODITIES INDEX	INDUSTRIAL COMMODITIES INDEX	CODE 1178 ELECTRONIC COMPONENTS INDEX
1973	139.7	127.4	104.6
1974	167.2	162.9	113.3
1975	177.7	173.1	114.5
1976	184.7	184.7	116.2
1977	195.3	197.8	120.5
1978	212.3	212.4	127.3
1979	241.7	243.8	139.9
1978-1979 GROWTH	13.9%	14.8%	9.9%
1973-1979 GROWTH	73.0%	91.0%	34.0%

MATERIAL ECONOMICS
THE PRESENT

KEY ISSUES:

- CONTINUING INFLATIONARY CYCLE
- IMPACT OF PRECIOUS METAL MARKET ON ELECTRONIC COMPONENT PRICING
- CONTINGENCY PRICING (PRECIOUS METALS)
- FEAR OF PRICE CONTROLS
- COST OF CAPITAL

HAS THE CURRENT RECESSION STEMMED THE RATE OF INFLATION?

THE RECESSION/INFLATION ANOMALY

ROCKWELL FISCAL YEAR (SEPT 30)	ALL COMMODITIES INDEX	INDUSTRIAL COMMODITIES INDEX	CODE 1178 ELECTRICAL COMPONENT INDEX
1979	241.7	243.8	139.9
1980	274.1	278.2	160.5
FY 1980 GROWTH	13.4 %	14.1 %	14.7%
FY 1979 GROWTH	13.9 %	14.8 %	9.9%
FY 1980 VS FY 1979 INCREASE/(DECREASE)	(3.6%)	(4.7%)	48.5%

CURRENT RECESSION/INFLATION ANOMALY

TIME PERIOD	ALL COMMODITIES INDEX	INDUSTRIAL COMMODITIES INDEX	CODE 1178 ELECTRICAL COMPONENT INDEX
SEPTEMBER 1980	274.1	278.2	160.5
DECEMBER 1980	280.3	286.1	162.0
1ST QTR FY 1981 GROWTH	2.26%	2.84%	0.94%
FY 1981 PROJECTED ANNUALIZED GROWTH	9.0%	11.4%	3.8%
FY 1980 GROWTH	13.4%	14.1%	14.7%

THE IMMEDIATE PAST
ELECTRONIC COMPONENTS AND ACCESSORIES
PAST 12 MONTH MOVEMENT
KEY COMMODITIES

PPI 1178 CODE	COMMODITY	JULY 1979 INDEX	JULY 1980 INDEX	INCREASE/ (DECREASE)
1173-01	ELECTRIC MOTORS	230.8	252.2	9.3%
11-3	CAPACITORS (ALL)	140.3	191.5	36.5%
1107.03	ALUMINUM CAPACITORS	134.7	142.6	5.9%
1111.04	TANTALUM CAPACITORS	98.0	205.5	109.7%
1113.05	CERAMIC CAPACITORS	145.6	169.9	16.7%
1119.01	FILM CAPACITORS	106.8	124.9	16.9%
12(3)	RESISTORS	155.3	162.9	4.9%
1239.03	POTENTIOMETERS	150.7	160.7	6.6%
24	CONNECTORS	183.5	209.6	14.2%
31	DIODES	86.3	86.7	0.5%
35	TRANSISTORS	86.5	96.5	11.6%
41	DIGITAL IC'S	51.1	57.4	12.3%
42	MOS IC'S	50.5	57.9	14.7%
45	LINEAR IC'S	55.3	59.6	7.8%

INDICES DO NOT REFLECT PRECIOUS METAL SURCHARGES

ELECTRONIC COMPONENTS AND ACCESSORIES PRODUCER PRICE INDEX CODE 1178

- WHAT SEGMENT OF THE INDUSTRY HAS THE MOST SIGNIFICANT IMPACT ON CODE 1178?
- THE SEMICONDUCTOR INDUSTRY
- HAS THE SLEEPING GIANT AWAKENED?

ELECTRONIC COMPONENTS AND ACCESSORIES
SEMICONDUCTOR INDUSTRY PRICING MOVEMENT

PPI 1178 CODE	COMMODITY	12 MONTH INCREASE/ (DECREASE) SEPT 1977 TO SEPT 1978	12 MONTH INCREASE/ (DECREASE) SEPT 1978 TO SEPT 1979	12 MONTH INCREASE/ (DECREASE) SEPT 1979 TO SEPT 1980
31	DIODES	(0.8%)	—	0.5%
35	TRANSISTORS	(2.9%)	(1.4%)	11.8%
41	DIGITAL IC'S	(23.2%)	(4.7%)	9.2%
42	MOS IC'S	(12.0%)	(1.2%)	13.6%
45	LINEAR IC'S	(18.2%)	(1.8%)	8.1%

MATERIAL AVAILABILITY

MATERIAL AVAILABILITY
CRITICAL PATH LEAD-TIME ANALYSIS

COMMODITY	JANUARY 1980 LEAD-TIME (WEEKS)	AUGUST 1980 LEAD-TIME (WEEKS)	COMMENTS
BALL BEARINGS (PRECISION MINIATURE)			CONTROLLED BY THREE (3) MAJOR SUPPLIERS. CAPACITY HAS BEEN ADDED. RECESSION HAS REDUCED DEMAND
STANDARD	28-32	17-22	
SPECIALS	40-46	36-40	
INVESTMENT CASTINGS	20-24	16-18	LEAD TIMES ARE IMPROVING. THE RECESSION IMPACTED THE FABRICATION SEGMENT OF THE INDUSTRY BEFORE IT DID ELECTRONICS
CONNECTORS:			
MIL-26482	28-32	32-34	DEMAND FOR MIL CONNECTORS CONTINUES AT STRONG PACE. ONLY MINOR EXPANSION OF INDUSTRY CAPACITY, E.G., BENDIX ON THE MIL-38999 SERIES 3 CONNECTORS. GENERAL SLOW-DOWN IN THE AIRFRAME INDUSTRY HAS RESULTED IN IMPROVED DELIVERIES IN SOME AREAS
MIL-26500	46-50	40-42	
MIL-38999 (SERIES 1 AND 2)	28-32	28-32	
MIL-38999 (SERIES 3)	36-40	30-34	

MATERIAL AVAILABILITY
CRITICAL PATH LEAD-TIME ANALYSIS

COMMODITY	JANUARY 1980 LEAD-TIME (WEEKS)	AUGUST 1980 LEAD-TIME (WEEKS)
INTEGRATED CIRCUITS:		
LOW POWER SCHOTTKY	30-52	24-42
TTL PRODUCT	22-50	22-40
MEMORY PRODUCT	28-42	16-24

COMMENTS

LOW POWER SCHOTTKY

SLOW-DOWN IN AUTOMOTIVE AND COMPUTER MARKETS HAS HELPED EASE THE SITUATION. TI IS CURRENTLY OFF ALLOCATION. OTHER INDUSTRY LEADERS STILL ON ALLOCATION, BUT SITUATION IS IMPROVING

TTL PRODUCT

FRONT-END DELIVERIES ARE REMAINING CONSTANT, BUT THE LONG-END OF THE CYCLE HAS BEEN SHORTENED ON LESS POPULAR DEVICE TYPES

MEMORY PRODUCT

ADDITIONAL CAPACITY PLUS ECONOMIC TURN-DOWN HAS VIRTUALLY REMOVED MEMORY PRODUCT FROM THE CRITICAL LIST. 2716 AND 2732 PRODUCT IS NOT CURRENTLY A PROBLEM

MATERIAL AVAILABILITY
CRITICAL PATH LEAD-TIME ANALYSIS

COMMODITY	JANUARY 1980 LEAD-TIME (WEEKS)	AUGUST 1980 LEAD-TIME (WEEKS)	COMMENTS
TANTALUM CAPACITORS	20-30	14-24	DELIVERIES HAVE IMPROVED. SOME OF THE REASONS ARE: 1. ECONOMIC DOWNTURN IN AUTOMOTIVE AND COMPUTER MARKET SEGMENTS 2. KEMET AND MEPCO/ELECTRA HAVE RECENTLY EXPANDED CAPACITY 3. DRAMATIC PRICE INCREASES HAVE PROMPTED SOME CUSTOMERS TO REDUCE TANTALUM USAGE
RESISTORS (CARBON COMPOSITION)	22-28	10-22	ALLEN BRADLEY'S NEW FACILITY START-UP PROBLEMS HAVE VIRTUALLY BEEN SOLVED. NO LONGER CONSIDERED A CRITICAL-PATH ITEM

MATERIAL AVAILABILITY
CRITICAL PATH LEAD-TIME ANALYSIS

COMMODITY	JANUARY 1980 LEAD-TIME (WEEKS)	AUGUST 1980 LEAD-TIME (WEEKS)	COMMENTS
MAGNETS	28-34	28-34	NO KNOWN EXPANSION OF CAPACITY. DELIVERIES REMAIN EXTENDED
MOTORS	25-28	25-32	LEAD-TIMES ARE EXTENDING ON SPECIALS. SOME DOMESTIC CAPACITY IS BEING ADDED, AS WELL AS OFF-SHORE ASSEMBLY FACILITIES. VISUALIZE SOME IMPROVEMENT WITHIN NEXT 8 MONTHS
RELAYS			
MIL-28776	30-34	30-34	DEMAND ON MIL RELAYS CONTINUES AT STRONG RATE. ONLY TWO (2) QUALIFIED SUPPLIERS ON MIL-39016. DELIVERIES ARE EXTENDING
MIL-39016	30-34	44-50	

LEAD TIMES -- FY 1981 PROJECTIONS

CONTINUED PROBLEM AREAS FOR 1981 AND BEYOND

- CONNECTORS
- MOTORS
- LOW POWER SCHOTTKY
- TTL PRODUCT
- MIL RELAYS
- SELECTED JAN-TX TRANSISTORS AND DIODES

PROJECTED IMPROVEMENT IN 1981

- MEMORY PRODUCT
- TANTALUM CAPACITORS
- MICA CAPACITORS

PROJECTED PROBLEM AREAS IN 1981 AND BEYOND

- POLYCRYSTALLINE (INTEGRATED CIRCUITS)
- TRANSISTORS
- DIODES

MATERIAL ECONOMICS
THE FUTURE

- WORLD-WIDE ECONOMIC UNCERTAINTY
- DOMESTIC RECESSION
- CONTINUING INFLATIONARY CYCLE
- BASIC LAW OF SUPPLY AND DEMAND
- VOLATILE PRECIOUS METAL MARKET
- CONTINUING HIGH COST OF CAPITAL

ELECTRONICS OPERATIONS ECONOMIC FORECAST
PRODUCER PRICE INDEX
CODE 1178

ELECTRONIC COMPONENTS AND ACCESSORIES

ACTUALS

ROCKWELL FISCAL YEAR	BEGINNING INDEX	ENDING INDEX	ANNUAL RATE OF CHANGE
1976	114.5	116.2	1.5%
1977	116.2	120.5	3.7%
1978	120.5	127.3	5.6%
1979	127.3	139.9	9.9%
1980	139.9	160.5	14.7%

FORECAST

ROCKWELL FISCAL YEAR	JULY 1979 PROJECTED GROWTH	DECEMBER 1980 PROJECTED GROWTH
1981	10.1%	10.1%
1982	9.0%	9.2%
1983	8.4%	8.6%
1984	7.9%	7.5%
1985	7.2%	7.0%
PROJECTED AGGREGATE FIVE YEAR PERFORMANCE	50.5%	50.2%

PREVIOUS FIVE YEAR GROWTH — 40.1%

PRECIOUS METAL IMPACT

PRECIOUS METALS IMPACT ON ELECTRICAL COMPONENTS

- CONNECTORS
- INTEGRATED CIRCUITS
- TRANSISTORS
- DIODES
- TANTALUM CAPACITORS
- CERAMIC CAPACITORS
- MICA CAPACITORS
- PRINTED CIRCUIT BOARDS
- RELAYS
- SWITCHES
- WIRE

PRECIOUS METAL MARKET MOVEMENT

IMMEDIATE PAST 20 MONTHS

COMMODITY	DECEMBER 1978	AUGUST 1980	% INCREASE
GOLD	$218.00/TR OZ	$635./TR OZ	191%
SILVER	$ 5.97/TR OZ	$ 16./TR OZ	168%
PALLADIUM	$ 68.00/TR OZ	$207./TR OZ	204%
TANTALUM POWDER	$ 75.00/LB	$240./LB	220%

PRIOR 3 YEAR PERIOD

COMMODITY	DECEMBER 1975	DECEMBER 1978	% INCREASE	AVERAGE INCREASE PER YEAR
GOLD	$121.00/TR OZ	$218.00/TR OZ	80%	27%
SILVER	$ 3.94/TR OZ	$ 5.97/TR OZ	52%	17%
PALLADIUM	$ 44.00/TR OZ	$ 68.00/TR OZ	55%	18%
TANTALUM POWDER	$ 58.00/LB	$ 75.00/LB	29%	10%

PRECIOUS METALS MARKET

- HAS, AND WILL CONTINUE TO, SIGNIFICANTLY IMPACT ELECTRONIC COMPONENT PRICES

- THE LARGEST DOLLAR IMPACT TO ACQUISITION COST IS CENTERED IN:

  - TANTALUM CAPACITORS
  - CONNECTORS
  - TRANSISTORS
  - SWITCHES
  - INTEGRATED CIRCUITS

- HAS ADMITTEDLY STABILIZED TO SOME EXTENT, HOWEVER, ASPECTS OF VOLATILITY CONTINUE

- MOST SEGMENTS OF THE INDUSTRY HAVE FINALLY AGREED TO "PRECIOUS METAL ADDER" AT TIME OF ORDER PLACEMENT – RATHER THAN SURCHARGE AT TIME OF SHIPMENT. THE LAST TWO HOLDOUTS, NAMELY THE SEMICONDUCTOR AND CONNECTOR INDUSTRIES, CONTINUE TO CLING TO SURCHARGE APPLICATIONS

PRECIOUS METAL MARKET

RECOMMENDATIONS

- THAT THE ASSOCIATION RECOGNIZE THE VOLATILITY OF THE MARKET, HOWEVER, THAT IN UNISON, WE CONTINUE TO APPLY PRESSURE TO THE SEMICONDUCTOR AND CONNECTOR INDUSTRY FOR THE "UP-FRONT" APPLICATION OF THE PRECIOUS METAL IMPACT AT TIME OF ORDER PLACEMENT — RATHER THAN ACCEPTING THE SURCHARGE AT TIME OF ORDER SHIPMENT

- THAT THE ASSOCIATION CONTINUE TO SUPPORT JOHN GERON AND AIA IN THEIR PURSUIT OF DOD IN REGARD TO THE ADOPTION OF A PRICE PROTECTION CLAUSE, DEALING WITH PRECIOUS METAL PRICES, FOR STANDARDIZED INCORPORATION INTO GOVERNMENT CONTRACTS. (REFERENCE AIA LETTER (F.O. OHLSON) DATED 3 JULY 1980 AS ISSUED ROBERT F. TRIMBLE)

ALUMINUM/TITANIUM

VITAL PRODUCTS FOR THE AEROSPACE INDUSTRY

Sally Couluris

Grumman Aerospace

GRUMMAN

ALUMINUM/TITANIUM

VITAL PRODUCTS FOR THE AEROSPACE INDUSTRY

FEBRUARY 1981

GRUMMAN

THE AEROSPACE INDUSTRY IS VITAL TO:

- THE ECONOMY
- NATIONAL SECURITY

GRUMMAN

IT IS IN THE INTEREST OF A HEALTHY ECONOMY
TO MAINTAIN AN EFFECTIVE AEROSPACE INDUSTRY
TO MEET COMMERCIAL AND MILITARY DEMANDS

- AEROSPACE IS A HIGH-TECHNOLOGY INDUSTRY
  - HIGH-TECHNOLOGY EXPORTS GIVE U.S. COMPETITIVE EDGE
  - CREATES JOBS
  - IMPROVES BALANCE OF PAYMENTS
- U.S. SHOULD SPECIALIZE IN WHAT IT DOES BEST AND KEEP IT IN THE FORE-FRONT

GRUMMAN

IT IS IN THE INTEREST OF U.S. NATIONAL SECURITY
TO INSURE ADEQUATE AND SAFEGUARDED SUPPLIES
OF AEROSPACE CRITICAL RAW MATERIAL PRODUCTS
IN MINIMAL TIME FRAMES

GRUMMAN

ADEQUATE AND TIMELY ALUMINUM SUPPLIES DEPEND UPON CRITICAL SEGMENTS OF THE INDUSTRY:

1. AVAILABLE RAW MATERIALS
2. AVAILABLE ENERGY RESOURCES
3. AVAILABLE CAPACITY
4. ECONOMIC/POLITICAL CLIMATE (DEMAND)
5. NEW APPLICATIONS

EACH DEPENDS ON THE OTHER

GRUMMAN

CURRENTLY:

EACH MAJOR SEGMENT IS PRECARIOUSLY BALANCED IN ITS OWN RIGHT AS WELL AS IN RELATION TO THE OTHER SEGMENTS

GRUMMAN

- RAW MATERIALS
  - LOW QUALITY, LOW QUANTITY U.S. ORES
  - INCREASING U.S. DEPENDENCE ON IMPORTS
  - FOREIGN POLITICAL AND ECONOMIC UNCERTAINTIES
    - CONSEQUENT AFFECT ON RAW MATERIAL IMPORTS
- ENERGY
  - A VOLATILE INGREDIENT
  - POSSIBLE SHORTAGES AND/OR INCREASING COSTS
  - RESTRICTIONS OF ENVIRONMENTAL REGULATORY AGENCIES
    - CONSEQUENT AFFECT ON PRODUCTION CAPACITY
- CAPACITY
  - COULD EASILY APPROACH MAXIMUM UTILIZATION OF AEROSPACE ALLOYS AND MAJOR FORGINGS AGAIN
    - CONSEQUENT AFFECT ON TIMELY DEFENSE BUILDUP
- ECONOMIC/POLITICAL CLIMATE
  - UNPRECEDENTED AND UNPREDICTABLE WORLDWIDE DEMAND
- NEW APPLICATIONS
  - INCREASED DEMAND

GRUMMAN

ACCORDINGLY:

CONSOLIDATED PLANNING FOR AEROSPACE CRITICAL MATERIALS IS ESSENTIAL TO INSURE AVERTING POTENTIALLY SEVERE IMPACTS ON THE INDUSTRY'S ABILITIES TO MEET DEMANDS OF BOTH THE MILITARY AND COMMERCIAL MARKETS IN A COST EFFECTIVE AND TIMELY MANNER.

GRUMMAN

DETAILS PERTAINING TO
EACH SEGMENT OF THE
ALUMINUM/AEROSPACE INDUSTRY

GRUMMAN

RAW MATERIALS

GRUMMAN

BAUXITE

- 4 LBS. BAUXITE REFINED INTO 2 LBS. ALUMINA, SMELTED INTO 1 LB. ALUMINUM
- ABOUT 90% OF BAUXITE CONSUMED IN U.S. IS IMPORTED
  - OF OTHER 10%, OVER 3/4 IS MINED IN ARKANSAS
  - JAPAN IS SECOND LARGEST SINGLE NATION IMPORTER OF BAUXITE
- U.S. BAUXITE IMPORTS (14 MILLION METRIC TONS AS OF 1979):
  - 45% FROM JAMAICA
  - 30% FROM GUINEA
  - 10% FROM SURINAM
  - 15% FROM OTHER
    - BRAZIL NEW SOURCE AS OF END 1979
- LESS THAN 15 MILLION TONS OF BAUXITE IN U.S. STOCKPILE - ONE YEAR'S SUPPLY

GRUMMAN

BAUXITE

- ARRANGEMENTS WITH JAMAICAN GOVERNMENT DURING LATTER HALF OF '70'S HAVE ASSURED 40-YEAR BAUXITE SUPPLY TO MAJOR ALUMINUM COMPANIES:
  - ALCOA
  - REYNOLDS
  - KAISER
  - ALCAN

BUT:

- JAMAICAN LEVIES ON BAUXITE EXPORTS HAVE RESULTED IN LOWER U.S. IMPORTS
  - U.S. COMPANIES EXPANDING BAUXITE MINING AND REFINING OPERATIONS IN BRAZIL, SURINAM AND AUSTRALIA
  - JAMAICAN ECONOMY IN SHAMBLES
    - UNEMPLOYMENT EXCEEDING 30%
    - INTEREST PAYMENTS TO FOREIGN LENDERS OVERDUE
    - FOREIGN EXCHANGE RESERVES NEARLY DEPLETED, MAKING RAW MATERIAL IMPORTING DIFFICULT.

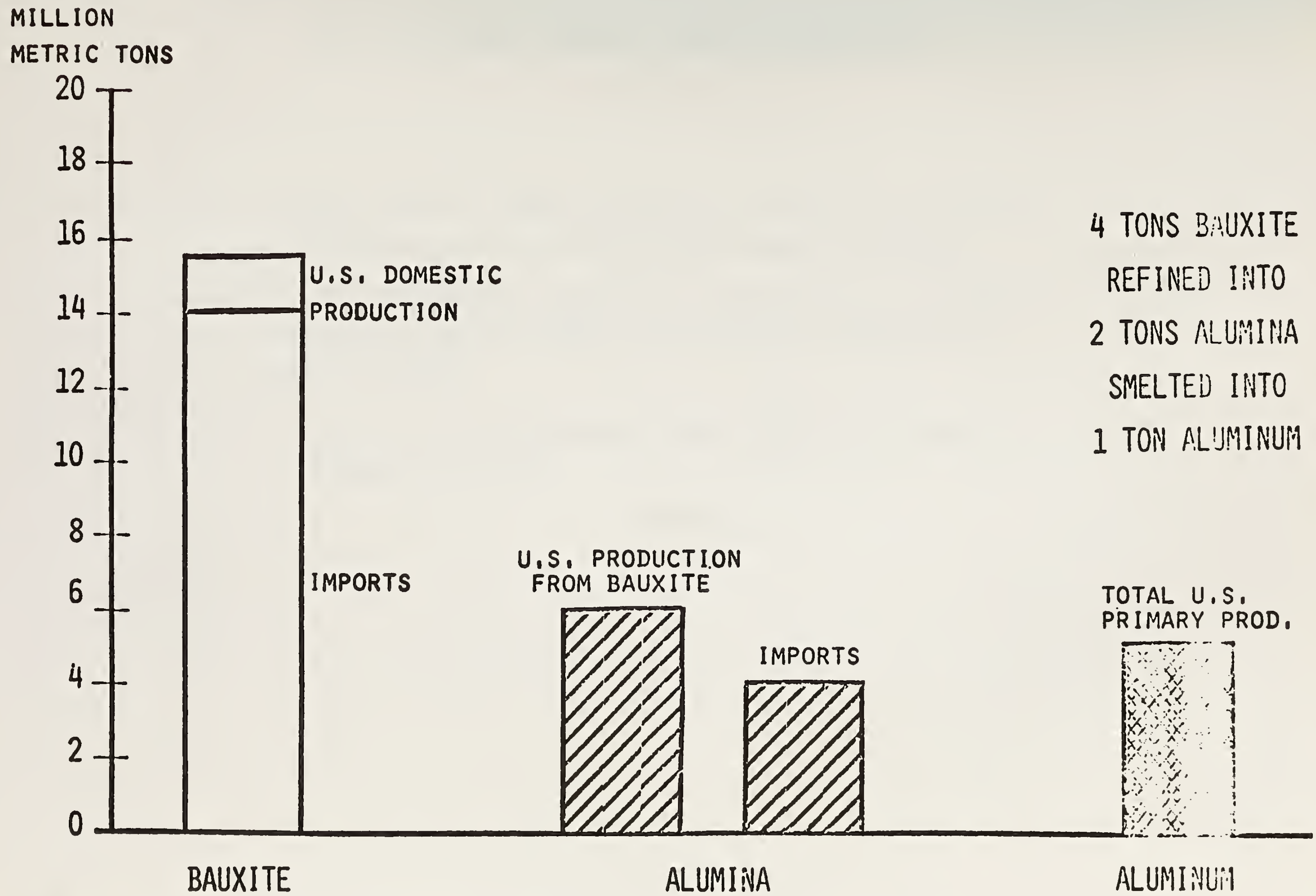
GRUMMAN

ALUMINA

- 4 LBS. BAUXITE REFINED INTO 2 LBS. ALUMINA, SMELTED INTO 1 LB. ALUMINUM
- ABOUT 93% OF U.S. BAUXITE SUPPLY IS USED TO PRODUCE ALUMINA
  - U.S. IS SECOND LARGEST PRODUCER OF ALUMINA WORLDWIDE (20%)
    - IS PRODUCING AT 84½% OF CAPACITY
- U.S. IMPORTS OF ALUMINA PROVIDE 40% OF TOTAL REQUIREMENTS
  - ABOUT 20% SUPPLIED BY JAMAICA AND SURINAM
  - AUSTRALIA:
    - ECONOMICALLY SOUND, POLITICALLY STABLE U.S. ALLY
    - SUPPLIES OVER 75% OF U.S. ALUMINA IMPORTS (ABOUT 3 MIL. MET. TONS)
    - IS LARGEST PRODUCER OF ALUMINA (¼ WORLD PRODUCTION)
      - PRODUCING AT 97½% OF CAPACITY
    - REYNOLDS/AUSTRALIAN VENTURE TO PRODUCE ONE MILLION TONS OF ALUMINA ANNUALLY BY 1984 (10% OF U.S. NEEDS)
    - DISADVANTAGE: 7,000 MILE SHIPPING LANE
- VIRTUALLY NO ALUMINA IN U.S. STOCKPILE

GRUMMAN

U.S. ALUMINUM PRIMARY PRODUCTION



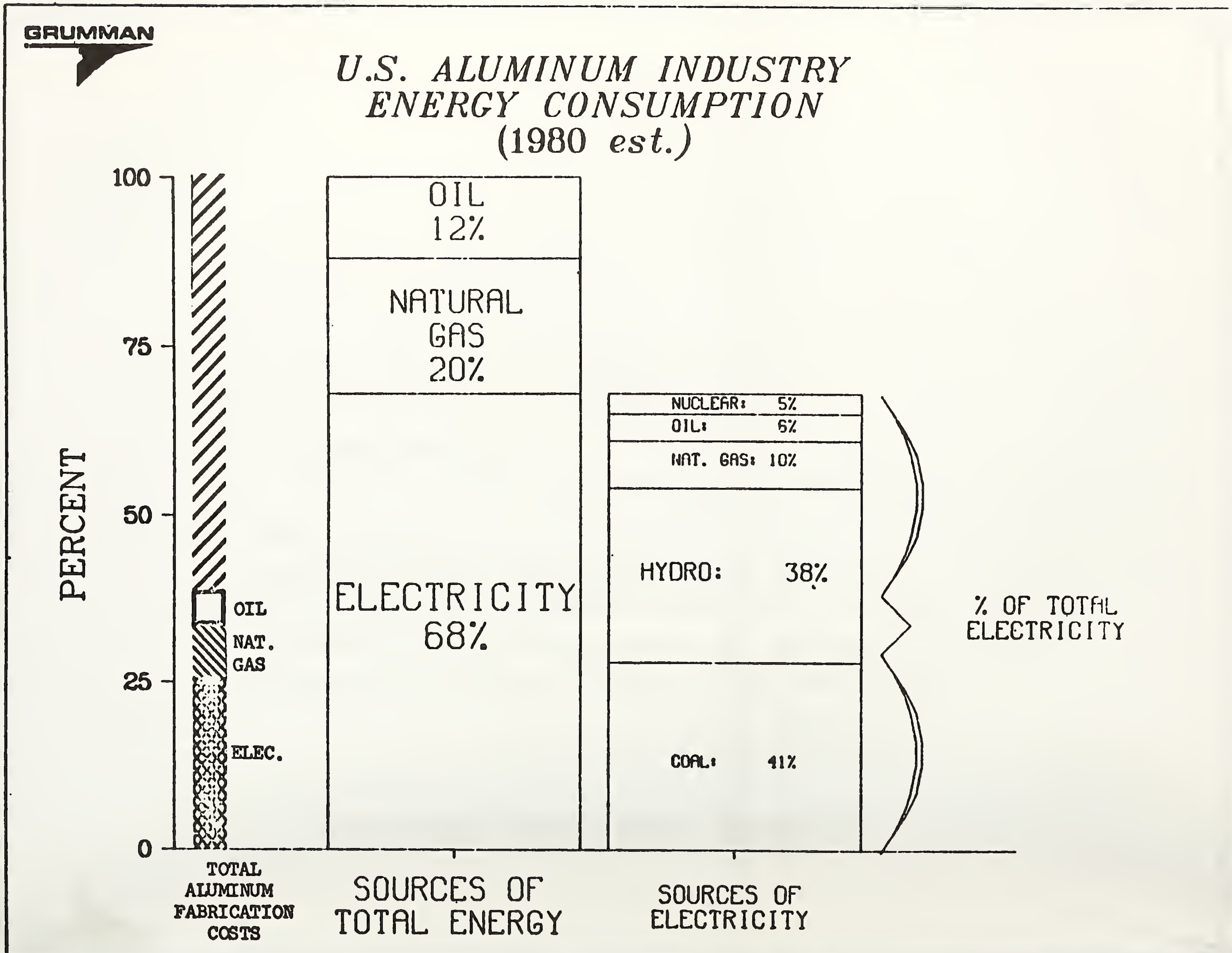
GRUMMAN

ENERGY

GRUMMAN

U.S. ALUMINUM INDUSTRY ENERGY CONSUMPTION

- AVERAGE COST OF ENERGY REQUIRED TO MAKE ONE POUND OF ALUMINUM UP MORE THAN 50% DURING PAST TWO YEARS.
- OF ALL INDUSTRIAL PROCESSES, PRODUCTION OF ALUMINUM REQUIRES GREATEST AMOUNT OF ELECTRICAL POWER PER UNIT OF OUTPUT.
  - ELECTRICITY CONSTITUTES ABOUT 25% OF ALUMINUM'S PRODUCTION COSTS.

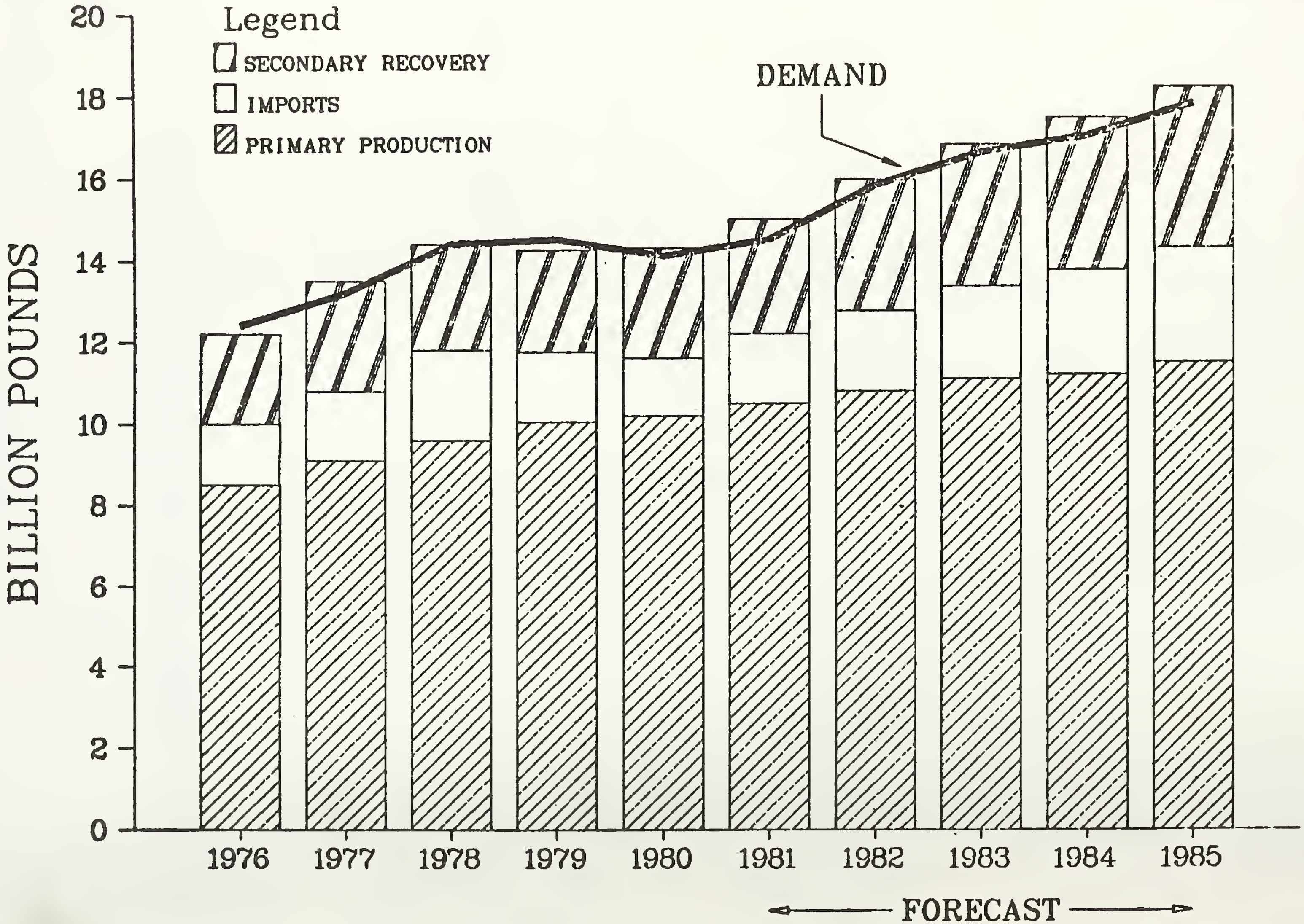

GRUMMAN
U.S. ALUMINUM INDUSTRY
ENERGY CONSUMPTION
(1980 est.)
PERCENT
100
75
50
25
0
OIL
NAT. GAS
ELEC.
TOTAL ALUMINUM FABRICATION COSTS
OIL 12%
NATURAL GAS 20%
ELECTRICITY 68%
SOURCES OF TOTAL ENERGY
NUCLEAR: 5%
OIL: 6%
NAT. GAS: 10%
HYDRO: 38%
COAL: 41%
SOURCES OF ELECTRICITY
% OF TOTAL ELECTRICITY

GRUMMAN

DEMAND

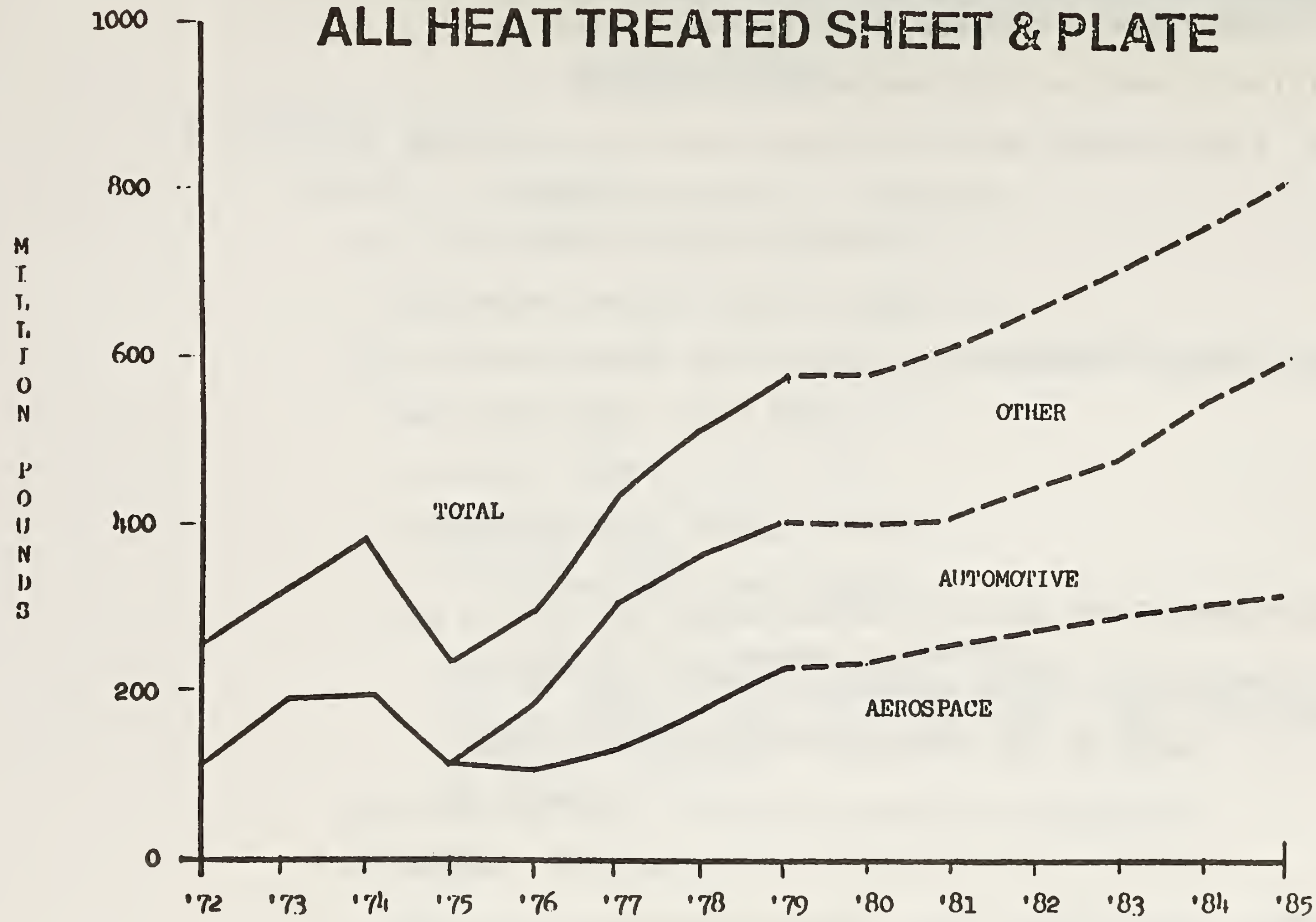
GRUMMAN

U.S. ALUMINUM INDUSTRY ESTIMATED TOTAL SUPPLY/DEMAND



GRUMMAN

U.S. ALUMINUM SHIPMENTS
ALL HEAT TREATED SHEET & PLATE



GRUMMAN

ALUMINUM DEMAND

- AUTOMOTIVE MARKET
  - FUEL ECONOMY
    - ENERGY POLICY AND CONSERVATION ACT OF 1975
      - BY 1985 AVERAGE AUTOMOBILE <u>FLEET</u> CONSUMPTION OF GASOLINE MUST BE 27.5 MILES PER GALLON
      - BILLIONS OF GALLONS OF GASOLINE CAN BE SAVED OVER LIFE OF ANY ONE YEAR'S MODELS
  - SMALL CAR SHARE OF AUTO MARKET
    - 1973: 42%
    - EARLY 1980: OVER 80%
    - IMPORT SHARE OF SMALL CAR SALES PEAKED AT 38% IN 1977
    - IMPORT SHARE: 30% IN 1979
      - DOLLAR'S DEPRECIATION
      - INCREASED DOMESTIC PRODUCTION
  - ALTHOUGH AUTO SALES EXPECTED TO RISE DURING 1980'S, SMALLER SIZE MAY REQUIRE LESS ALUMINUM THAT PREVIOUSLY ANTICIPATED
  - WILL BE GROWING COMPETITOR OF AEROSPACE MARKET FOR HEAT-TREATED ALUMINUM DESPITE RESEARCH AND DEVELOPMENT OF LIGHT STEEL ALLOYS AND SYNTHETIC MATERIALS

GRUMMAN

ALUMINUM DEMAND

- AEROSPACE MARKET
  - COMMERCIAL AIRCRAFT
    - FUEL EFFICIENCY AND NOISE ABATEMENT
      - REPLACING OR RETROFITTING OLD FLEETS
    - FREE WORLD SALES OF U.S. COMMERCIAL TRANSPORTS DURING 1980's
      - OLD GENERATION: OVER 2,000 A/C
        - BOEING 707, 727, 737, 747
        - DOUGLAS DC-9, DC-10
        - LOCKHEED L1011
      - NEW GENERATION: ABOUT 4,000 A/C
        - BOEING 757, 767, 777
        - DOUGLAS DC-9/80, DCX—200, ATMR (ADV. TECH. MED-RANGE)
        - LOCKHEED L1011-400
    - FREE WORLD SALES OF FOREIGN COMMERCIAL TRANSPORTS
      - AIRBUS: 1,000 A/C ?
      - EUROPEAN AND JAPANESE ENTRIES INTO THE AEROSPACE INDUSTRY
        - POSSIBLE JOINT VENTURES WITH U.S. COMPANIES

GRUMMAN

ALUMINUM DEMAND

AEROSPACE MARKET

- COMMUTER AIRCRAFT
  - GROWING MARKET FOR 20-80 PASSENGER, SHORT-HAUL AIRCRAFT
  - EXPECTED MARKET OF 1200-2000 A/C OVER 1984-'95 TIME FRAME.

GRUMMAN

ALUMINUM DEMAND

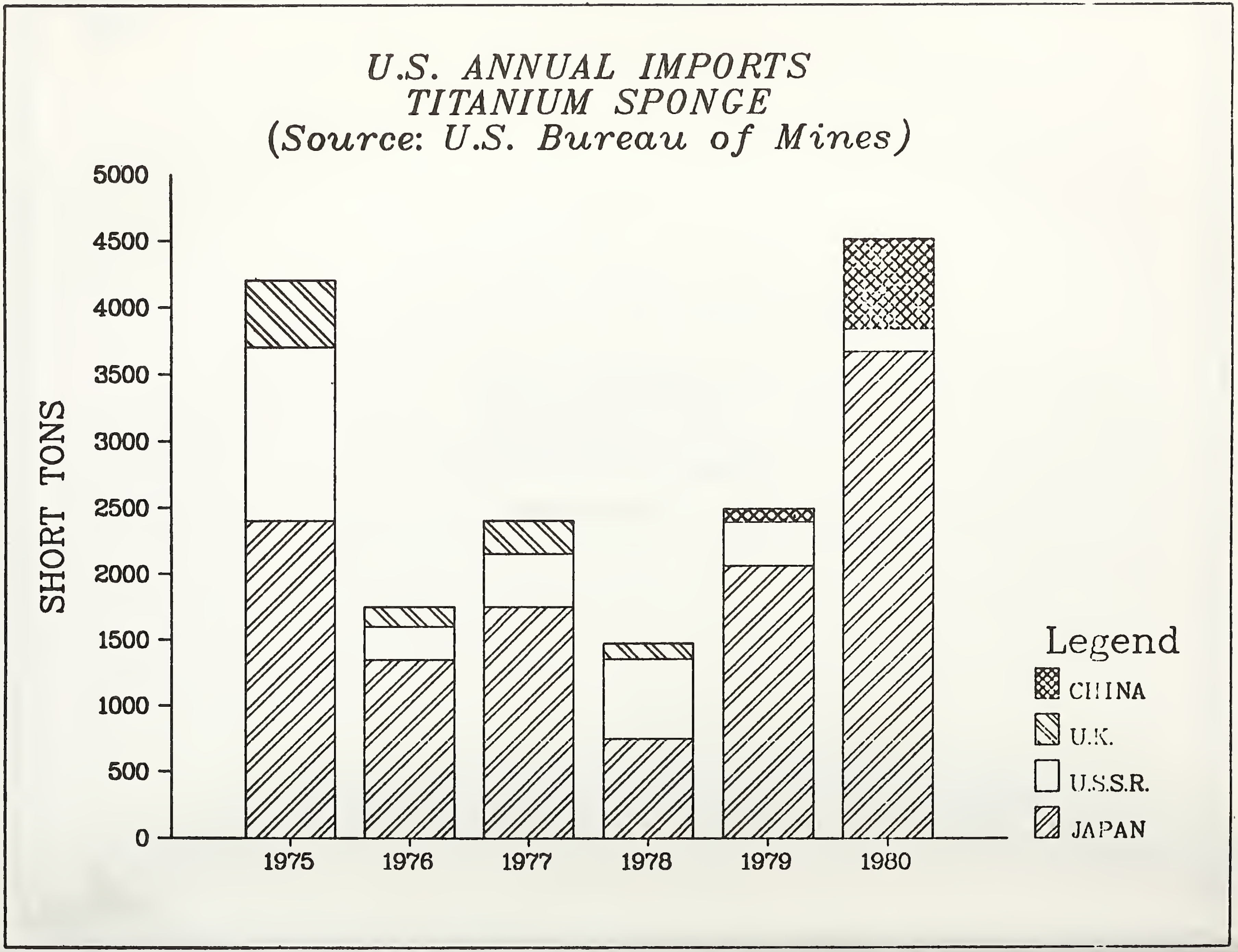
- AEROSPACE MARKET
  - MILITARY AIRCRAFT
    - INCREASING EMPHASIS ON U.S. DEFENSE
      - RESULTING ARMAMENTS BUILDUP WILL REQUIRE SIGNIFICANT INCREASE IN DEMAND FOR CRITICAL RAW MATERIALS
  - PRESENT MILITARY AIRCRAFT REQUIREMENTS FOR ALUMINUM BEING MET, BUT SUBJECT TO LONG LEAD TIMES
    - WITHOUT PROPER PLANNING, ANY INCREASE IN DEMAND FROM THIS MARKET MAY RESULT IN:
      - LONGER LEAD TIMES
      - MATERIALS SHORTAGES
      - THREAT TO NATIONAL SECURITY
    - MILITARY PRIORITY SYSTEM FOR CRITICAL RAW MATERIALS COULD PROVE DETRIMENTAL TO U.S. ECONOMY
      - COMMERCIAL AIRCRAFT MARKET WILL SUFFER
        - COSTS MAY CLIMB
        - EMPLOYMENT MAY DROP
        - SHIPMENTS MAY EXTEND
    - AUTO/TRUCK INDUSTRY MAY BE DEPRIVED OF TIMELY RECEIPT OF ALUMINUM HELPFUL IN MEETING FUEL ECONOMY GOALS

GRUMMAN

DETAILS PERTAINING TO
EACH SEGMENT OF THE
TITANIUM/AEROSPACE INDUSTRY

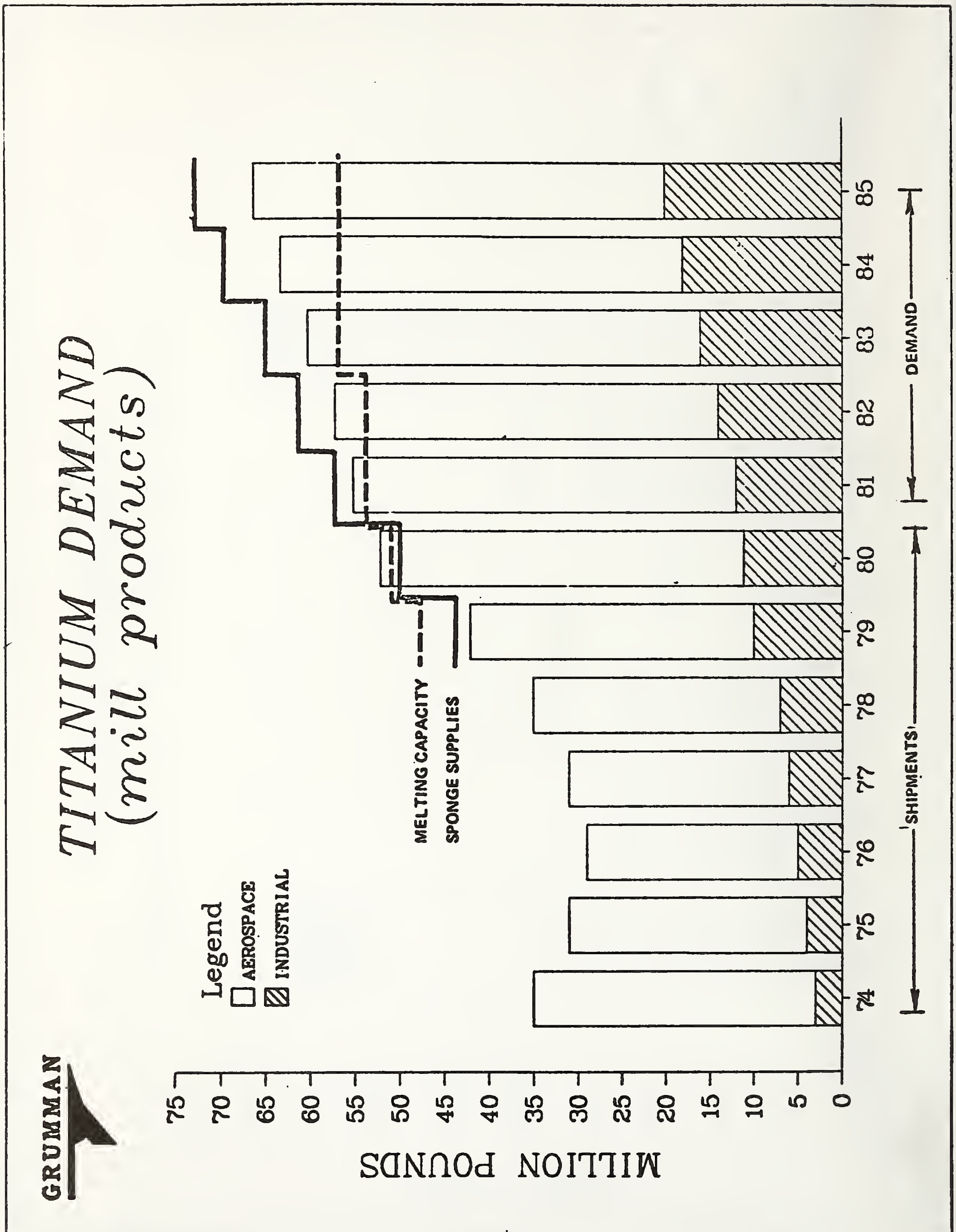
GRUMMAN

RAW MATERIALS


U.S. ANNUAL IMPORTS
TITANIUM SPONGE
(Source: U.S. Bureau of Mines)
SHORT TONS
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1975
1976
1977
1978
1979
1980
Legend
CHINA
U.K.
U.S.S.R.
JAPAN

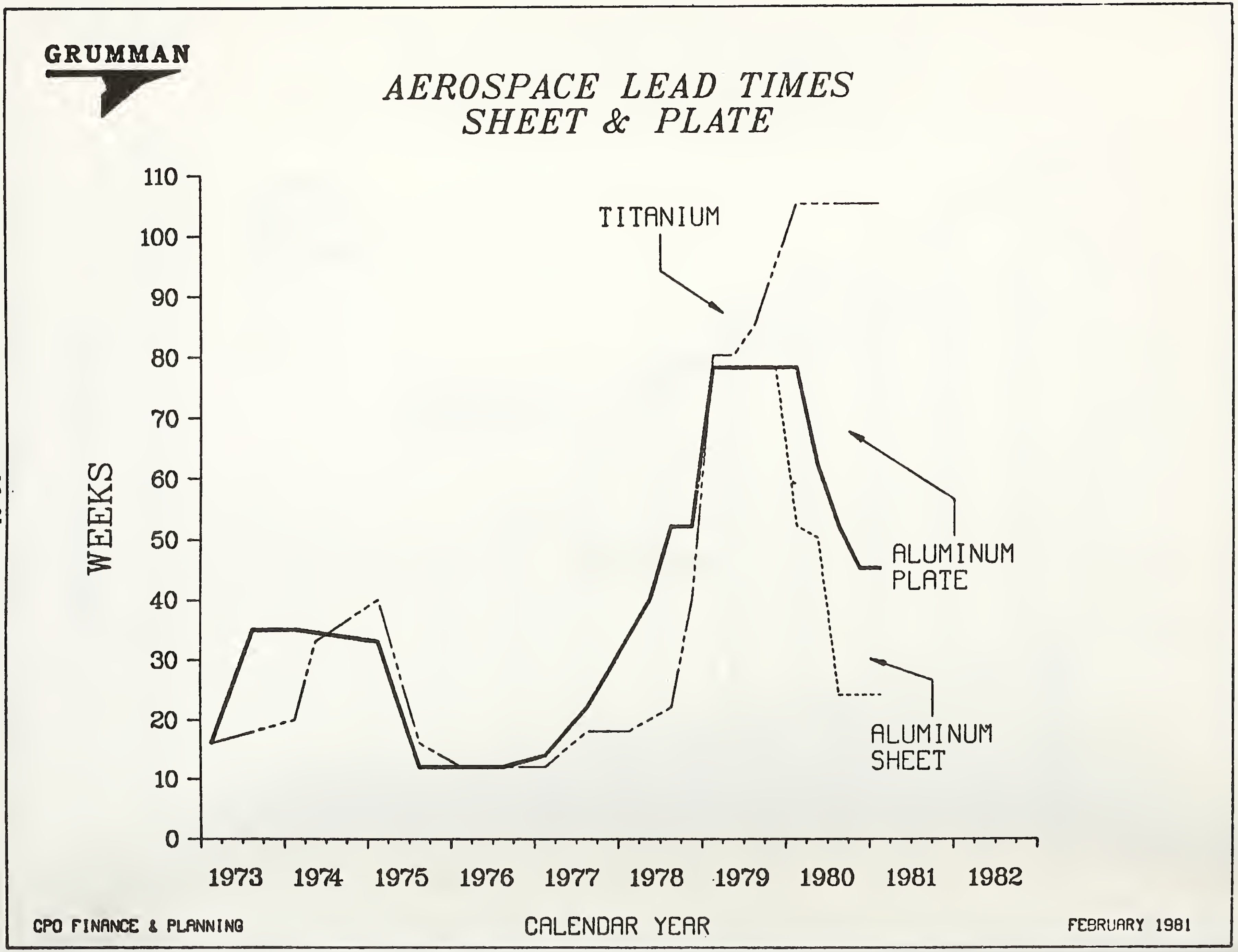
DEMAND

GRUMMAN


GRUMMAN
TITANIUM DEMAND
(mill products)
Legend
AEROSPACE
INDUSTRIAL
MELTING CAPACITY
SPONGE SUPPLIES
MILLION POUNDS
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
74
75
76
77
78
79
80
81
82
83
84
85
SHIPMENTS
DEMAND

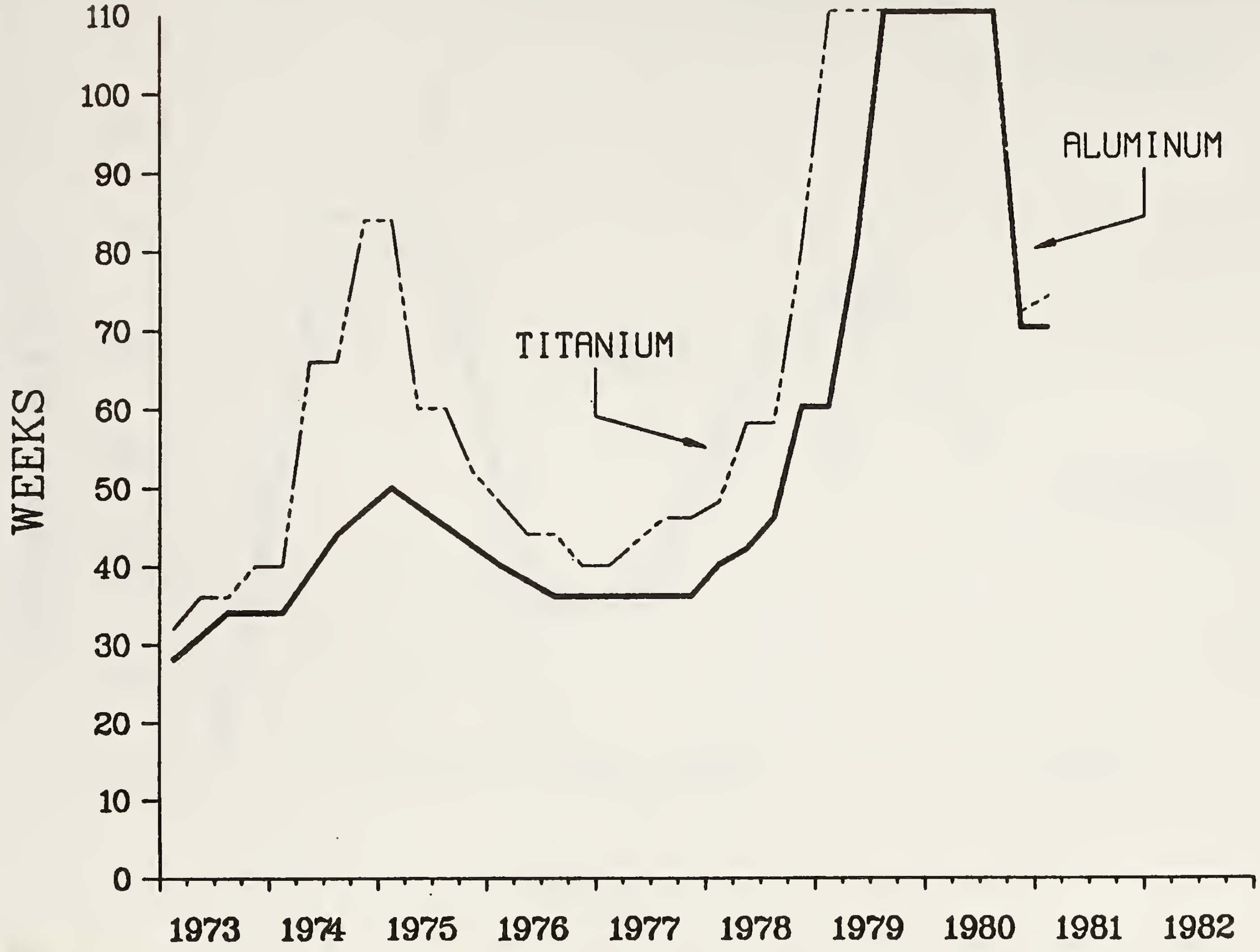
GRUMMAN

LEAD TIMES


GRUMMAN
AEROSPACE LEAD TIMES
SHEET & PLATE
WEEKS
110
100
90
80
70
60
50
40
30
20
10
0
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
CALENDAR YEAR
TITANIUM
ALUMINUM PLATE
ALUMINUM SHEET
CPO FINANCE & PLANNING
FEBRUARY 1981

GRUMMAN

AEROSPACE LEAD TIMES
MAJOR FORGINGS



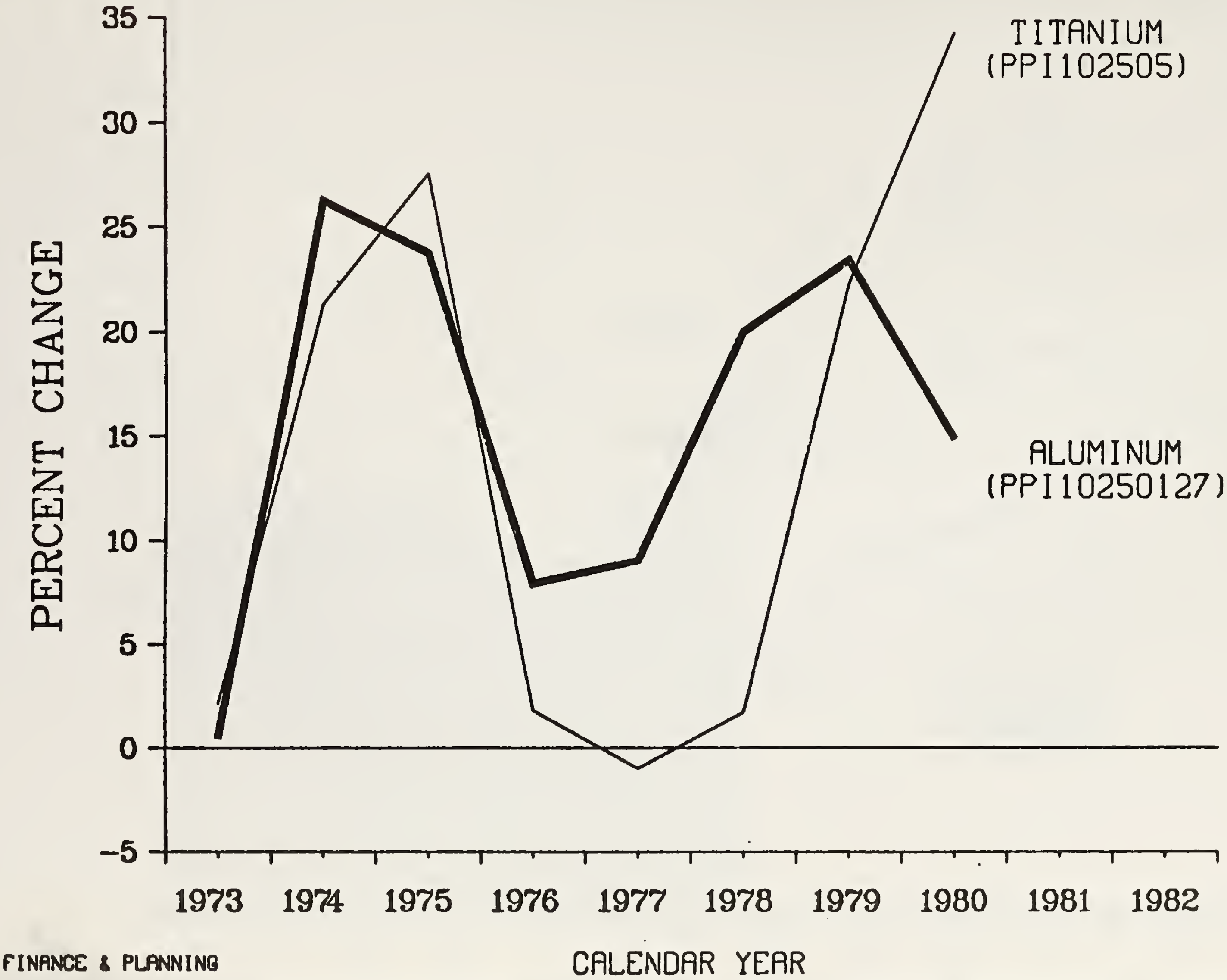
CPO FINANCE & PLANNING

FEBRUARY 1981

PRICES

GRUMMAN

AEROSPACE PRICES

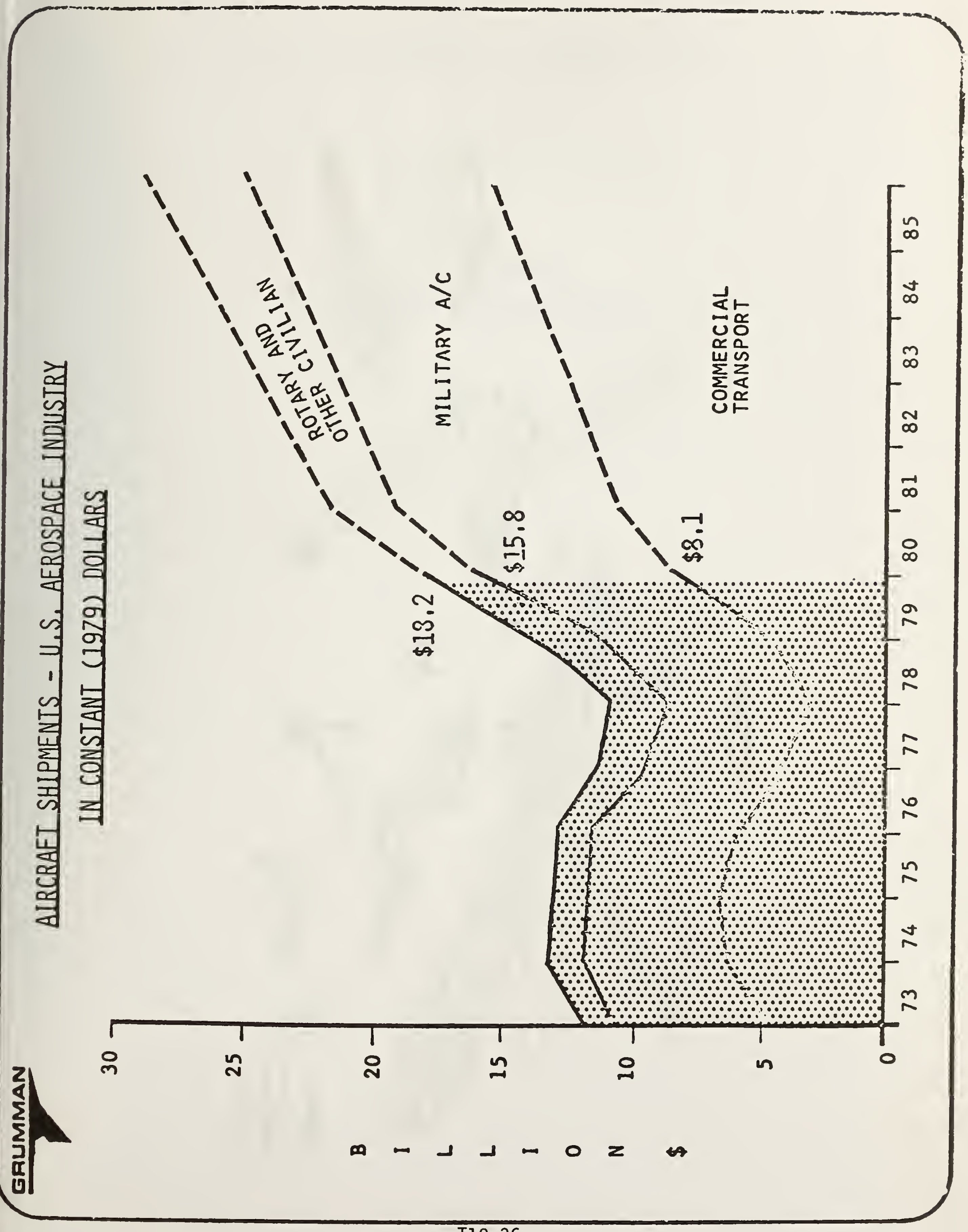


CPO FINANCE & PLANNING

FEBRUARY 1981

GRUMMAN

OUTLOOK


GRUMMAN
AIRCRAFT SHIPMENTS - U.S. AEROSPACE INDUSTRY
IN CONSTANT (1979) DOLLARS
BILLION $
0
5
10
15
20
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ROTARY AND
OTHER CIVILIAN
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COMMERCIAL
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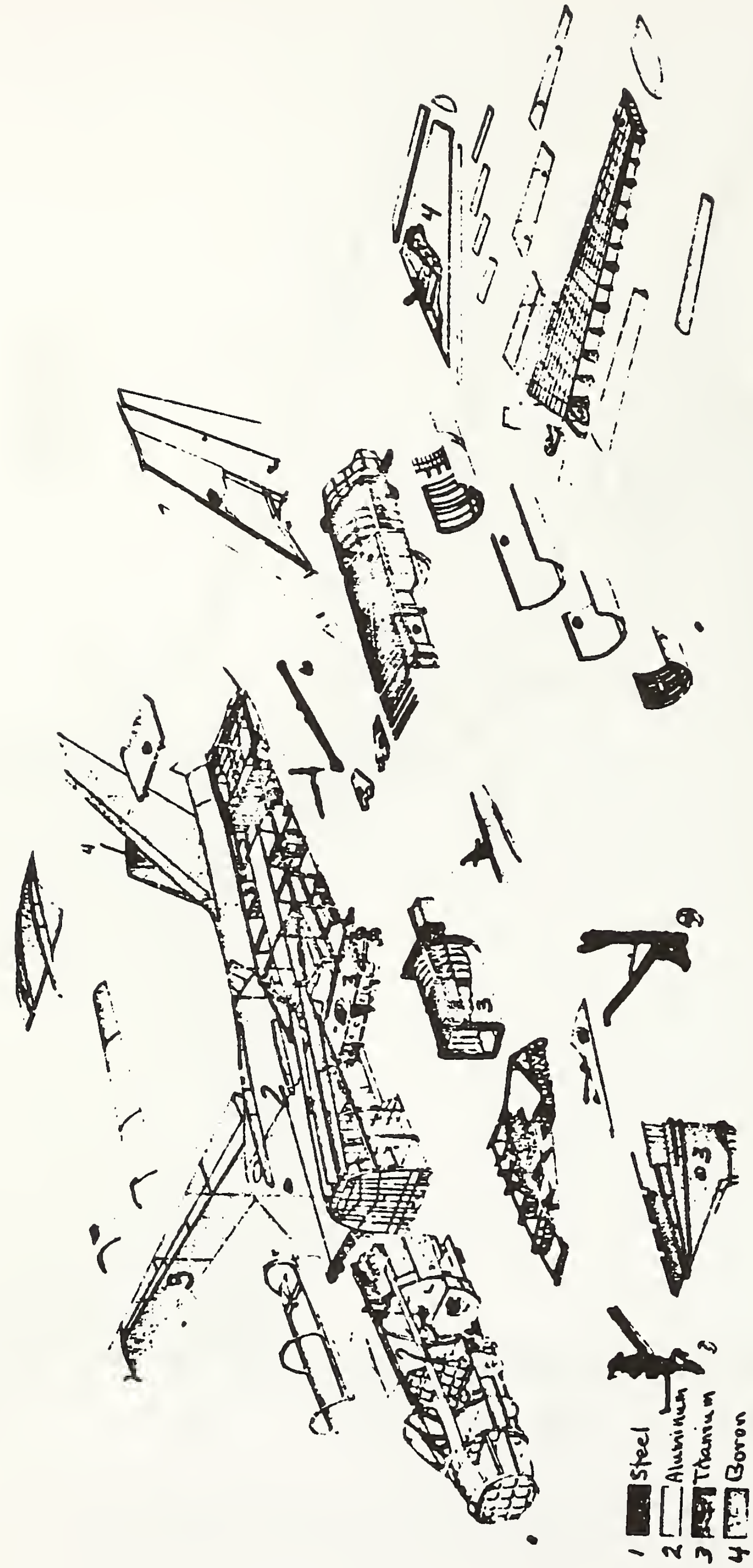
1 Steel
2 Aluminum
3 Titanium
4 Boron

CRITICAL MATERIALS & MACHINE TOOLS

C. J. Beigle
Rockwell International

CRITICAL MATERIALS & MACHINE TOOLS

C. J. BEIGLE

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IN THE COMPLEX WORLD OF AEROSPACE PRODUCTION, CHANGES IN AVAILABILITY OR LEAD TIMES CAN ALTER THE CRITICAL PATH IN THE PRODUCTION SCHEDULE AND FOCUS ATTENTION ON A SMALL AREA SUCH AS MACHINE TOOL ACQUISITION. MOST NEW AEROSPACE PROGRAMS GENERATE A FLURRY OF ACTIVITY PLACING ORDERS FOR NEW CAPITAL EQUIPMENT. A PORTION OF THIS WILL BE FOR EXPANSION OF CAPABILITY AND CAPACITY AND A PORTION WILL BE FOR REPLACEMENT OF EXISTING EQUIPMENT. A SELECTION OF MAJOR MACHINE TOOLS IS NO LONGER AVAILABLE TO GOVERNMENT AEROSPACE CONTRACTORS FROM GOVERNMENT INVENTORY AS IT WAS IN PREVIOUS TIME PERIODS. BIDS FOR THIS EQUIPMENT WOULD BE REQUESTED FROM THE GENERAL MACHINE TOOL INDUSTRY.

WE NEVER SEEM TO HAVE THE LUXURY OF ADEQUATE LEAD TIME FROM CONTRACT GO-AHEAD TO THE DATE THE EQUIPMENT MUST BE ON THE LINE AND OPERATING. "NORMAL" LEAD TIMES ARE INFLUENCED BY MANY FACTORS AND VARY FOR THE DIFFERENT TYPES OF MACHINES. LARGE, 3 AND 5 AXES GANTRY TYPE NC MILLS RUN 14 TO 20 MONTHS LEAD TIME. MACHINING CENTER

TYPE MILLS RUN 14 TO 18 MONTHS, AND CONVENTIONAL MACHINES RUN 9 TO 14 MONTHS FROM ORDER DATE TO DELIVERY. THIS LEAD TIME IS MORE DEPENDENT ON THE MANUFACTURER'S BACKLOG, AVAILABILITY OF TRAINED MANPOWER, MACHINING CAPACITY AND ASSEMBLY FLOOR AREA THAN ON CRITICAL MATERIALS.

THE CURRENT ECONOMIC DOWNTURN HAS REDUCED BACKLOGS IN GENERAL. HOWEVER, SOME COMPANIES HAVE STARTED PLACING ORDERS FOR CAPITAL EQUIPMENT TO MODERNIZE AND INCREASE THEIR PRODUCTION CAPABILITY TO MEET THE EXPANDING MARKET THAT THEY FORECAST FOR THE NEXT FEW YEARS. AS MORE COMPANIES JOIN IN THIS TREND, BACKLOGS WILL INCREASE AND THE LEAD TIME FROM ORDER PLACEMENT TO DELIVERY DATE WILL INCREASE.

THE MACHINE TOOL DESIGNERS DID NOT HAVE THE SEVERE WEIGHT, STRENGTH AND ENVIRONMENTAL CONSTRAINTS THAT FACE THE AEROSPACE ENGINEERS. EXOTIC ALLOYS WERE AVOIDED WHERE POSSIBLE FOR REASONS OF COST AND AVAILABILITY.

THE MOST FREQUENTLY USED MATERIALS IN MACHINE TOOLS ARE IRON CASTINGS, FORGINGS AND WELDMENTS. THERE ARE, OF COURSE, SELECTIVE APPLICATIONS OF COMMON STEELS AND IN AREAS WHERE HIGH STRENGTH, HARDNESS, ACCURACY AND LONG LIFE ARE IMPORTANT, STEEL ALLOYS ARE USED THAT

DO CONTAIN CRITICAL MATERIALS SUCH AS COBALT, CHROMIUM AND MOLYBDENUM. THE AMOUNT OF THESE MATERIALS IN A MACHINE TOOL IS VERY SMALL IN RELATION TO THE MASS OF THE COMPLETE MACHINE. HOWEVER, THESE PARTS IN MOST CASES ARE CRUCIAL TO THE OPERATION OF THE MACHINE (CLUTCH PARTS, HARDENED WAYS, ETC.). IF SOME OF THESE CRITICAL MATERIALS WERE NOT AVAILABLE, SUBSTITUTIONS COULD BE MADE TO ALTERNATE MATERIALS IN MANY CASES. THIS COULD LEAD TO INCREASED COST, LONGER LEAD TIMES, AND POSSIBLE LOWER PERFORMANCE OR LIFE OF THE EQUIPMENT. IN SOME CASES, FOLLOWING THE "FOR LACK OF A NAIL, A SHOE WAS LOST" SYNDROME, THE DELIVERY OF THE ENTIRE MACHINE COULD BE DELAYED UNTIL THE CRUCIAL PARTS COULD BE PROVIDED.

IF A CRITICAL MATERIAL SUCH AS MANGANESE WERE NOT AVAILABLE, THE IMMEDIATE DROP IN STEEL PRODUCTION WOULD HAVE A DIRECT EFFECT ON AEROSPACE CONTRACTORS LONG BEFORE THE SECONDARY PROBLEM OF DELAYED MACHINE TOOL DELIVERIES COULD BE FELT.

A SEPARATE, BUT EQUALLY IMPORTANT FIELD, IS MACHINE TOOL CUTTERS AND DRILLS. YOUR COMPANY COULD HAVE ALL OF THE MACHINE TOOLS INSTALLED BUT WITHOUT CUTTERS YOU CANNOT MAKE PARTS.

THE HIGH STRENGTH, HIGH HEAT RESISTANT STEEL AND TITANIUM ALLOYS THAT ARE USED IN TODAY'S AEROSPACE VEHICLES REQUIRE

SPECIAL CUTTERS. THESE CUTTERS HAVE TO BE EXTREMELY HARD. CARBIDE, WHICH IS NOT A CRITICAL MATERIAL, WORKS FINE IN SOME APPLICATIONS BUT MANY CUTTERS AND DRILLS ARE MADE FROM MOLYBDENUM AND COBALT RICH ALLOYS.

DURING THE LAST COBALT SHORTAGE A PROGRAM WAS ESTABLISHED AT ROCKWELL INTERNATIONAL TO SEGREGATE WORN, BROKEN AND OBSOLETE CUTTERS AND DRILLS. THESE SCRAP CUTTERS WERE SOLD TO OUR SUPPLIERS WHO HAD THEM REPROCESSED INTO NEW CUTTERS. PRIOR TO THIS PROGRAM THE SCRAP HAD BEEN SOLD ON THE OPEN MARKET AND PROBABLY ENDED UP IN JAPAN. THIS METHOD OF RECLAIMING CRITICAL MATERIALS SHOULD BE ENCOURAGED AND EXPANDED.

THE MACHINE TOOL CUTTER INDUSTRY HAS BEEN TRYING TO DEVELOP NEW CUTTERS TO REPLACE COBALT. THE LIFE OF CARBIDE TURNING CUTTER INSERTS HAS BEEN GREATLY IMPROVED (ABOUT 7 TIMES THE LIFE OF STANDARD INSERTS) BY COATING THE INSERTS WITH TITANIUM. IT HAS BEEN FOUND THAT THIS REDUCED PITTING AND CRAZING OF THE CARBIDE.

ANOTHER NEW CUTTER DEVELOPMENT THAT SHOWS PROMISE IS THE NEW SINTERED METAL CUTTERS. THESE CUTTERS, WHICH ARE MADE FROM POWDERED METAL ALLOYS THAT ARE HEATED AND COMPRESSED, ACTUALLY CONTAIN 10-12% COBALT IN CONTRAST TO THE 8% IN A CONVENTIONAL COBALT ALLOY

CUTTER. AT PRESENT THE SINTERED CUTTERS ARE ABOUT TWICE THE COST OF CONVENTIONAL COBALT ALLOY CUTTERS BUT THEY ARE HARDER THAN COBALT AND THEY HAVE ABOUT EIGHT TIMES THE CUTTING LIFE. THE EXPANDED USE OF THIS CUTTER WILL HAVE THE NET EFFECT OF REDUCING COSTS AND CONSERVING COBALT IN THE CUTTER INDUSTRY.

THIS PROCESS HAS BEEN SUCCESSFULLY USED FOR END MILLS AND SOME REAMERS. TESTING IS NOW GETTING STARTED ON TWIST DRILLS. EIGHTY PERCENT OF THE TWIST DRILLS THAT WE USE ARE HIGH MOLYBDENUM ALLOY. IF SUCCESSFUL, THE NEW SINTERED TWIST DRILLS COULD ALSO CONSERVE THIS CRITICAL MATERIAL.

RESEARCH AND DEVELOPMENT IN THE CUTTER INDUSTRY SHOULD BE ENCOURAGED TO GREATLY EXTEND THE LIFE OF EXISTING CUTTERS OR DEVELOP NEW CUTTERS THAT WOULD NOT USE CRITICAL MATERIALS.

A THIRD AREA OF CONCERN IS THE DIMENSIONAL TOOLING THAT IS USED IN AEROSPACE PRODUCTION. TOOLS RANGING FROM HOT FORMING DIES TO DIFFUSION BONDING TOOLING AND THE NEW SUPERPLASTIC FORMING TOOLING, ALL REQUIRE HIGH STRENGTH, HIGH HEAT RESISTANT STEELS. THESE NEW PRODUCTION TECHNIQUES REDUCE MANUFACTURING HOURS PRODUCE SUPERIOR PARTS BUT REQUIRE EXTENSIVE TOOLING

OF STEEL ALLOYS UTILIZING CRITICAL MATERIALS.

IN CONCLUSION, THE LOSS OF COBALT IMPORTS COULD BE OFFSET FOR ABOUT TWO YEARS BY UTILIZING THE GOVERNMENT RESERVES. THIS WOULD ONLY BE A SHORT TERM SOLUTION. DOMESTIC SOURCES OF COBALT AND MOLYBDENUM SHOULD BE DEVELOPED. MACHINE TOOL CUTTER RESEARCH SHOULD BE ENCOURAGED TO DEVELOP MORE EFFICIENT SUBSTITUTE CUTTERS FOR MOLYBDENUM AND COBALT CUTTERS. AEROSPACE CORPORATIONS, POSSIBLY WITH GOVERNMENT R&D FUNDING, SHOULD EXPLORE THE USE OF NEW ALLOYS, COATINGS, AND SURFACE TREATMENTS INCLUDING METGLAS AND ION IMPLANT TO REDUCE THE DEPENDENCE ON CRITICAL MATERIALS IN TOOL STEELS.

THE MANUFACTURERS OF MACHINE TOOLS COULD BE ENCOURAGED TO FIND SUBSTITUTION MATERIALS FOR THE CRITICAL ALLOYS USED IN THEIR PRODUCTS. IT IS DOUBTFUL THAT ANY ACTION WOULD BE TAKEN IN THIS DIRECTION UNTIL THE CRITICAL MATERIALS ARE NO LONGER AVAILABLE OR A NEW MATERIAL COULD BE OBTAINED AT LOWER COST.

CRITICAL MATERIAL ISSUES

Jim D. Martin
General Dynamics Corporation

CRITICAL MATERIAL ISSUES
GENERAL DYNAMICS CORP.

The specific areas I have been asked to discuss are Castings, Forgings and Extruded Shapes and the related issues surrounding these items. These items, or their equivalents, machine from plate, bar or rod are the basic structural components from which our aircraft and missile programs are manufactured. They are used extensively throughout the F-16 Fighter Aircraft, the cruise missile and various other missile programs manufactured by our aerospace divisions. As the charts presented indicate, the lead times and price history of these items indicate they have been real problems in the past and are likely to be in the future. A discussion of castings and forgings must necessarily involve a brief analysis of the primary metals from which these products are made.

A. Aluminum - The largest number of castings and forgings, machined parts, etc. for aerospace applications is made from aluminum. It has been stated by one of our large aerospace divisions that the greatest impact to their business in the 1978/1979 time period was the failure of the aluminum industry to keep pace with the demand. Currently, due to general economic conditions, there has been a softening in the aluminum marketing. We view this, however, as only temporary relief and expect a return to tight market conditions when economic recovery begins and increased defense requirements occur. It is pertinent to note that the automotive industry is requiring increased amounts of aluminum due to environmental and fuel economy considerations. Reasons given to us by the aluminum industry for its slow pace in increasing capacity are: Uncertain market conditions - a large capital expenditure is required - and the lack of a firm energy policy.

B. Titanium - This is the other primary metal associated with availability of the structural components for our products and is also a critically short material. Prior to 1978, there were reasonable capacity and price stability. Since 1978, the demand has substantially increased for this material, creating availability on a strict allocation basis including those with DX and DO rated orders. This increased demand has further resulted in lead times of 90 weeks with mills requiring "no cancellation" provisions and price in effect at time of shipment. We have received some statistical data compiled by a major titanium producer which projects demand by program and commodity during the period 1981 thru 1987. This data rejects a cumulative deficit of 7.8 million pounds of sponge during the 1984 thru 1987 period without considering the potential multi-roll bomber and other new programs. Obviously, these conditions will result in severe shortages and in more rigid allocation programs unless corrective measures are taken.

Even assuming there were no shortages of the basic metals, there are some specific problems associated with the castings and forgings industry as they relate to aerospace requirements.

1. <u>Precision Forgings</u> - In the last five years a significant advancement in the state of the art of making forgings has occurred which enables the manufacturer of forgings to produce parts with extremely tight tolerances and unusual shapes. The utilization of these types of forgings is a cost effective alternative to the expensive hog outs and is becoming increasingly popular throughout the industry. We believe engineers will increasingly specify the forgings in the interest of freeing up machinists and spindle time which also have been in short supply. As the charts presented indicate, the lead time for these items have been excessive. We believe that these lead times are indicative of a fundamental lack of capacity by the forging industry. This capacity is governed by the following items:

    a. <u>Number of Producers</u> - It is our understanding that the forging industry has recently given testimony about the industrial base indicating there is plenty of forging capacity in the U.S. We believe that precision forgings for aerospace application are an exception. There are approximately 200 companies in the forging industry association with only 40 of these doing aerospace work. Of these 40, 19 do over 95% of the aerospace business. Our Pomona Division recently solicited over 80 companies for a forging for the SM1 and SM2 Missile with only 2 responses.

b. Lack of Presses - We understand that there are only 30 presses in the industry that have a range from 500 to 3,000 tons. Although the investment is relatively small ($500,000 to $1,000,000 per press), it represents a large investment for many which are small businesses. Further, they express reluctance to make these investments in what they perceive to be an unstable market. For certain, very specialized forgings requiring the very large presses, there is even a more limited capacity. There are only two presses in the country of the 50,000 ton variety.

c. OSHA and EPA - The forging industry reports that their productivity and ability to deliver product is to some extent affected by these governmental agencies. One California supplier reports that he has repeatedly paid fines for use of a petroleum based dye lubricant. We believe that other forging houses could be susceptible to the same strict enforcement. The industry is pressing for development of a water based formula.

2. Casting - As you will note from the lead time trends on the charts presented, the lead times for castings have remained relatively constant but are still troublesome

items. In spite of the loss of many foundries over the last several years, there is still a significant casting capacity in the U.S. We have, however, experienced a significant problem with premium sandcastings which have high property requirements. There are essentially only three large companies in this business for which demand has exceeded supply. This has resulted in lead time of 72 weeks and rapidly escalating prices up to 21% per year. A program like the cruise missile has a significant number of such castings, and a surge in production rate would severely impact the available capacity.

In addition to the materials discussed above, several other items warrant investigation and action. These are graphite composites, electrical connectors, integrated circuits and discrete semiconductors, bearings, titanium fasteners and other items as may be identified by the aerospace manufacturers.

No specific recommendations are made on the topics presented except that the solutions to these problems fit into a broader picture that was recently covered by the Air Force Systems Command in their "Pay Off 80" publication. We join with the Air Force Systems Command in their recommendations reprinted as follows and feel these are pertinent to the DOD in general.

CONDITION: Government contracts do not fully utilize available contracting techniques to provide appropriate motivation for industry to produce efficiently.

RECOMMENDATIONS: Increase the use of multi-year contracting as an excellent way to achieve program stability and economy. It not only allows contractors to optimize their schedule, stabilize their workforce, and purchase economic lot buys of material; but provides the incentives to make needed investments since return-on-investment (ROI) decisions are based on more than one year.

Use incentive fees contract techniques to encourage contractors to implement new manufacturing technology embodied in new processes, methods, and equipment. Such contracts provide a fee percentage payable if a target is met -- in this case, the investment in a new technology and/or equipment that reduces cost or improves responsiveness in the performance of the contract.

Use termination protection clauses to guarantee the contractor the ability to recoup its investment in modern cost-effective manufacturing severable plant equipment. This technique, as defined in DAR 3-815, does not provide a contractor with complete risk protection. However, it is especially useful in situations where ROI is sufficient but substantial risk exists with regard to program continuity.

Use of Capital Investment Clause to provide the contractor with a share of the savings that result from their investment in severable plant equipment which significantly reduces the cost of a system acquired by the Government.

Use an award fee to provide an additional incentive to encourage contractors to implement an aggressive and innovative Manufacturing Modernization program. The award fee should be tailored to the specific system being acquired, and it should be of sufficient magnitude to provide a real incentive for the company to perform in an outstanding manner.

AFSC should continue to use competitive procurements for production options but should also encourage contractors to invest in one-time development, capital equipment, tooling or start-up charges that can demonstrate cost savings spread over larger quantities planned for the future. These incentives could include follow-on guarantees if the contractor can demonstrate significant cost savings or other benefits.

Provide Government technology funding as an incentive to commit the contractor(s) to develop plant modernization programs or to invest in new processes, methods, and equipments that embody new technology.

CONDITION: The US is a major mineral and material user and is becoming increasingly dependent on foreign sources. Some of our imported supplies are concentrated in only a few countries that are susceptible to political turbulence. Some of our imported materials/minerals could be supplied by domestic sources, if the right types of incentives were provided. The US has specific legislation, Title III of the Defense Production Act and the National Stockpile Act, which could be used to provide incentives and encourage domestic expansion of supplies.

RECOMMENDATIONS: Use the National Stockpile Act to encourage expansion of productive capacity of critical raw materials and minerals. Long term commitments to purchase would encourage expansion of domestic sources and partially fulfill stockpile inventory goals.

Revitalize the Defense Production Act, Title III, Expansion of Productive Capacity and Supply, to provide incentives for domestic industries to expand capacity and/or develop domestic capability. These incentives could include loan guarantees, direct loans, commitments to purchase, direct purchases, subsidies, and R&D efforts to encourage our domestic industries to produce needed materials for defense purposes.

CONDITION: The US's near total dependence on foreign sources for scarce and critical materials leaves our programs open to sudden supply disruption and rapid escalation in cost and lead times. Our present budgetary process is too slow and is unable to adjust to the rapidly changing world market conditions. Programs need the authority to advance buy limited supplies of select critical raw and semi-processed materials when it makes good business sense or when national security needs require it.

RECOMMENDATIONS: DODD 7200.4, Full Funding for DOD programs, needs to be changed to permit long lead procurement, not only for components but for raw and semi-processed materials.

The use of multi-year procurements (MYP) would encourage our contractors to buy materials in economic lot quantities and secure favorable long term material supply agreements. In addition, it would provide our contractors with the flexibility to advance buy material when market conditions project dramatic price/lead time increases. Current MYP cancellation ceilings are too low ($5M) to effectively use this procurement technique in many applications without significant efforts to obtain congressional waivers. This ceiling should be raised to allow effective and timely implementation of MYP.

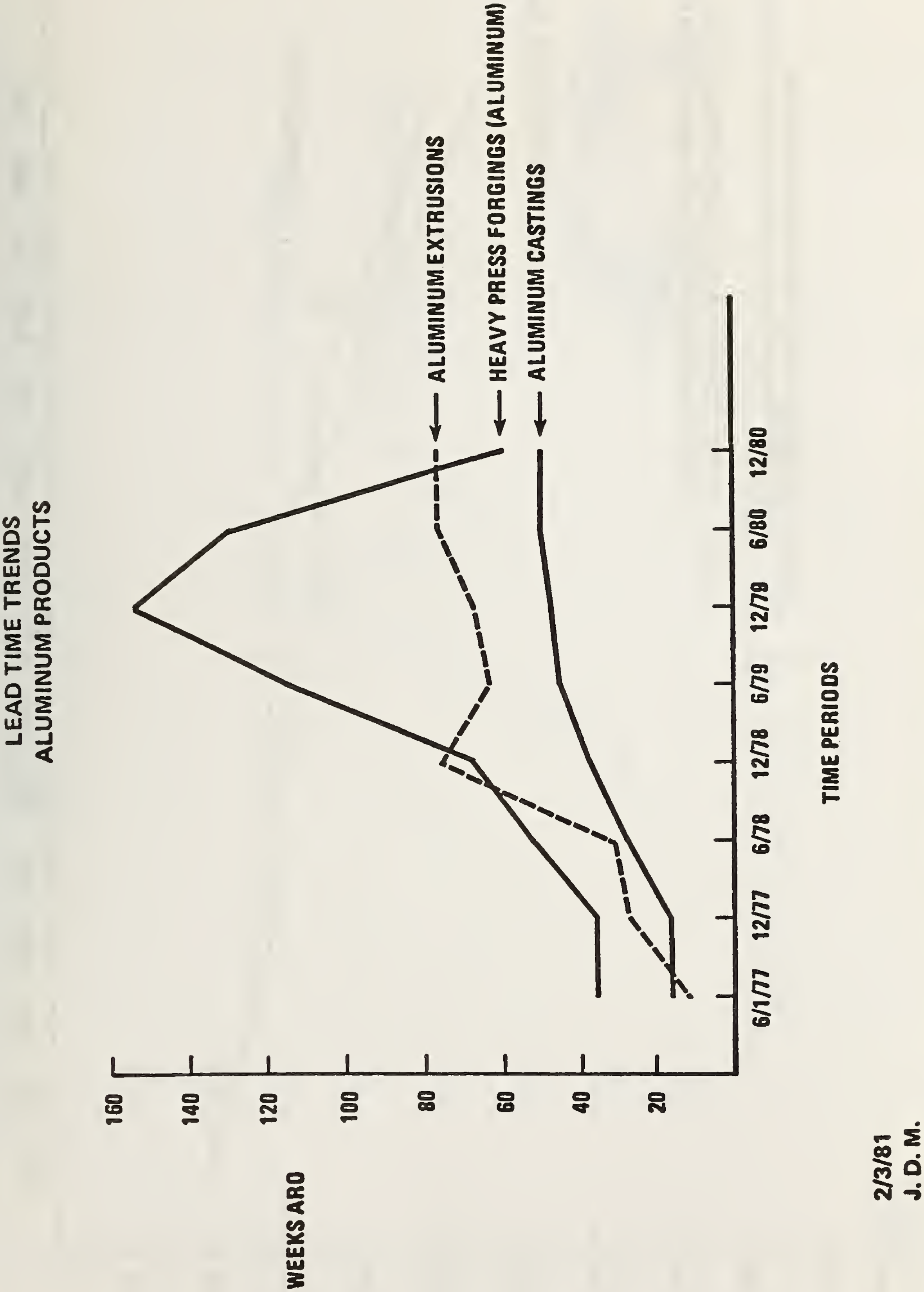
CONDITION: Lead times for aircraft and related aerospace products have increased dramatically over the past few years due to the allocation of critical materials (e.g., titanium sponge, cobalt), eroding industrial base, and increases in commercial orders. The nationwide industrial problems of low productivity growth, low capital investment, and a shortage of skilled labor, especially in defense related lower tier contractors and basic industries, have contributed to the erosion in the responsiveness of the industrial base.

RECOMMENDATIONS: Perform a detailed analysis on the impact of critical material and critical industrial sector choke points to quantify their effects on Air Force systems acquisitions.

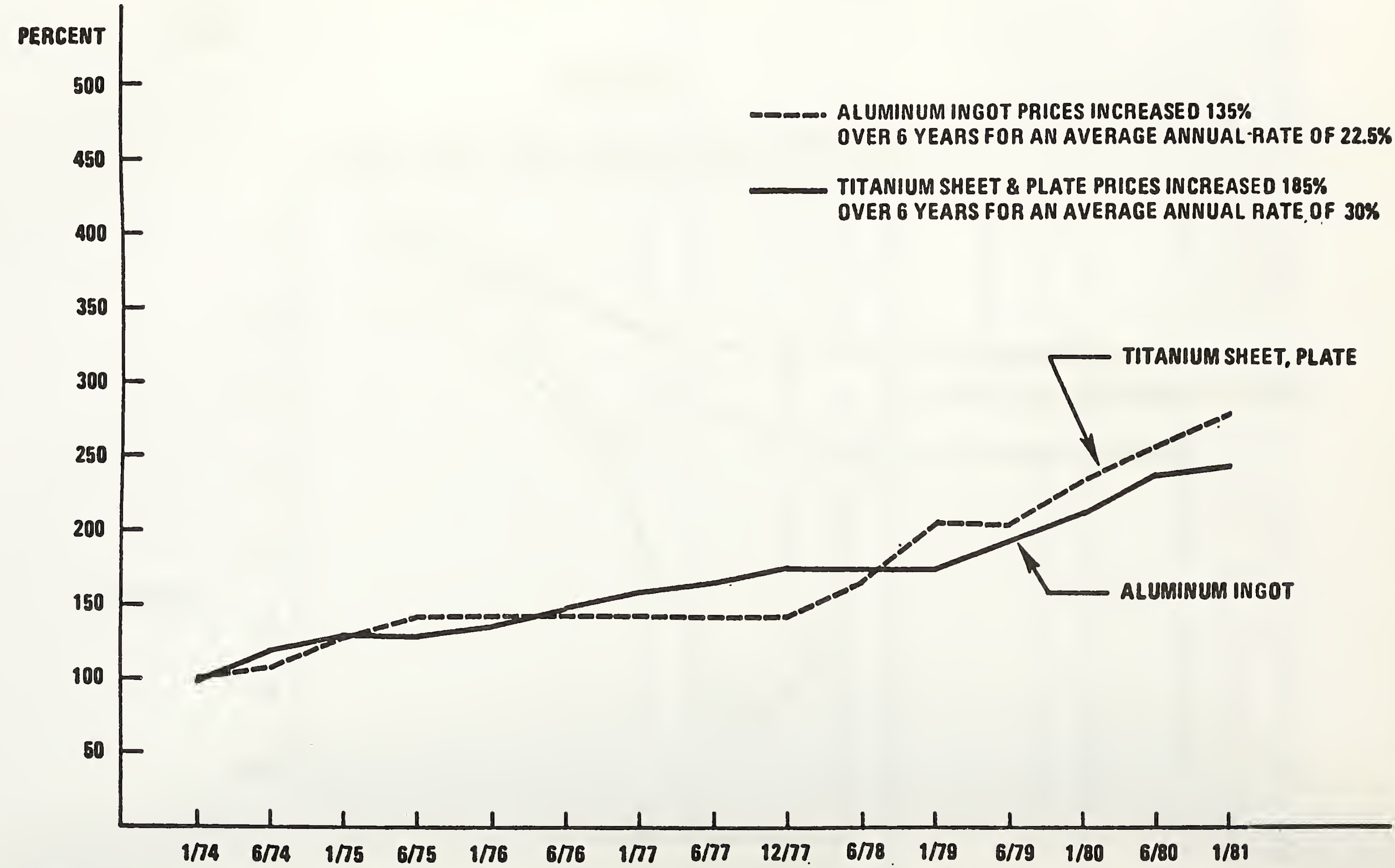
Develop long term as well as short term solutions to improve industrial responsiveness and reduce the probability of material and parts availability problems.

Develop a forecast model for shortages of critical materials and parts used by the Air Force. In addition, utilize this model as a decision-making tool for planning purposes.

Develop remedial actions for those institutional issues surfacing as a result of our industrial critical sector analyses.


LEAD TIME TRENDS
ALUMINUM PRODUCTS
WEEKS ARO
160
140
120
100
80
60
40
20
6/1/77
12/77
6/78
12/78
6/79
12/79
6/80
12/80
TIME PERIODS
ALUMINUM EXTRUSIONS
HEAVY PRESS FORGINGS (ALUMINUM)
ALUMINUM CASTINGS
2/3/81
J. D. M.

PRICE TRENDS
ALUMINUM INGOT & TITANIUM SHEET & PLATE



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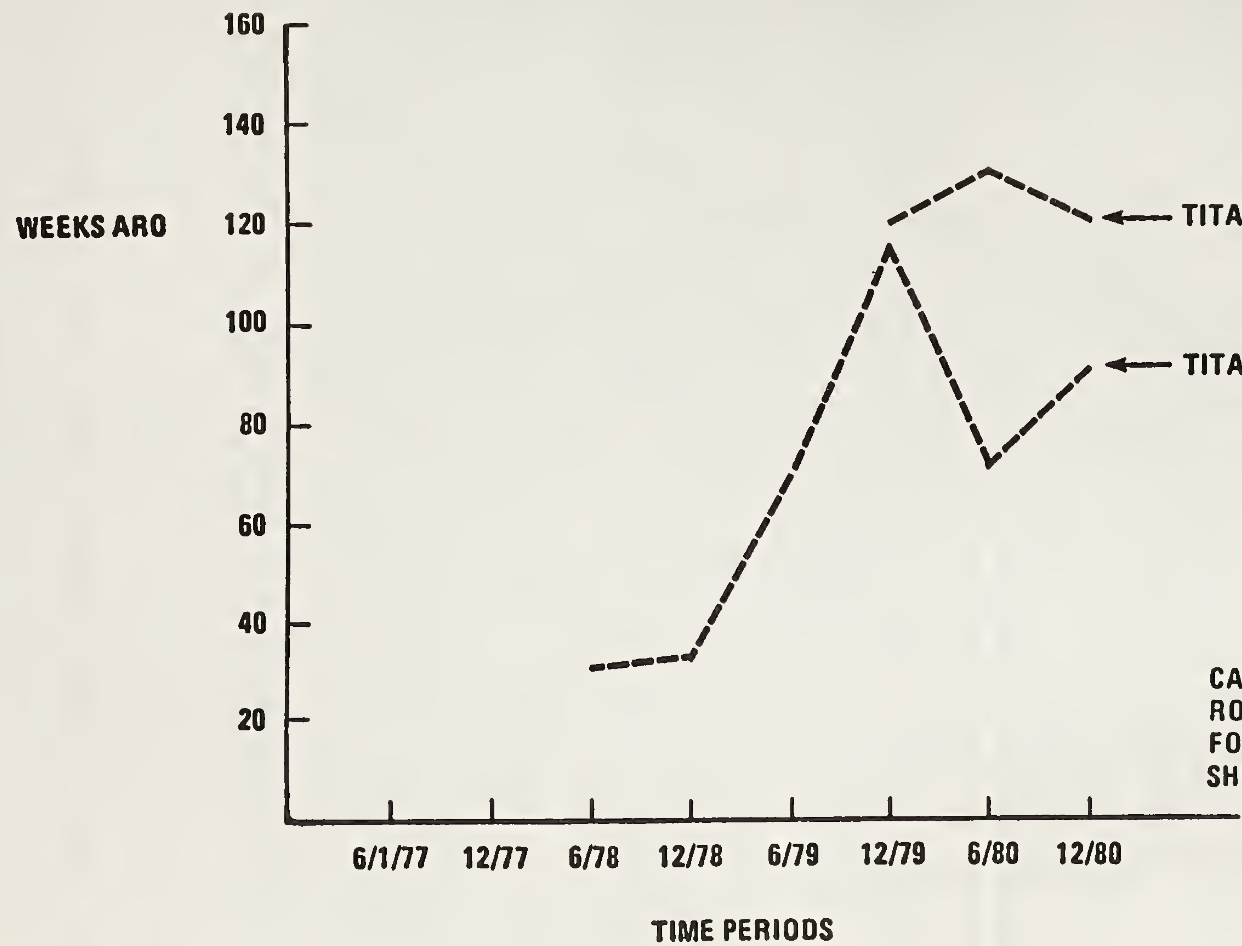
LEAD TIME TRENDS
TITANIUM PRODUCTS



CURRENT LEAD TIMES

ITEM	WEEKS ARO
CASTINGS	72
ROD & BAR	90
FORGINGS	115
SHEET	90

2/3/81
J. D. M.

PRESENTATION ON TITANIUM

Ward W. Minkler
Titanium Metals Corporation

Presentation on Titanium

by Ward W. Minkler

NATIONAL MATERIALS ADVISORY BOARD

SEMI-ANNUAL MEETING

September 3, 1980

REVIEW OF MATERIALS AVAILABILITY ISSUES

Of the metals being considered in this two day session, titanium has the advantage of being the newest engineering structural material. We have a shorter commitment to our past mistakes. Since 1950, the start of production, there are three characteristics which make titanium of interest for this assessment of major critical and strategic material availability issues:

1. The industry has exhibited a repetitive pattern of overcapacity, interrupted by short periods when supply has been temporarily insufficient to satisfy customer delivery requirements. The industry is in such a cycle today; since mid-1978 sponge and ingot capacity limitations throughout the world have been one cause for extended delivery commitments. (I presume this is the primary reason for including titanium in this availability study). There is strong evidence that the industry is now entering a more normal period where supply will exceed demand and commercial considerations, selling price rather than delivery commitment, will determine supply source(a conventional buyer's market appears at hand).
2. The commercial production of titanium metal in a competitive multi-source environment was established in the United States in 1950. Since then, the U.S. has been the world leader in the manufacture of titanium metal. Presumably, it is in our national interest to maintain a strong industry because of its importance as a structural metal in current and future commercial airplanes and military systems.
3. Finally, unlike many other strategic metals, dependence on foreign ore sources is not a consideration. The U.S. has sufficient ore and technology to support anticipated critical titanium applications for the foreseeable future. Rather, the titanium supply will be determined by the development of sound markets and the ability of the industry to attract investment for the plants necessary to maintain the most up-to-date efficient production base, compared to our foreign competitors.

In 1980, the bulk of U.S. titanium metal is being manufactured by processes conceived in the 1930's and reduced to commercial practice in the 1950's and early 1960's.

*Ward W. Minkler is Vice President - TIMET Division, Titanium Metals Corporation of America.

Titanium Flow Chart

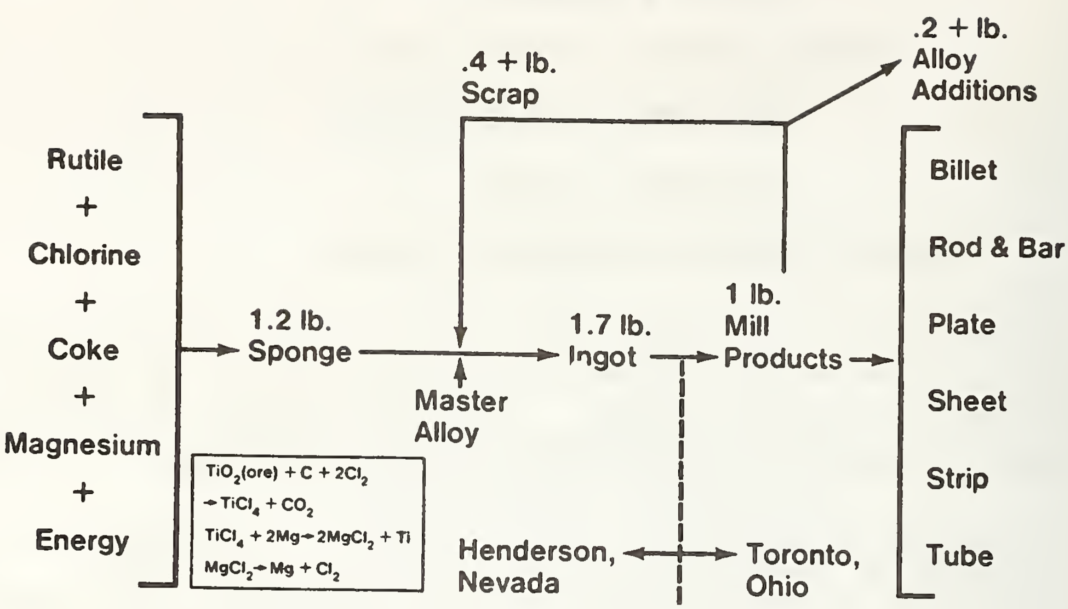


Figure 1

As shown in Figure 1, titanium ore, most generally rutile concentrates, is reacted with chlorine and carbon to form titanium tetrachloride. Alternate methods include mixtures of synthetic rutile and ilmenite, the latter extensively available in the United States. After purification, the tetrachloride is reacted with magnesium to produce titanium sponge and magnesium chloride. While the bulk of titanium sponge throughout the world is produced by reacting the tetrachloride with magnesium, sodium is being used in three plants, one in the U.S., one in the United Kingdom and one in Japan. In most instances, the magnesium or sodium chloride is recycled with only makeup quantities of magnesium or sodium, and chlorine required.

The sponge is purified, then mixed with specially prepared scrap and alloy additions, most frequently aluminum, vanadium, zirconium and molybdenum, then pressed into compacts. The compacts are vacuum-consumable arc-melted into ingots weighing from three to ten tons. Wrought products are manufactured from ingot on conventional shaping equipment such as that used to roll and form steel.

The availability of titanium metal is most frequently equated to sponge capacity. While equipment used for other metals can melt or shape the titanium, a sponge plant can only manufacture titanium and paces availability. It is also the controlling item in determining the cost of a titanium mill product.

One of the characteristics of the titanium sponge plant is the high capital investment compared to other structural metals. This is due to the complexity of the metal winning process coupled with the small plant size.

Sponge drives not only availability but also economics relative to other materials. Ore, melting, rolling and forming are not controlling so long as dramatic demand increases are not required on short notice.

Table I is a summary of 1979 world sponge capacity and includes announced expansions. By 1981, U.S. sponge capacity will have been expanded 28%, Japanese capacity 61% and non-communist world capacity 35%. Further sponge installations are planned and some under construction. These should start producing in 1982-1984. Currently, there are numerous U.S. and foreign titanium sponge ventures under study.

Table I.

World Titanium Sponge Supply For Mill Product Production
(1000 lbs)

	1979	1980	1981	1982-1984
U.S.				
TIMET	25,000	28,000	30,000	32,000+
RMI Co.	14,500	17,000	19,000	19,000
Oremet	4,000	4,500	6,500	7,500
DH Co.	-	-	-	?
Total	43,500	49,500	55,500	
UK				
ICI	5,000	4,000	3,000	-
RR Consortium	-	-	-	11,000
European Consortium	-	-	-	?
Japan				
Osaka	14,000	20,000	29,000	29,000
Toho	12,000	13,000	19,500	19,500
Total	26,000	33,000	48,000	48,500
Non-communist total	74,500	86,500	100,500	
PRC	4,000	6,000	15,000	?
USSR	77,175	92,600	92,600	?

With one exception, the current expansions are incremental additions to producing operations(thus substantially lower cost than new greenfield sponge manufacturing plants). In the U.S., these incremental expansions are the completion of sponge capacity planned for the late 1960's to support the SST, B-70 and The YF12A, but left uncompleted due to the severe downturns of the early 1970's.

This is illustrated in Figure 2. From 1970 to 1978, the U.S. titanium sponge producers operated at a capacity only in one year, 1974, during a period of intensive inventory building by the aircraft manufacturers.

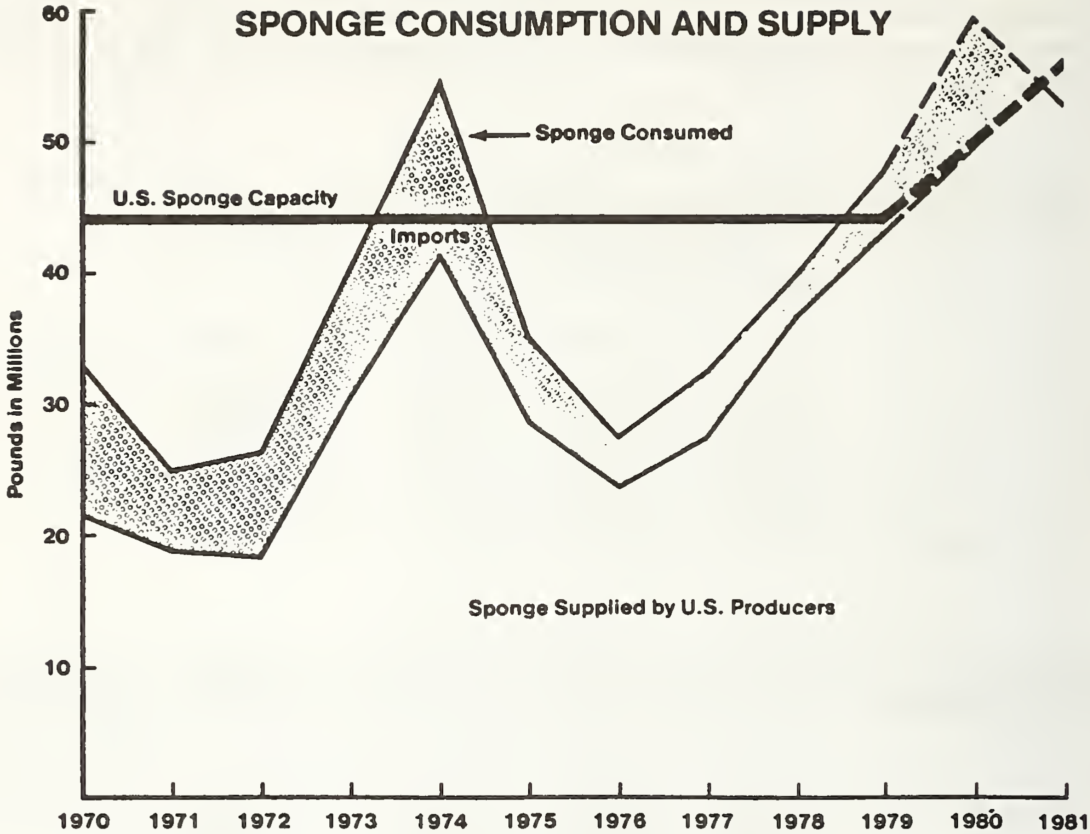


Figure 2

As shown in Table II, foreign sponge producers have historically supplied the non-integrated melters with the bulk of their sponge. In 1980, it is estimated imports may exceed 8,000,000 pounds.

Table II

Sponge Imports
1972-1980
(1000 lbs)

	Japan	USSR	UK	PRC	Total
1972	4,580	2,817	325	0	7,722
1973	5,860	3,179	1,109	0	10,148
1974	5,505	6,897	877	0	13,279
1975	4,638	1,416	359	0	6,413
1976	2,647	632	189	0	3,468

Table II (Cont'd)

Sponge Imports
1972-1980
(1000 lbs)

	Japan	USSR	UK	PRC	Total
1977	3,417	1,410	489	0	5,316
1978	1,632	1,202	227	0	3,061
1979	4,116	660	2	198	4,976
Est. 1980	6,230	712	89	1,869	8,900

The genesis of the titanium industry was the gas turbine engine and its airframe. As shown in Figure 3, the 1979 military and commercial airplane applications still consumed over 75% of the mill products shipped. While industrial applications are expanding, we anticipate that, for the next several years, aerospace will continue to be the backbone of the titanium markets.

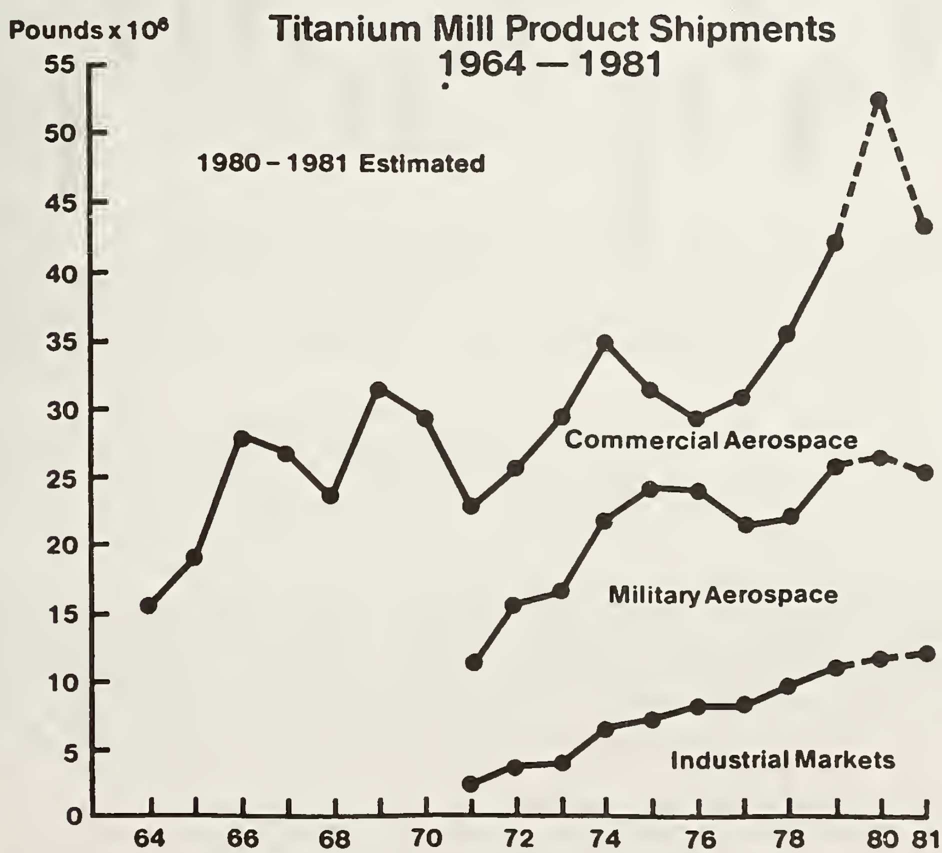


Figure 3

The swings in demand have been unusually severe for a capital intense basic metals business such as titanium. This is illustrated in Figure 4, where I have attempted to show the percentage change in titanium mill product shipments from year to year during 1964-1980. In Figures 3 and 4, I have plotted our lastest 1981 forecasts of mill product shipments. With such rapid changes, planning and operating a titanium venture becomes a challenge. If we have correctly identified and quantified market requirements, there will be an excess of sponge capacity relative to consumption in 1981.

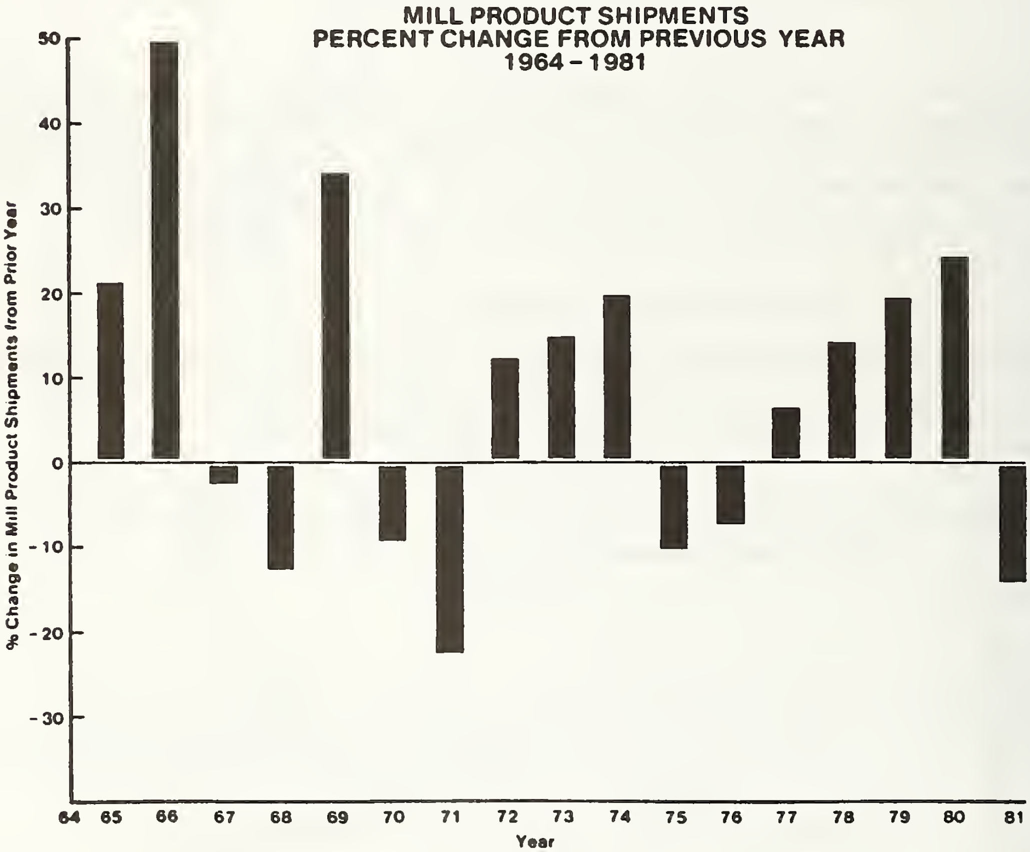


Figure 4

Since 1964, the U.S. has experienced three periods when buying demand has caused lead times in excess of consumer's desires, these were in 1966, 1974 and from mid-1978 to mid-1980. For the purposes of studying material availability issues, I believe it would be helpful to review some factors that were present in 1974 and 1979-1980 to determine their likelihood of recurrence in the foreseeable future. (In this analysis, I have found Bill Swager's excellent study "Periodic Materials Scarcity: Our National De Facto Materials Policy", presented to the Aerospace Technical Council, AIA in April, 1979, to be useful). Mr. Swager quoted the report of the National Commission on Supplies and Shortages published in December, 1976, which listed the following causes of shortages in 1973-1974:

* Sharp demand increases
* Limitations on investment in materials processing industry
* A shortage mentality
* Cutbacks by foreign suppliers and price increases

In 1974 and 1978, the titanium industry was buffeted by all these factors. Based upon grossly overly optimisitc market forecasts in 1968, excessive sponge capacity was installed. Thus, the surge capacity was available to absorb sudden demand increases until 1978. By 1978, the growth of the industrial uses of titanium, coupled with unusually high purchases of commercial airplanes, raised the market to new levels. While the current sponge expansion appears consistant with forecasted markets, the surge capacity of the 1970's no longer exists.

Limitations on investment will influence future titanium expansion. Despite uncertain profitability and high capital investment of the titanium business, incremental additional sponge capacity has been installed reasonably quickly during that shortage period. This, coupled with a following downturn in sales, has satisfied customer availability and commercial demands.

Long periods of idle capital investment have taken their toll of earnings records that would not attract knowledgeable investors. Now the U.S. industry is not faced with decisions on new greenfield capacity. The day is not far off, however, when greenfield plants will be necessary if the U.S. industry is to continue to grow. Financial risks and return potential relative to historical widely fluctuating prices and market demand will be closely assessed. The normal condition in the titanium industry has been overcapacity. This has led to product prices insufficient to justify new capacity. Prior to past incremental expansions, the titanium market demand has been strong; producers could raise prices sufficiently to justify rapid incremental expansion.

However, the lead time for new greenfield capacity is substantially longer, three to five years, and much more costly. Attracting private investment in view of historical overexpansion and the cyclical market history of titanium will be a challenge; a problem that this forum might consider, particularly if the anticipated increased demand is based upon programs considered to be in the national interest.

It appears the shortage mentality has influenced overbuying in 1974 and in the present cycle. Because of the limited number of suppliers, the small size of the industry and the engineering necessity of titanium as an aerospace structural material, buyers are obviously sensitive to availability. This leads to aggressive procurement practices and inventory accumulation in excess of that actually needed to support true consumption, when a potential tight supply is perceived. The abnormal inventory buildup in 1974 then caused severe reduction in titanium purchases in 1975 and 1976. There is mounting evidence this has occurred in 1979 and 1980 and is one of the reasons for the forecasted downturn in titanium mill product shipments in 1981.

Cutbacks and price increases by foreign sponge suppliers were, to some extent, a factor in the most recent titanium shortage. Until recently, foreign sponge was available at prices lower than domestic sponge; at times lower than domestic costs. This discouraged investment in new sponge capacity and encouraged the growth of the non-integrated domestic ingot producers with modest capital investment who were willingly dependent on the lower cost foreign sponge.

However, in 1978, the foreign sponge producer was faced with a new situation. Energy costs had increased. Demand for titanium external to the United States, particularly in the industrial markets for products more profitable than sponge, increased; 1978 and 1979 pruchase contracts were made based upon the depressed markets in 1976 and 1977. The Japanese producers diverted their production to other markets. The USSR ceased exporting, apparently for unrelated reasons. Foreign sponge exports to the U.S. fell dramatically during a period of high market demand.

In 1980, the non-integrated melter, representing approximately 25% of the U.S. ingot capacity will import a record quantity of sponge from Japanese sponge producers currently at prices double that of 1978. This expanded foreign capacity will again influence U.S. producers' sponge expansion plans, particularly if a strong buyer's market develops breeding historical price degredation.

In concluding, I would like to identify some of the issues facing the titanium industry which will affect the availability of titanium from U.S. producers, as well as the strength of our industry relative to our overseas competitors.

1. By next year, the domestic industry will have sufficient sponge capability to provide 48 million pounds of mill products. With present ingot melting capacity and expansions now underway, the integrated and non-integrated domestic melters will have the ability to ship 65 to 70 million pounds of mill products, 60% higher than last record year, 1979. With foreign sponge expansions, the titanium industry may be faced with overcapacity for the near term rather than under supply, with the attendant commercial problems.
2. As I stated previously, the world industry has been highly cyclical. Except for short periods of undercapacity, profitability of sponge producers has been poor. Despite this, the U.S. industry has responded to increased demand for overexpanding. These shortage periods resulted in short term profits used for these incremental expansion investments. Non-market related factors such as price controls, suspension of tariffs that encourage a temporary surge of foreign imports, or subsidies by the U.S. users to new foreign sponge producers, will stunt future domestic incremental expansions.

3. Despite tariff protection, the uncertain commercial priorities of foreign sponge producers in the United States market has made domestic sponge producers wary. In view of the foreign expansion now underway, or being discussed, the environment is ripe for another such cycle.

4. The bulk of the U.S. sponge plants were based upon process designs of the 1950's and 1960's. Foreign sponge plants have been more recently installed and could be expected to have operating cost advantages. The product quality of these foreign sponge manufacturers is preferable to the non-integrated ingot manufacturers. At some time in the future, assuming the demand for titanium continues to grow at the historic rate, 7% per year, new greenfield plants will be required. Do we duplicate magnesium or sodium reduction cycles or do we commit to a more promising but commercially untested method, such as electrowinning? These decisions will be required soon, particularly if we assume the three to five year period normally required to engineer and construct a new reduction plant. This choice can determine the competitiveness of the U.S. industry for the latter part of this decade and certainly well into the 90's.

5. If it is determined to be in the national interest to expand titanium production beyond that which valid demand forecasts would dictate, some form of government financial encouragement would be considered appropriate. Underlying this decision could be a temporary increase in titanium required for defense related projects or for stockpile purchases. This encouragement could involve:

   a. Multi-year material commitments for defense-related contracts that would allow for appropriate cancellation reimbursement to the titanium producer for cost of capital equipment, inventory accumulation and loss of revenue, as a result of the cancellation.

   b. An indexed stockpile procurement program which contains multi-year purchase contracts to fill stockpile objectives. Purchases would be made when domestic sponge demand fell below a pre-established percentage of domestic capacity and be suspended when demand exceeded these levels. One of the factors weighted in contract awards could be encouragement to construct new or upgraded manufacturing plants.

The future of the U.S. titanium industry will depend on the confidence of producers and investors in an acceptable return on investments, titanium's competitiveness as an engineering metal and supportive government policies. Unlike many other strategic metals, the selectivity of nature will not be a factor.

DEPARTMENT OF COMMERCE WORKSHOP: NATIONAL MATERIALS & MINERALS POLICY ACT OF 1980, P.L. 96-479

Gregory B. Barthold
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Aerospace Industry Considerations - Aluminum

Today's Conditions

A. The U. S. imports almost all of its metal grade ore either in the form of bauxite or alumina.

B. The industry's raw material base is broadly dispersed so that any interruption of supply at one source can be accommodated from other sources. The industry has researched a number of possible alternatives to bauxite and has developed the technology to use them. All are processes that would use domestic sources.

C. The National strategic stockpile contains a sufficient amount of bauxite to meet defense requirements for aluminum until such time as facilities to process alternative domestic ores can be brought on stream.

D. U. S. domestic expansion of refining capacity and primary ingot production has slowed down considerably. The ability to build power capacity at a reasonably competitive cost is so constrained by the regulatory process as to virtually eliminate aluminum smelting expansion domestically.

E. The U. S. aluminum industry is expanding its metal production capabilities outside the United States in such places as Brazil and Australia partially because these countries continue to demand a growing share of downstream production. They have the ore, they want to refine it, and produce the metal to gain the added value. They have the electrical energy, and the will to meet the challenge of growth of power supply and the environmental consequences.

F. The industry's technology base is very strong. New higher strength, lower density, higher modulus alloys in both ingot technology and rapid solidification technology are emerging from our laboratories especially for the aerospace industry. In addition, our process efficiency in energy use is improving with the application of new smelting technology and improvements on the conventional reduction process.

G. Fabricating facilities for aerospace grade sheet, plate, forgings and extrusions are being expanded to meet the forecast of increased demand. The airlines' current cash flow problem has reduced the demand for aircraft that was experienced last year and was the cause of the extended deliveries experienced by some builders. More recently the aluminum industry's expansion plans have been stretched out to keep capacity in balance with forecast demand.

H. Our international trading competitors have a more advantageous tax policy than exists in the United States. This tax policy allows them to modernize facilities and increase productivity. In the long run they will become more price competitive in fabricated products to the disadvantage of our domestic industry.

I. The balance between capacity and demand in the aluminum industry is extremely delicate and fragile but it must be achieved because the cost of idle facilities in a capital intense business is too high to endure in today's high interest economy. A standby surge capacity cannot be afforded.

J. A surge capacity for national security requirements, however, does exist. The aluminum industry's current production for defense requirements is approximately 1% of total production. The balance - 99% is for commercial applications, i.e., automobiles, beer cans, siding, electrical cable, foil, etc. These uses would lose their place in line as non-essential in a national emergency thus releasing a great portion of that 99% to defense applications. The convertibility of fabricating facilities from non-defense to defense can easily be accomplished. There would be some bottlenecks. Advance planning as to the type and quantity of aluminum would be needed to provide for a quick transition. The bottlenecks that occurred during the past two years have been recognized and additional capacity is being added. Current capacity expansions include heat treated sheet and plate, large press extrusions, and intermediate and large press forgings.

K. Recycling, mainly of used beverage containers is becoming a more and more important source of raw material to the aluminum industry. Recycling consumes five percent of the energy required to make virgin metal. Thus the use of recycled metal is an extremely energy-efficient process.

L. Substitution research and development to uncover replacements for critical alloying elements is worthwhile. The aluminum industry is highly dependent upon manganese as an alloying element. A potential manganese shortfall could occur. The elements of cobalt and chromium while not as important to aluminum as they are to steel, are used in small quantities in some of the new alloys being developed in both ingot metallurgy and rapid solidification technology.

Recommendations:

For the primary aluminum industry to remain competitive and also expand domestically . . .

1. Long term power at competitive prices must be available. Current regulations inhibiting the growth of power must be removed.

2. A balance between environmental goals and national defense needs must be achieved. Opening western lands to selected mining of critically short minerals should be allowed. Water rights to exploit domestic aluminum ores must be provided.

3. U. S. tax policy should be changed to allow for faster depreciation of facilities so that expansion and modernization and greater productivity can occur.

The Defense Department should provide industry with detailed information regarding its weapons requirements for both peacetime and mobilization scenarios so that industry can plan to meet these needs.

Research to develop substitutes for critical elements that are in short supply should be encouraged.

The aluminum industry, although critical to aerospace, is in comparatively good health. Those materials and minerals that are subject to geopolitically caused shortages or those that are naturally scarce should receive our attention. Aluminum is not in this category. Federal actions that would assist the domestic health of industrv in general should be favored instead of those actions that would discriminate in favor of one material.

ROLE OF SUBSTITUTION, CONSERVATION, RECYCLING AND HIGHER PERFORMANCE

Allen G. Gray
American Society for Metals

KEYNOTE TALK

Workshop on Critical Materials Needs of the Aerospace Industry
...Role of Substitution, Conservation, Recycling and Higher Performance

By

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The United States is heavily dependent upon foreign sources for the supply of most strategic metals required by the aerospace industry. This country imports almost 100 percent of the strategic aerospace metals, cobalt, columbium, tantalum, chromium, and manganese.

For example, of the strategic imports noted above, a single F-100 Turbofan engine for the F-15 and F-16 airplanes requires 1656 lb chromium, 910 lb cobalt, 171 lb columbium and 3 lb tantalum. Also required are 5366 lb of titanium, 5204 lb of nickel and 720 lb of aluminum. These too are classed as strategic imports but circumstances on availability are different which reduces the vulnerability to cutoff.

The potential for foreign cartels, political unrest, and production limitation on strategic aerospace metals is great and is intensified by steadily declining reserves. Thus, it's likely that the United States will be faced with supply shortages and price escalations. Since these metals are vital to the welfare of the nation's economy and security, their continued availability at a reasonable cost and provisions for substitution, recycling and conservation, to meet a crisis situation are national issues.

The strategic aerospace metals - chromium, cobalt, columbium, and tantalum are contained in steels, stainless steels and superalloys that are employed in engine manufacturing. Their essential nature requires that supplies or viable materials technology options derived from substitution, conservation, or recycling be available at reasonably acceptable costs. Efforts to develop these options must begin now, since a new material can take from 5 to 10 years of research and development efforts before qualifying for aerospace service.

It should be noted that the need for high performance alloy steels, stainless steels, and superalloys requiring the strategic aerospace metals is increasing as demands have grown for higher durability, plus higher performance fuel efficient aircraft turbine engines.

Likewise, it should be pointed out that a transfer of aerospace high temperature technology will be a major asset in the development of this country's alternative energy programs including coal gasification and liquefaction, even deep well exploitation of domestic oil resources. It's significant that extensive tests on alloys for these uses conducted by the Metal Properties Council have shown that a minimum chromium content of 25% is required for long term service.

This adds emphasis to the strategic importance of chromium which continues to appear more critical than the other critical metals, and less secure than ever before. A cutoff of oil supply and chromium supply would attack this country on two fronts.

As a sidelight on this issue, I might say that in an article in TIME magazine entitled, "Strategic Metals, Critical Choices," published last January, I was quoted as Technical Director, American Society for Metals, that "A cutoff of our chromium supply could be even more serious than a cutoff in our oil supply. We do have some oil but almost no chromium."

Thus, we conclude that materials availability, either short term during critical situations or long term due to resource depletion or overconsumption, is of vital concern to all industries and to this country's security. Without proper materials many companies would be forced to close unless they made alternative plans well in advance.

In fact, supplies of critical materials and their rising cost present what may be the most serious challenge facing the industrial American in the remainder of the twentieth century.

Likewise, there is a new awareness of the interdependence between materials and energy,and further, there is the realization that materials, energy, the environment, and the economy are strongly connected.

The pursuit of our most important national goals dictates that we be concerned about materials availability and that we implement an enlightened National Materials Policy which requires the development of alternatives and contingency plans which include the technology available for substitution in the event of a materials crisis, as well as conservation through improved processing and recycling. These are among the important options we are considering at this workshop session.

To start, I would like to emphasize the importance of developing a substitution potential for critical materials, since I have been a strong proponent of efforts to foster the substitution initiative in testimony on the National Materials Policy Bill in the U. S. Senate in July last year, and in the U. S. House of Representatives shortly after the bill was introduced.

In my testimony I proposed that the United States should embark on an organized effort to foster and support research and development programs that will advance the practical application of substitution technology to reduce the impact of supply interruptions in critical metals, particularly chromium and cobalt.

Likewise, it's evident that a plan should be developed to document known substitution technologies and "stockpile" this information.

As R & D programs are developed to plug gaps and create new options for substituting for critical metals, this technological information would be added to the information stockpile.

As a spokesman for "substitution preparedness," which is how I referred to my recommendations in the Congressional testimony, I emphasized that it is essential that appraisal and recording of substitution procedures in specific applications be as complete as available information allows.

Needs for additional information should be identified and defined so that research and development projects can be assigned to gather data required to expand capabilities in those areas which appear to be sound and achievable with available means.

It should be noted that leadtime is very short in an emergency situation. Thus a stockpile of information on substitution technology is also a stockpile of time, and a valuable yet relatively low cost supplement to the commodity stockpile.

Substitution programs should be an important part of strategic materials planning for individual manufacturing firms as I will touch on later.

Last year I was invited to make a presentation to the National Science Foundation, their Metallurgy and Materials Advisory Board and Staff, on recommendations for materials substitution research.

I would like to review these recommendations for a national initiative on materials substitution and conservation which I included as a part of my testimony in U. S. Senate hearings last July.

In presentations I have made before company management groups concerned with strategic materials planning I have encouraged the development of substitution programs and pointed out that the objectives of a national initiative on substitution can be applied to internal (company) substitution R & D programs.

My recommendations for a materials substitution initiative are summarized below:

1. Find out just how much we know about substitutes for the most critical strategic metals, particularly chromium, cobalt, manganese, columbium, tantalum and platinum group metals.

2. Appraise the reliability of the information that is available on substitutes for these critical metals and determine what research is needed to round out available data so that the substitute materials can be used with full confidence.
3. Document known substitution technologies and stockpile this information in a form that can be utilized immediately by industry and defense in an emergency. This is "Substitution Preparedness." This information might take the form of a Substitution Handbook.
4. Identify basic research programs needed to create new options for substituting for these critical materials and as this information is developed, add it to the substitution information stockpile. Avoid waiting for a crisis.
5. Structure research to have substitution as its only goal. Research priority would be determined on basis of <u>probability of need</u>; and <u>probability of success</u>. (This enhances substitution preparedness.)
6. Develop ways to improve awareness, interaction, and communications in substitution technology through a program of workshop/conferences including government, industry and universities. Likewise, provide universities with information and encouragement needed to utilize more substitution and resource availability information in materials selection course.

7. Accept the fact that the government has justification to assume leadership in supporting research to develop an enhanced substitution potential and in sponsoring work to gather, store, and deliver reliable information on substitutes for critical materials in a form that can be applied immediately by defense and industry in an emergency cutoff.

8. Emphasize substitution research in the most critical areas, particularly, chromium and cobalt, and expand research to develop new manganese alloys on basis of long term-availability through ocean mining. Emphasize research to utilize substitutes with wide distribution and domestic sources such as vanadium and molybdenum.

9. Recognize that the government has an important stake in replacements and that the nation as a whole and its security depends upon imports of critical metals. Realize that industry is involved in solving near term problems and has increasingly turned to application type work and that if government leaves the task of substitution research totally to industry it probably will not get done.

Regarding the final point, although there are good reasons for individual business firms to underwrite work on substitutes for metals critical to their existence, I would like to comment briefly on the rationale for government support.

An important consideration in appraising government support for substitution research is to realize that industry's motivation to substitute has been principally economic -- the tendency is not to address a critical supply situation until a material is completely unavailable and a crisis has developed. Then, it's likely that before anything can be done the situation would be beyond the critical stage.

For example, as long as chromium is available and is relatively economical, as it is today, there's no incentive to substitute for it in heat treatable steels. But since substitution appears possible in this instance, it makes good sense to research and "stockpile" information now on the production and heat treatment of chromium-free steels for production of important engineering components. The data could be drawn on immediately in a chromium emergency.

It should be noted that about 10% of chromium used annually in this country goes into two grades of constructional alloy steels, the 8600 series and 4600 series. These steels are typically used to produce such things as gears and shafts. In this application, chromium is both highly effective and cost efficient.

However, technology can be developed through research to substitute other alloying elements for chromium. In an emergency this would release 10% of chromium for uses where substitution is not available, such as in jet engine alloys. This information would be equivalent to having 10% more chromium in the stockpile available for essential uses, and should be weighed against the cost of adding 10% chromium to the strategic stockpile.

It should be noted that new tools are available today for studying substitution and interchangeability of alloying elements. Computer systems provide new approaches to the design of steels and alloys with specific properties for substitution applications.

For example, a system known as Computer Harmonized-Application Tailored (CHAT) alloys was employed during the nickel shortage a few years ago to develop an alloy gear steel without nickel to substitute for SAE8620. This substitute steel continues to be used for gears and other components in the world's largest truck plant with economic advantages. A similar technique should be applicable for developing chromium-free alloy steels.

Substitution is one important approach to meeting the challenges of strategic critical metals. There is, of course, an underlying need to understand and deal with other options for conservation, including recycling, improved extraction, optimum utilization of material properties in design, net shape processing, and enhanced durability.

Processing innovations will play a major role in advancing both substitution and conservation technology. For instance, high speed steels without cobalt utilizing increased quantities of molybdenum and tungsten are being produced by hot isostatic pressing (HIP) of powders. Such alloys cannot be produced by conventional melting methods because massive segregation of molybdenum and tungsten carbides would make the alloys unworkable.

Hot isostatic pressing will make increasingly important contributions to conservation by reducing the amount of strategic raw materials required to produce a component. Likewise, the process enables the optimum utilization of alloying elements in design.

For example, new strength goals for nickel base superalloys can be achieved by increasing the hardener content utilizing such elements as aluminum, titanium, hafnium, or columbium. However, when applied to conventionally cast ingots extensive segregation takes place resulting in an unforgeable product. This problem can be circumvented by employing hot isostatic pressing of powders.

Advanced materials technology has pushed the use of superalloys to temperatures close to their melting points and materials must continue to be developed to allow the design of products for operating more efficiently at increasingly elevated temperatures, to meet over-all conservation goals.

A better understanding of the role of the gamma prime precipitate in relation to nickel and cobalt and other alloying elements is crucial. This high temperature strengthener makes possible the production of superalloys that can be used at the "highest fraction of their melting temperatures of any material ever developed."

Further improvements are imminent, and research and development must continue to advance the technology of materials for: production of single crystal turbine blades; for directionally solidified eutectics, wherein aligned whiskers grow from the eutectic phase within a ductile matrix, to produce fiber reinforced alloys of great strength and stability.

In other areas of progress, the use of powder metallurgy to disperse oxide particles in gamma prime strengthened superalloys promises to improve high temperature strength.

And rapid solidification of powder particles has demonstrated that higher strength levels combined with better second order properties are possible through enhanced alloying capabilities.

Regarding the latter, rapid solidification technology holds promise for the development of materials with higher performance as well as conservation of critical elements. Some of the potentials that relate to critical materials, if this new technology can be moved forward, have been noted by Dr. Arden Bement, formerly Deputy Undersecretary of Defense for Research and Engineering (now Vice President for Technical Resources, TRW)) as follows:

1. Cobalt free, high creep strength nickel base superalloys for turbine airfoils in high performance engines.
2. Increase in incipient melting point of nickel base superalloys by as much as 55°C.
3. Oxidation/corrosion resistant iron-aluminum alloys as substitutes for chromium stainless steels.
4. Laser glazing to produce layers with different alloy compositions.

It also should be noted that RST promises to improve aluminum and titanium alloys as well as superalloys.

Perhaps you have heard that an industry/academia workshop is being planned by National Bureau of Standards for next July to explore the potential for RST.

In appraising alternate materials, certainly it must be recognized that such research in many instances must be considered to be high risk and long range. But there is a potential high payoff by significantly reducing the nation's dependence on strategic materials.

An example is the intermetallic compounds, such as the nickel and iron aluminides. The potential high temperature strength of these materials is of interest, in fact, nickel aluminides have the capability of competing with current nickel base alloys. However, ways must be found to improve the mechanical properties,particularly room temperature ductility,and NASA is sponsoring work to better understand the fundamental deformation mechanisms in the aluminide system.

Earlier it was mentioned that R & D should be aimed at building on resources that are most likely to be available or that are reasonably well distributed. (It appears that the Soviets are givng much consideration to this.)

In this regard, manganese is of interest. It is a requirement in every ton of steel produced. Fortunately, it is more widely distributed than chromium and cobalt; even so, more than 85% of the manganese ore is produced by only six countries, namely, U.S.S.R., South Africa, Australia, Gabou, Brazil and India

Of future significance is that manganese nodules can be extracted from the ocean floor and could possibly provide this country with a reliable source for large quantities of the metal The American Mining Congress estimates that many billions of tons of manganese nodules containing about 30% manganese are available for ocean mining from more than 300 prime mine sites -- many in the Central Pacific Area. These nodules also contain smaller amounts of nickel, cobalt, and copper but significantly no chromium which again emphasizes the criticality of this metal.

While the impact of ocean mining technology is unlikely to be significant until at least the next decade, the long term potential for abundant supplies of manganese suggests research support for alloy designers to develop a new austenitic stainless alloy system which would substitute manganese and aluminum for the strategic and expensive alloying elements, nickel and chromium. ("An Austenitic Stainless Steel Without Nickel and Chromium," Metal Progress April 1978.) A very limited amount of research has been done on the Fe-Al-Mn-C compositions and there's promise that this system should give an austenitic alloy with good hot strength and cold work workability, while retaining good oxidation resistance.

Successful development of this class of steels, which would contain no nickel or chromium could have a significant impact on the stainless steel industry in relation to raw material needs and both cost and weight savings.

Enhanced activity is being generated in conservation of strategic elements by recycling and reclaiming parts by remanufacturing.

Special challenges exist in reclaiming and refining superalloy hardware that has been in engine service due to possibility of contamination. The likelihood of picking up a number of contaminants from combustion products and protective coatings, generally means that used parts cannot be recycled directly by vacuum induction melting.

This concern for contamination in recycled metals for premium quality superalloys has caused a large amoung of scrap to be eliminated as recyclable back into superallyoys. This has resulted in superalloy scrap materials finding their way into the world's scrap market at prices far below their intrinsic metal values for additives in operations such as steelmaking. Other elements such as cobalt, tantalum and tungsten are lost.

Progress is being made on the commercial front to advance recycling technology, however, research and development work is needed on processes to enhance cost effectiveness of recycling critical alloys back to the quality of virgin metals.

Likewise, commercial technology is moving forward to develop more precise methods for building up worn areas in high temperature parts, such as jet blades, or bearing surfaces and other types of critical inserts. Experience has shown that rebuilt parts may last longer than original ones and the time for procurement as cut drastically. This segment of conservation through reclaiming and rebuilding shows unusual promise and research is needed to develop improved methods. Likewise, a philosophy of design for rebuildability should be encouraged. This means that provisions are made in advance for replacement of parts, bearings etc., that are subject to wear or other forms of deterioration and may need to be rebuilt or replaced.

Now a few main points in closing:

1. Chromium must be rated at the top of the priority list. We must address policy and research and development tactics to ward off a crisis with chromium. More widely dispersed mineral sites must be sought for. The technological search for substitutes should be unrelenting, despite the frustration of attempts to date. The technology for recycling chromium must be advanced. As Dr. Raymond Decker, Vice President, INCOtd., put it, in comments on chromium in his keynote address at the International Conference on Superalloys, "It is prudent to have such technologies on the shelf, piloted, and ready as a contingency plan."
2. We must understand more fully the role of cobalt in superalloys vital to the aerospace industry and in other essential products such as high speed steels.
3. We should prioritize areas for materials substitution research on basis of probability of need and probability of success. Substitution research should be initiated on a broad front.
4. Emphasize research to utilize metals with wide distribution and domestic sources. Institute programs to develop the manganese-aluminum alloys system to supplement the nickel-chromium stainless steels.
5. Advance a continuing program to alert industry of the need to develop and implement strategic materials planning for their products including and aggressive program on materials substitution technology.

6. Improve recycling capability including the ability to utilize a broad range of less pure revert materials and recover minor strategic metal content.

7. Select the rapid solidication technology (RST) area for emphasis in a vigorous and comprehensive program of materials research and development and establish the necessary mechanisms for coordination and evaluation of these programs.

I am sure that many other fine ideas will evolve from the deliberations in this important workshop.

The implications of a critical materials crisis are far-reaching and extend beyond the aerospace industry. To illustrate this I will close with one sentence from an address by Robert J. Buckley, Chairman and President, Allegheny Ludlum Industries, Inc. before the Economic Club of Detroit on 26 January 1981. Mr. Buckley's address was entitled, "Critical Materials for Industry -- A Predicament That Need Not Become A Crisis," and he states: "All of our national plans for "reindustrialization, putting people back to work, encouraging economic growth, seeking technological breakthroughs can go for naught if America's current predicament in strategic non-fuel materials is allowed to become a crisis."

Granted the problem and solutions related to materials require looking to the future, the important thing is to get started now. If we act now to marshall, our technical resources along with proper organization, we can avoid a predicament that could become a crisis.

WORKSHOP ON CRITICAL MATERIALS NEEDS OF THE AEROSPACE INDUSTRY

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WORKSHOP ON CRITICAL MATERIALS NEEDS OF THE AEROSPACE INDUSTRY

- by -

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WORKSHOP ON CRITICAL MATERIALS NEEDS
OF THE AEROSPACE INDUSTRY

RECYCLING OF SUPERALLOYS

Introduction

It is now generally recognized that the United States is heavily dependent on imported primary metals for the manufacture of superalloys. Further, the critical importance of superalloys to military and commercial aviation and energy conversion is apparent. This workshop reflects the concern of many people that this dependence is undersirable, especially where it imperils this country's capabilities of military deterrance and encourages market manipulation for political purposes. Obviously, there is no single solution to this problem. However, improved recycling of superalloy scrap and recovery of metals from waste generated in the production of these alloys must be an important aspect of our program to ease our dependence of foreign supplies.

Scrap Generation and Use

Recycling of scrap is extensively practiced by superalloy producers because of the high cost and periodic scarcity of many of the metals used in these alloys. Procedures employed to identify, sort and clean solid scrap are well developed and widely practiced by commercial scrap processors (1). The quantity of scrap which is consumed by this industry is restricted by stringent product specifications, limited refining capabilities of alloy producers and by the number of different chemically complex alloys in commercial use. Because of these limitations, One of the major findings of the survey was that the 141.2 thousand metric tons (kt) of metal units consumed by the superalloy industry in 1976 consisted of 42% home scrap, 17% purchased scrap and 41% primary metal. Individual segments of the industry varied from this average raw materials mix, but all producers used some scrap. An estimated 133.7 kt of superalloy scrap, including obsolete scrap, was generated in 1976. This material was comprised of 72% solids, 14% turnings, 7% grindings, 1% oxidized material, and 6% in various physical forms which was lost or discarded. Of the 125.7 kt of material that was recycled, 6% was remelted for use in superalloys, 27% was downgraded for use in stainless and low alloy steel or cast iron, and about 7% was exported. The report assumed that the remelted and exported scrap was already being efficiently used. It thus concluded that programs to improve recycling efficiency should be aimed at the 41.7 kt of superalloy scrap that was downgraded or lost. This figure includes material from all scrap classifications although the bulk of it is mixed alloy turnings and grindings and oxidized or otherwise contaminated material.

<u>Technological Trends in Superalloy Scrap Recycling</u>

Scrap or secondary alloys made from recycled scrap are desirable raw materials for alloy melters because they are generally less costly than primary metals when supply and demand are in balance. However, to be useful, scrap must be free from impurities such as lead which very detrimental to superalloy properties. Nonmetallic or organic matter often associated with lower grade forms of scrap cannot be tolerated by alloy producers and some physical forms such as turnings and grindings are very difficult to handle. Finally, very complex alloys such as IN-100 or B-1900 which contain eight or more major alloying constituents can only be recycled back into the same alloy. All of these factors combine to limit the amount of scrap which can be directly reused. However, recent technological trends have increased the use of scrap and there are prospects for significant further improvements.

The superalloy industry has traditionally required the highest quality raw materials because its melting furnaces had little refining capability. For example, costly pure chromium metal or low-carbon ferrochromium was used instead of charge chromium for most alloys. The adoption of the Argon-Oxygen Decarburization process (AOD) in the 1970's provided wrought superalloy producers with the capability of removing many common impurities. This and related processes have had a significant impact on the raw materials used by the industry. Much lower grade forms of scrap and primary metals can now be used to produce wrought superalloys on a high volume basis. The use of the AOD process is now increasing among master alloy producers who supply the investment casting foundries. Newer systems such as VOD and plasma-arc refining offer additional refining capability needed to produce high quality superalloys. In a similar vein, a recent paper by Woulds (4) described the use of oxygen lancing in an electric arc furnace followed by refining in a vacuum induction furnace to produce a high quality master alloy ingot of B-1900 alloy directly from scrapped engine blades. Testing of investment cast blades produced from this material indicated that they were essentially equivalent to blades produced from virgin raw materials. Although more work needs to be done in this area to fully demonstrate reproducibility, this development should go a long way toward removing limitations on the use of recycled material for cast superalloys.

Improved Recovery of Metals from Low Grade Scrap and Waste

Until recently most low grade material was returned to the primary metals refinery (usually the nickel smelter for nickel base superalloys) or was melted by a secondary refiner to produce a nickel or nickel-chromium product for sale to the steel industry. Refractory metals are generally lost into the slag and cobalt is lost by dilution in steel where it is generally an ineffective alloying element. There are other methods of utilizing this material, some not involving an intermediate melting process; however, the effect is the same: low recovery of metals other than nickel.

Although recycling of these low grade materials is currently unsatisfactory, there has been a significant amount research interest in the problem and in some cases efficient recovery is now commercially achieved. The principal limitations have been the relatively small quantities of material available at a given location, the complexity of recovery systems and frequently unfavorable economics.

At one time superalloy turnings were downgraded for use in steel because they were contaminated and alloy types were mixed. Now manufacturers are much more careful about segregating alloy turnings as they are generated. Scrap processers have become skillful at identifying alloy types. Pedigree turnings are now routinely degreased, fragmented and compressed for remelting by superalloy producers. Losses of refractory elements have been significantly reduced.

Considerable attention is now being paid to the recovery of alloy grindings which are also generated by component manufacturers. Grindings are produced in smaller quantities than turnings and are contaminated with oil, oxygen or grinding wheel debris. Because of their lower value, less care is often exercised in their collection so that extraneous metallic debris is often present. Recently, a commercial system for the recovery of oily stainless steel and tool steel grindings was commissioned (5). The extension of this process to treat superalloy grindings would be an important advance in recycling technology. It is also likely that processes for treating dry grindings using advanced mineral separation and agglomeration techniques will be developed within the next few years. It is reasonable to expect that, with increased care in collection by grindings by scrap generators and improved treatment capabilites by scrap processers, efficiency of recovery of metals from grindings will approach that of turnings.

In the future, recovery from materials now considered as wastes will also take place. Large quantities of material such as electrochemical machining sludge, electrical discharge machining sludge, pickle liquor sludge, metalliferrous slag, furnace dust and mill scale are generated(6). Nickel, chromium and cobalt are recovered directly from some of these materials by large producers of wrought alloys such as Huntington Alloys, Inc. and Cabot Corp. Some furnace dust and mill scale is treated along with stainless steel mill waste by Inmetco(7) and some is recycled to primary refining facilities.

The above recycling methods either result in recovery of all of the elements contained in the scrap directly or as a master alloy, or some elements are deliberately removed and lost. It has long been recognized that optimum recycling of complex superalloys would require separation of the individual elements. The currently downgraded scrap and some of the waste could form the pool of material from which a separation plant feed could be drawn. The Bureau of Mines has sponsored research on separation processes(8-11). Laboratory scale work, which has been conducted in Japan, Europe and the Soviet Union, was reviewed in reference (12). Although complete separation of elements is technically feasible and viewed by many as the ultimate solution to metals recovery, no process has ever reached the commerical stage. The reasons for this are the complexity and hence high capital cost of a recovery plant, the volatility of scrap prices and the difficulty in acquiring sufficient feed for a plant scaled for optimum efficiency. It is quite possible that the materials supply situation will make some of these separation processes economically viable, especially if they are operated by large primary metal refiners with capabilities for reducing capital investment by utilizing existing refining capacity for part of the recovery process. Under normal market conditions, a commercial process could be in operation in about 5 years. This time frame could be compressed through government stimulation in a time of materials crisis.

Industry Trends Which Will Affect Recycling

There have been a number of estimates of superalloy production for the remainder of this century. These estimates have a wide variation because of uncertainty over major segments of the superalloy consuming market such as military spending and energy conversion policies. A 5% annual growth rate is a median estimate. However, the volume of scrap generated by this industry will not grow at this rate and may actually decline because of significant technological trends.

Component manufacturers frequently use a term buy-to-fly (BF) ratio as a direct indicator of the amount of scrap generated in the production of a given part. BF ratios of 5 (80% scrap) are not uncommon for complex parts machined from forgings of ingot cast alloy. For the past decade the industry has been adopting processes which have had the effect of reducing the BF ratio by 50% or more. The steady replacement of forgings with investment castings and the introduction of hot isostatic pressing and powder metallurgy have promoted this trend. Other manufacturing developments such as powder rolling and continuous casting may provide future improvements in efficiency. The ultimate result of this trend is to reduce the availability of the preferred home and prompt industrial scrap. The proportion and absolute quantity of obsolete scrap will increase so development efforts should be aimed at more efficient utilization of that material.

Another significant trend in the gas turbine industry is the shift toward alloys and processing techniques which require higher purity raw materials. This is manifest in the increasing use of investment cast alloys, directionally solidified and monocrystal alloys, and powder metallurgy alloys. Very little obsolete scrap is now used by that industry. In view of the increasing proportion of this type of scrap, the recent progress in refining(4), referred to previously, is noteworthy. Although castings and powder metallurgy parts are replacing wrought parts in some aerospace applications, the use of wrought superalloys in energy conversion is increasing. This segment of the industry has much more flexibility in its use of raw materials and can accommodate more obsolete scrap than it currently uses. One limitation is that scrap from very complex alloys may contain valuable elements which are undesirable for some wrought alloys. Maximum recycling efficiency would served by treating such alloys by an element separation process.

Recently it has become fashionable to talk about "designing alloys and parts for increased recyclability". Although it may be possible to apply this concept in some industries, it is unlikely to have much success in the aerospace industry. In fact, several trends in the industry are leading it toward reduced alloy recyclability. The new alloys are less tolerant of impurities and more complex in terms of the number of contained elements. As performance requirements increase, engine components are progressively upgraded by adding more complex and hence more difficult to recycle alloys. In response to the high cost and scarcity of some raw materials, designers are making more and more use of components fabricated from different alloys by brazing or resistance welding. Many components are coated and cladding technology is seeing a revival. The concept: "only use the alloy where it's needed" makes good sense to many designers and they are pursuing it vigorously. However, this current design trend will have important adverse consequences for the processor of obsolete scrap as the end of the century approaches. It is possible that many complex components will have to be treated by an element separation process if they are to be efficiently recycled.

Critical Materials Workshop Focus

An examination of current superalloy recycling practices shows that, of the contained elements, nickel is by far the most efficiently recycled. Scrap which is downgraded is usually purchased for its nickel content and recovery of this element is high. Furthermore, primary nickel suitable for use in superalloys is readily available from secure sources. Consequently, nickel lost to the industry through downgrading is not a major concern.

Although chromium used for many superalloys is expensive, this is due to production cost and capacity limitations and not due to the availability of chromium ore. Superalloy consumption of chromium is very small relative to total chromium consumption. In a crisis, the vast pool of stainless steel scrap could be drawn upon as a source of chromium for preferred use in superalloys. Production of chromium metal from stainless steel scrap would require adapting existing electrochemical production processes to a new feed. Chromium of acceptable quality from this source could probably be commercially available within a year.

The elements in superalloys which are of most concern are cobalt and the refractory metals tungsten, tantalum and columbium. All are largely imported and costly. These elements are essentially lost when scrap is downgraded, either by inclusion into the slag or by dilution. Furthermore, in the case of the refractory metals, the form used in superalloys is considerably more costly than the form used for specialty steel. Accordingly, from the standpoint of the contribution that improved recycling efficiency could make to metals availability, these four metals are suggested for study.

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MATERIALS CRITICALITY IN JET ENGINES

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THE HEART OF MODERN AIRCRAFT IS ITS JET ENGINE (FIG. 1). A JET ENGINE IS MADE OF MANY SOPHISTICATED METAL ALLOYS, CHOSEN FOR LIGHTNESS, HEAT RESISTANCE, STRENGTH AND DURABILITY. TITANIUM ALLOYS AND HEAT-RESISTANT "SUPERALLOYS" CONSTITUTE MORE THAN 85% OF THE ENGINE'S WEIGHT. THESE TWO CLASSES OF ENGINEERED ALLOYS ARE INDISPENSABLE TO THE PRODUCTION OF A JET ENGINE WITH THE POWER, DURABILITY AND EFFICIENCY REQUIRED BY OUR NATION'S MILITARY AND COMMERCIAL AIRCRAFT. THESE ALLOYS ARE FORMULATED FROM A VARIETY OF BASIC METALLIC INGREDIENTS. TO BUILD AN F100 ENGINE (FIG. 2), WHICH POWERS OUR NATION'S FRONT LINE DEFENSE AIRCRAFT, THE F-15 AND F-16, REQUIRES AN INPUT WEIGHT OF 5204 LBS. OF NICKEL, 1656 LBS. OF CHROMIUM, 910 LBS. OF COBALT, 5366 LBS OF TITANIUM, 720 LBS. OF ALUMINUM, 3 LBS. OF TANTALUM, AND 171 LBS. OF COLUMBIUM. EACH OF THESE METALS IS IMPORTED FROM SOME OVERSEAS SOURCE. SOME FOREIGN SOURCES LIKE CANADA OR AUSTRALIA ARE SECURE, STABLE AND FRIENDLY; OTHERS SUCH AS THE SOVIET UNION OR ZAIRE ARE LESS RELIABLE FOR DIFFERENT REASONS. WE ALL KNOW THAT IN 1978 CIVIL WAR ERUPTED IN ZAIRE, CAUSING THE COBALT MINES TO CLOSE. MORE THAN 50% OF THE WORLD'S COBALT COMES FROM ZAIRE AND THE DISRUPTION IN PRODUCTION CAUSED WORLD-WIDE SHORTAGES. BY 1978 COBALT WAS ALLOCATED TO USERS AT 70% OF 1977 CONSUMPTION AND WELL BELOW ACTUAL REQUIREMENTS. THE SHORTAGES CAUSED PRICE JUMPS FROM $6.85/LB. TO ABOUT $50.00/LB. IN THE SPOT MARKET AND CAUSED LARGE INCREASES IN LEAD TIME FOR OBTAINING BASIC MATERIALS TO PRODUCE ENGINE PARTS. TODAY, THE MINES ARE PRODUCING AGAIN BUT ECONOMIC PROBLEMS BESIEGE ZAIRE AND THE RISK OF DISRUPTION REMAINS.

TO ILLUSTRATE THE NATURE OF OUR CONCERN, LET'S EXAMINE THE IMPACT OF A LONG-TERM COBALT SUPPLY CUT-OFF ON U.S. AIRLINES BY LOOKING AT ONE PART IN ONE ENGINE TYPE. IN 1979, SOME 83% OF THE COMMERCIAL FLIGHTS

IN THE UNITED STATES WERE IN AIRCRAFT EQUIPPED WITH OUR JT8D ENGINE. ON THE AVERAGE, THESE ENGINES OPERATE ABOUT 2,500 HOURS PER YEAR AND THE FIRST TURBINE VANE (FIG. 3), WHICH IS A 60% COBALT ALLOY, HAS A USEFUL LIFE OF 10,000 HOURS BEFORE IT IS REPLACED. THE PIPELINE FOR REPLACEMENT PARTS IS ABOUT TWELVE MONTHS LONG FROM OUR MELTING SUPPLIERS TO DELIVERY OF SPARE VANES TO THE AIRLINES. FROM THE TIME COBALT SHOULD BE CUT OFF FROM OUR MELTING SUPPLIERS, WE COULD SUPPLY SPARE PARTS TO OUR AIRLINE CUSTOMERS FOR ONLY A YEAR. AT THE END OF THAT TIME, THE JT8D-POWERED FLEET WOULD START TO BE GROUNDED AT THE RATE OF ABOUT 25% PER YEAR.

ALTHOUGH THE ILLUSTRATION HAS BEEN LIMITED TO ONLY JT8D PARTS (FIG. 4), ALL ENGINES, FROM ALL MANUFACTURERS, USE COBALT-CONTAINING ALLOYS FOR FIRST TURBINE VANES. IN THE REAL CASE, TO AVERT GROUNDINGS, LESS SATIS-FACTORY ALTERNATIVE MATERIALS WOULD BE USED, BUT SIGNIFICANT PENALTIES WOULD RESULT. THE IMPACT ON OUR DEFENSE AND COMMERCIAL AVIATION SYSTEMS WOULD BE EXTREMELY SERIOUS.

CHROMIUM, WHICH IS ALSO USED IN TURBINE VANES, TURBINE BLADES AND TURBINE DISKS, SHAFTS, BEARINGS, CASES, SEALS AND COATINGS, IS ANOTHER METAL IMPORTED FROM SOUTH AFRICA AND THE SOVIET UNION. THE UNITED STATES IS 90% IMPORT-DEPENDENT ON CHROMIUM, AND THE REMAINDER COMES FROM RECYCLED SCRAP, NOT DOMESTIC MINERAL SOURCES. JET ENGINE NEEDS FOR CHROMIUM CANNOT BE SATISFIED FROM COMMERCIAL SCRAP BECAUSE OF PURITY REQUIREMENTS. A STUDY BY THE NATIONAL MATERIALS ADVISORY BOARD IN 1978 STATED: "WHILE (CHROMIUM) IS AN IMPORTANT INGREDIENT IN MANY COMMODITIES, IT IS IRREPLACEABLE IN STAINLESS STEELS AND HIGH TEMPERATURE-

RESISTING SUPERALLOYS, TWO CLASSES OF MATERIALS THAT ARE VITAL TO THE TECHNOLOGICAL WELL-BEING OF THE NATION. CURRENTLY THERE IS NO CHROMIUM-FREE SUBSTITUTES THAT CAN BE USED IN THESE CRITICAL APPLICATIONS, NOR ARE ANY SUCH SUBSTITUTES LIKELY TO BE DEVELOPED IN THE FORESEEABLE FUTURE." ALTHOUGH THE CURRENT SUPPLY SITUATION IS STABLE, THERE REMAINS A RISK TO BE ADDRESSED FOR THE LONG-TERM FUTURE.

TITANIUM ALLOYS ARE USED FOR NEARLY 30% OF THE ENGINE BY WEIGHT IN FAN AND COMPRESSOR BLADES, DISKS AND CASES. TITANIUM COMPONENTS ARE ONE-THIRD LIGHTER THAN EQUIVALENT STEEL PARTS AND MAKE POSSIBLE THE WEIGHT ADVANTAGE WHICH GIVES THE ENGINE AND AIRCRAFT FUEL EFFICIENCY AND SUPERIOR PERFORMANCE. TITANIUM SHORTAGES OCCURRED IN 1979 AND 1980, NOT BECAUSE OF RAW MATERIAL SUPPLY INTERRUPTIONS FROM AUSTRALIA, WHERE 85% OF THE WORLD'S RUTILE IS, BUT BECAUSE OF DOMESTIC AND WORLD SPONGE-MAKING CAPACITY. SPONGE IS THE INITIAL METALLIC FORM OF TITANIUM WHEN IT IS REFINED FROM THE RUTILE ORE. THE SPONGE SHORTAGE WAS INTENSIFIED WHEN THE SOVIET UNION, A MAJOR SUPPLIER, CUT ITS EXPORTS TO THE U.S. SIGNIFICANTLY.

THE OVERALL LIST OF MATERIALS DESCRIBED EARLIER FOR THE F100 ARE USED IN BROADLY SIMILAR QUANTITIES IN ALL JET ENGINES (FIG. 5). BUT BASED ON CRITICALNESS TO PRODUCT, RISK FACTORS AND ACTIONS WHICH CAN BE TAKEN, WE BELIEVE THAT COBALT, CHROMIUM AND TITANIUM ARE MATERIALS WHICH DRAW THE FOCUS OF ATTENTION AT THE DEPARTMENT OF COMMERCE IN THIS STUDY REQUIRED BY THE NATIONAL MATERIALS AND MINERALS POLICY, RESEARCH AND DEVELOPMENT ACT OF 1980.

ACTIONS HAVE ALREADY BEEN TAKEN AT PRATT & WHITNEY AIRCRAFT TO ADDRESS THE CRITICAL MATERIALS ISSUES. SUBSTITUTION (FIG. 6) OF ONE ALLOY BY

ANOTHER AVAILABLE ALLOY HAS BEEN ACCOMPLISHED WHERE POSSIBLE TO REDUCE CRITICAL MATERIAL USE. ALLOY CHANGES IN ONE MILITARY ENGINE VANE RESULTED IN A SAVINGS OF 65,000 LBS. OF COBALT IN 1980. DISK ALLOYS ARE BEING CERTIFIED FOR USE IN COMMERCIAL ENGINES WHICH WILL RESULT IN FURTHER SAVINGS. HOWEVER, THESE ARE THE EASY SUBSTITUTIONS WHICH HAVE BEEN IDENTIFIED, AND ALTHOUGH IMPLEMENTATION IS COSTLY, THEY ARE BEING PURSUED. FURTHER PROGRESS TOWARD SUBSTITUTION WILL COME MORE GRUDGINGLY, INVOLVING HARD DECISIONS ON TRADE-OFFS IN PERFORMANCE OR IN FIELD MAINTAINABILITY. BEYOND THE USE OF AVAILABLE MATERIALS THERE IS THE OPPORTUNITY FOR NEW MATERIALS YET TO BE DISCOVERED. ONE SUCH RESEARCH EFFORT IS BEING FUNDED BY THE DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA) AND THE AIR FORCE IS FOSTERING RAPID SOLIDIFICATION RATE (RSR) POWDER TECHNOLOGY, TO SEEK NEW ALLOYS WHICH CAN PERFORM WITH REDUCED CRITICAL METAL CONTENT.

CONSERVATION EFFORTS ARE ALSO BEING IMPLEMENTED IN THE FORM OF INCREASED EMPHASIS ON MATERIAL RECYCLING. IN ONE CASE, THE CHIPS FROM MACHINING A TURBINE DISK ALLOY WITH HIGH COBALT AND CHROMIUM CONTENT ARE COLLECTED, AND AFTER CLEANING RETURNED TO THE MELTERS TO MAKE THE ALLOY FOR NEW DISKS. WE HAVE REACHED A POINT WHERE UP TO 20% OF THIS DISK MATERIAL USED CONSISTS OF THE RECYCLED MATERIAL. EMPHASIS ON NET-SHAPE MANUFACTURING TECHNOLOGY IS ANOTHER SOURCE OF CONSERVATION. WHEN A PART FORGING CAN BE MADE CLOSER TO NET-SHAPE, LESS INPUT MATERIAL IS REQUIRED. USE OF ADVANCED TECHNOLOGIES SUCH AS GATORIZING^R, AN ISOTHERMAL FORGING PROCESS, ALLOWS REDUCED FORGING ENVELOPES. A PROGRAM IS IN PROCESS TO REDUCE THE INPUT WEIGHT OF NINE KEY F100 PARTS FROM 1200 TO 600 POUNDS BY THIS PROCESS. MORE WORK IS NEEDED AND WILL CONTINUE, BUT THESE EFFORTS DO NOT ELIMINATE THE NEED FOR CRITICAL MATERIALS; THEY JUST REDUCE THEM.

THE CRITICAL MATERIALS PROBLEM IS MULTI-FACETED AND WILL REQUIRE A VARIETY OF SOLUTIONS. THREE SPECIFIC ACTIONS WHICH ARE NEEDED WILL REQUIRE GOVERNMENT, PRODUCER AND CONSUMER COMMITMENT AND COOPERATION (FIG.7). THESE ARE: (1) INCREASE DOMESTIC SUPPLIES OF CRITICAL MATERIALS; (2) IMPROVE THE USE OF OUR NATIONAL STOCKPILE; AND, (3) PROMOTE AND SUPPORT ADDITIONAL CONSERVATION.

WHILE THERE HAS BEEN SOME RECENT PROGRESS IN RECOGNIZING THAT MULTIPLE USE OF THE 760 MILLION ACRES OF FEDERAL LANDS IS NECESSARY, FURTHER ENCOURAGEMENT IS NEEDED TO SEEK, DEVELOP AND PRODUCE DOMESTIC SOURCES OF CRITICAL MATERIALS. THE COBALT, CHROMIUM AND NICKEL DEPOSITS IN IDAHO AND CALIFORNIA ARE EXAMPLES OF POTENTIAL DOMESTIC RESOURCES THAT CAN BE DEVELOPED WHILE RECOGNIZING THE NEED TO PRESERVE THE NATURAL BEAUTY OF THE WILDERNESS IN WHICH THEY EXIST. THANKS TO THE IDAHO WILDERNESS BILL, THE MINERALS IN THE BLACKBIRD MINE CAN PROVIDE MUCH NEEDED COBALT METAL IN THE NEAR FUTURE. IT MAY ALSO BE NECESSARY IN THE CONTEXT OF A MATERIALS INSURANCE POLICY TO PROVIDE FINANCIAL INCENTIVES FOR DOMESTIC PRODUCTION. HIGHER PRODUCTION COSTS OF LOW GRADE ORES IN THIS COUNTRY, COUPLED WITH THE ADDITIONAL COSTS OF ENVIRONMENTAL OR REGULATORY RESTRICTIONS, MAY HINDER THE NORMAL ECONOMIC DEVELOPMENT PROCESS OF DOMESTIC MINES. SOME FORM OF TAX AID, DEPLETION ALLOWANCE OR GOVERNMENT PRICE SUPPORT COULD BE NEEDED TO PERMIT DEVELOPMENT OF AN ECONOMICALLY-MARGINAL BUT BADLY-NEEDED SOURCE.

THE TECHNOLOGY FOR MINERAL BENEFICIATION SHOULD RECEIVE FEDERAL SUPPORT AND STIMULATION IN THE FORM OF RESEARCH AT BUREAU OF MINES, AT UNIVERSITIES OR OTHER RESEARCH INSTITUTIONS TO FIND WAYS TO DISCOVER AND PRODUCE MINERALS

NOT PRESENTLY ADAPTABLE TO JET ENGINE PRODUCTION. FINALLY, THE LONGER TERM FUTURE MAY FIND THAT MAJOR MINERAL RESOURCES WILL COME FROM THE SEA. THE CURRENT LAW OF THE SEA TREATY APPEARS TO WORK AGAINST THE KIND OF STRONG GOVERNMENT SUPPORT NECESSARY TO ESTABLISH AN AMERICAN TECHNOLOGY AND SEA MINING INDUSTRY WITH GUARANTEED ACCESS TO THOSE MINERALS WHICH THE OCEAN FLOORS CAN PRODUCE.

NEXT TO INCREASED DOMESTIC SUPPLY, THE USE OF THE NATIONAL STOCKPILE CAN BE THE BEST GUARDIAN AGAINST FUTURE TEMPORARY SUPPLY INTERRUPTIONS. AT LEAST FOR SHORT-TERM EMERGENCIES, OUR STOCKPILE CAN PROVIDE THE MATERIALS TO KEEP GOING. BUT THE PRESENT STATE OF THE STOCKPILE IS INADEQUATE IN QUANTITY AND PROBABLY IN QUALITY. THE STATIC NATURE OF THE STOCKPILE SUGGESTS THAT THE SPECIFICATIONS OF TODAY MIGHT NOT BE MET BY RAW MATERIALS PUT INTO STOCKPILE 20, 30, OR 40 YEARS AGO. THE EXISTING STOCKPILE MUST BE INVENTORIED FOR QUALITY, RESUPPLIED WHERE NEEDED AND THEN KEPT DYNAMIC TO AVOID FURTHER OBSOLESCENCE. THE EXCLUSIVE USE OF THE STOCKPILE AS A DEFENSE STOCKPILE MAKES IT RELATIVELY USELESS IN TIMES WHEN WE ARE NOT AT WAR. IT WOULD BE FAR MORE EFFECTIVE IF ITS USE COULD BE CONSIDERED FOR ECONOMIC EMERGENCIES AS WELL, SUCH AS WOULD HAPPEN IF AFRICAN COBALT OR CHROMIUM WERE NOT AVAILABLE. FURTHERMORE, IF NATURAL DISASTERS PREVENTED PRODUCTION OR SHIPMENT OF A CRITICAL MATERIAL, THE STOCKPILE SHOULD BE AVAILABLE TO AVOID ECONOMIC DISRUPTION WHICH COULD DAMAGE OUR INDUSTRIAL BASE. RECENT TESTIMONY BY GENERAL ALTON D. SLAY, COMMANDER, AIR FORCE SYSTEMS COMMAND, WARNS OF AN ALREADY THIN DEFENSE INDUSTRIAL BASE AND "SPRINT" CAPABILITY. THE STOCKPILE CAN ALSO BE USED TO HELP STIMULATE SOUND CAPITAL INVESTMENT

IN CRITICAL MATERIALS-PRODUCING INDUSTRIES BY BUYING TO FILL THE STOCKPILE DURING THE VALLEYS OF DEMAND AND THEN SUPPLYING DURING THE PEAK "CRUNCH." IT MIGHT BE USED TO STABILIZE SEGMENTS OF INDUSTRY LIKE THAT OF TITANIUM SPONGE PRODUCTION WHICH HAVE BEEN RELUCTANT TO ADD CAPACITY DUE TO THE CYCLIC HISTORY OF THE USE OF TITANIUM IN OUR COUNTRY.

THE THIRD ELEMENT, CONSERVATION, HAS NOT BEEN EXHAUSTED AND COULD BE FURTHER STIMULATED BY GOVERNMENT RESEARCH AND DEVELOPMENT SUPPORT THROUGH AGENCIES LIKE THE DEPARTMENT OF DEFENSE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, DEPARTMENT OF ENERGY, AND NATIONAL SCIENCE FOUNDATION. SUPPORT OF NEW KNOWLEDGE-BUILDING STUDIES CAN HELP INDUSTRY UNDERSTAND WHY MATERIALS HAVE THE PROPERTIES THEY DO AND LEAD TO DEVELOPMENT OF NEW MATERIALS AND METHODS FOR MANUFACTURING THEM.

CONCERTED ACTION TO SOLVE OUR NATIONAL MATERIAL CRISIS IS LONG OVERDUE. PRATT & WHITNEY AIRCRAFT PLANS TO CONTINUE TO DO WHAT IT CAN AND IS PLEASED TO CONTRIBUTE TO THIS CASE STUDY. ONE CANNOT PROVIDE DETAILS IN THE TIME THIS TALK ALLOWS, BUT WE WILL BE AVAILABLE AND ANXIOUS TO EXPAND ON THESE BRIEF COMMENTS DESCRIBING THE PROBLEM AND ITS SOLUTIONS AT ANY TIME.

THANK YOU FOR THE OPPORTUNITY TO PARTICIPATE.

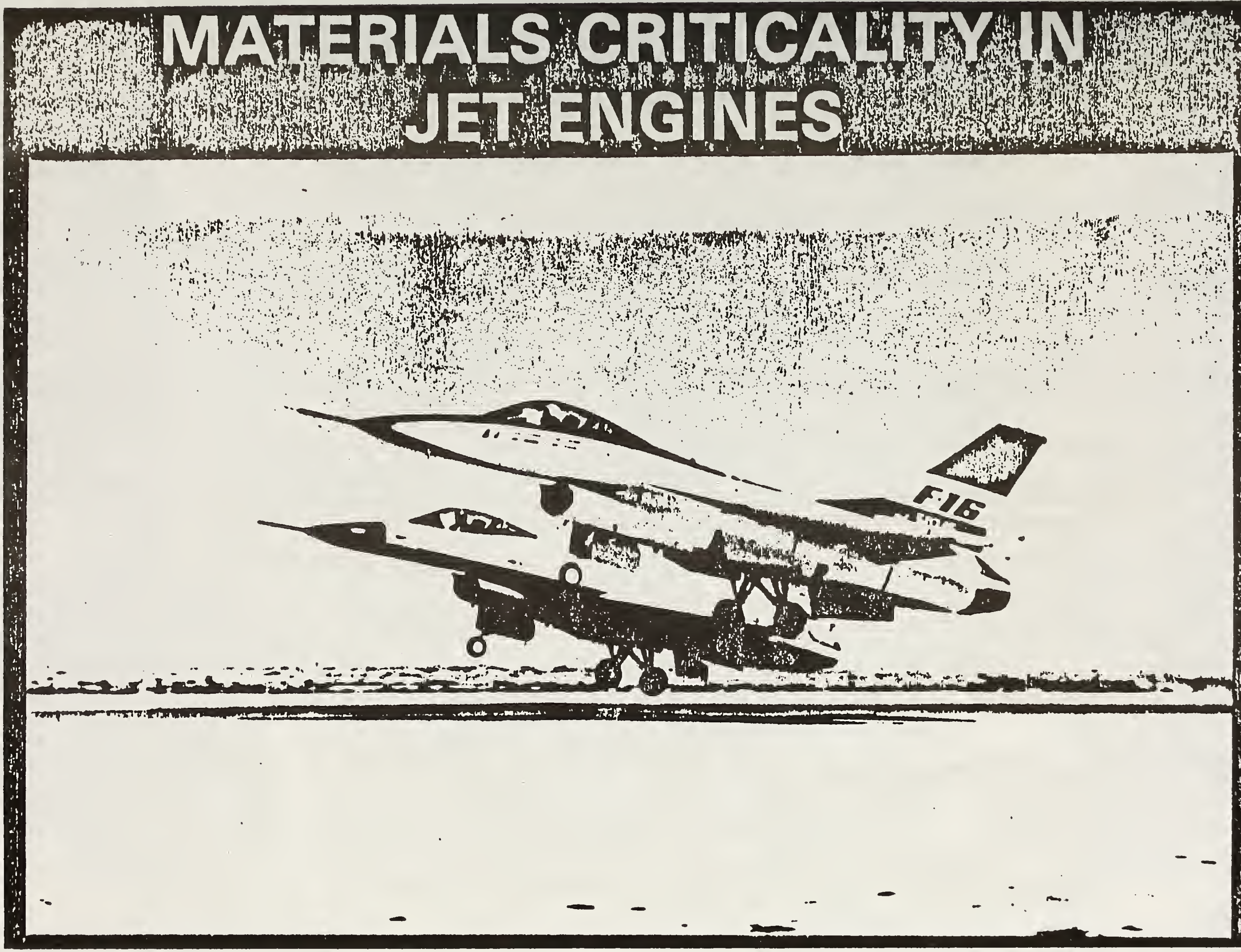
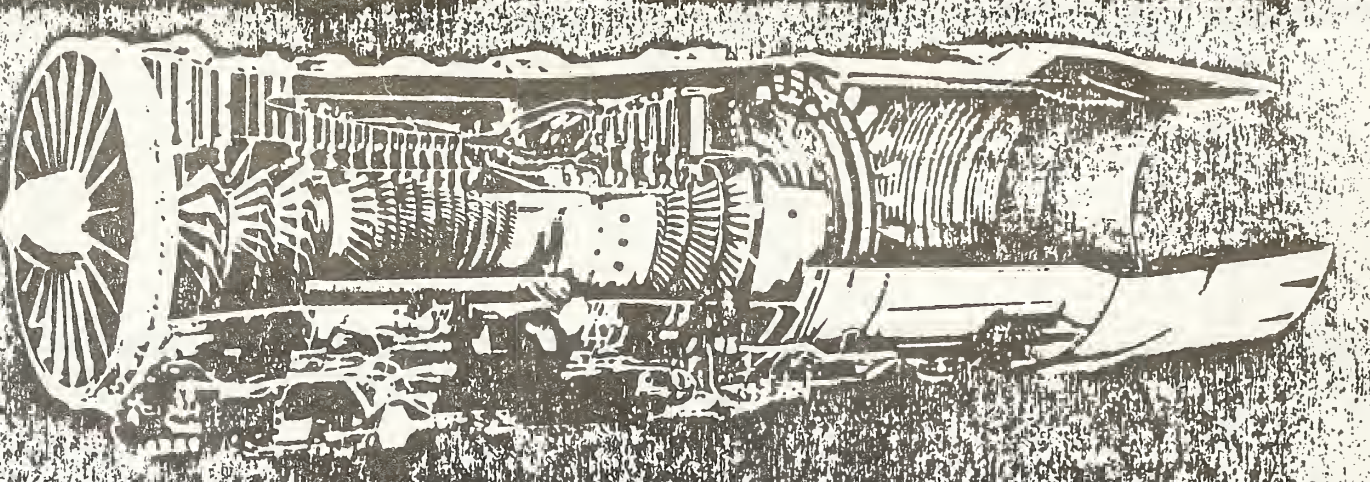


Figure 1



	Pounds	% Dependency	Sources
Nickel	5204	77	Canada, USSR, Australia
Chromium	1656	90 •	South Africa, USSR
Titanium	5366	100	Australia, Japan
Cobalt	910	90	Zaire, Zambia
Columbium	171	100	Brazil, Canada
Tantalum	3	96	Thailand, Canada

Figure 2

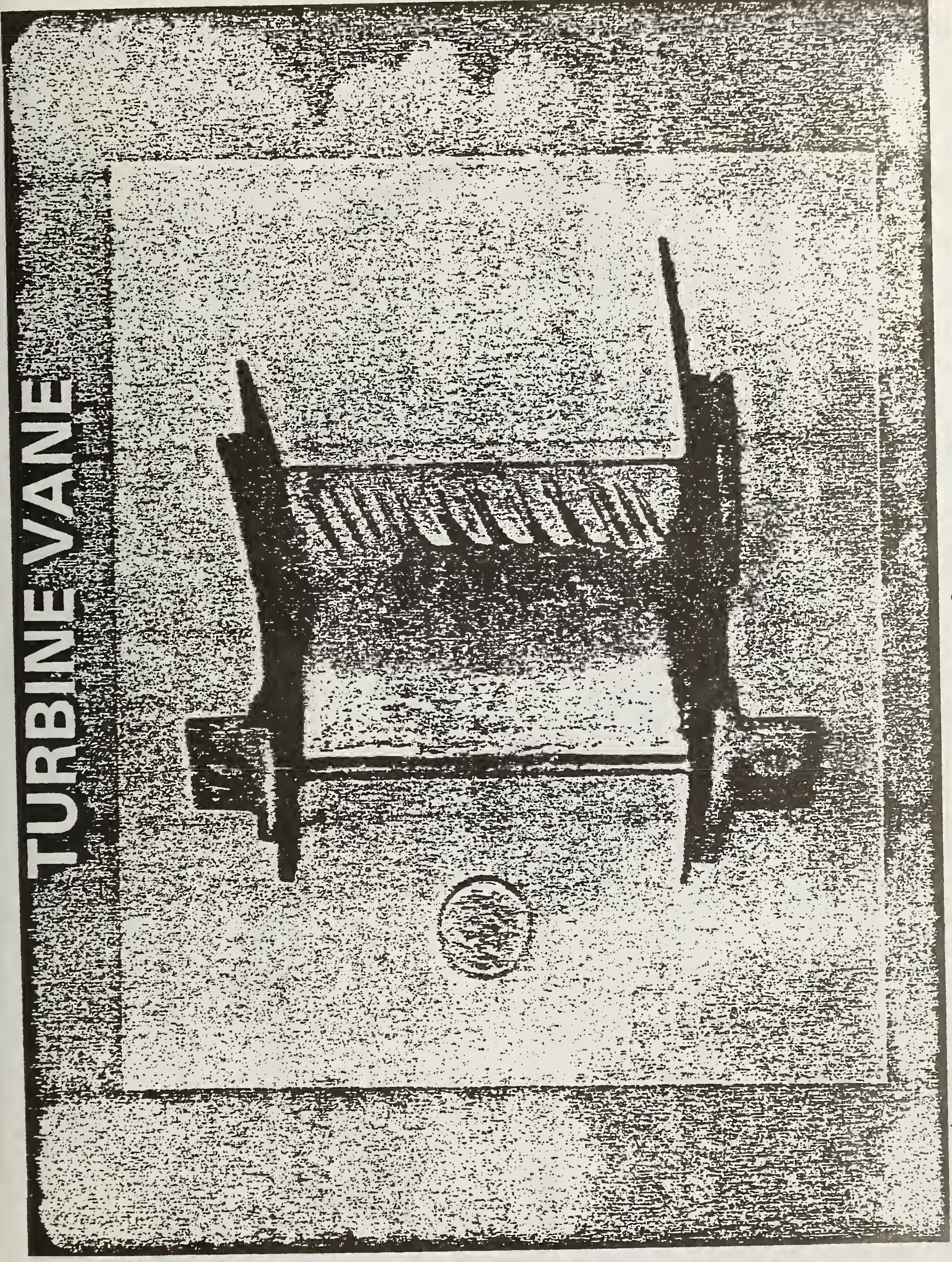


Figure 3

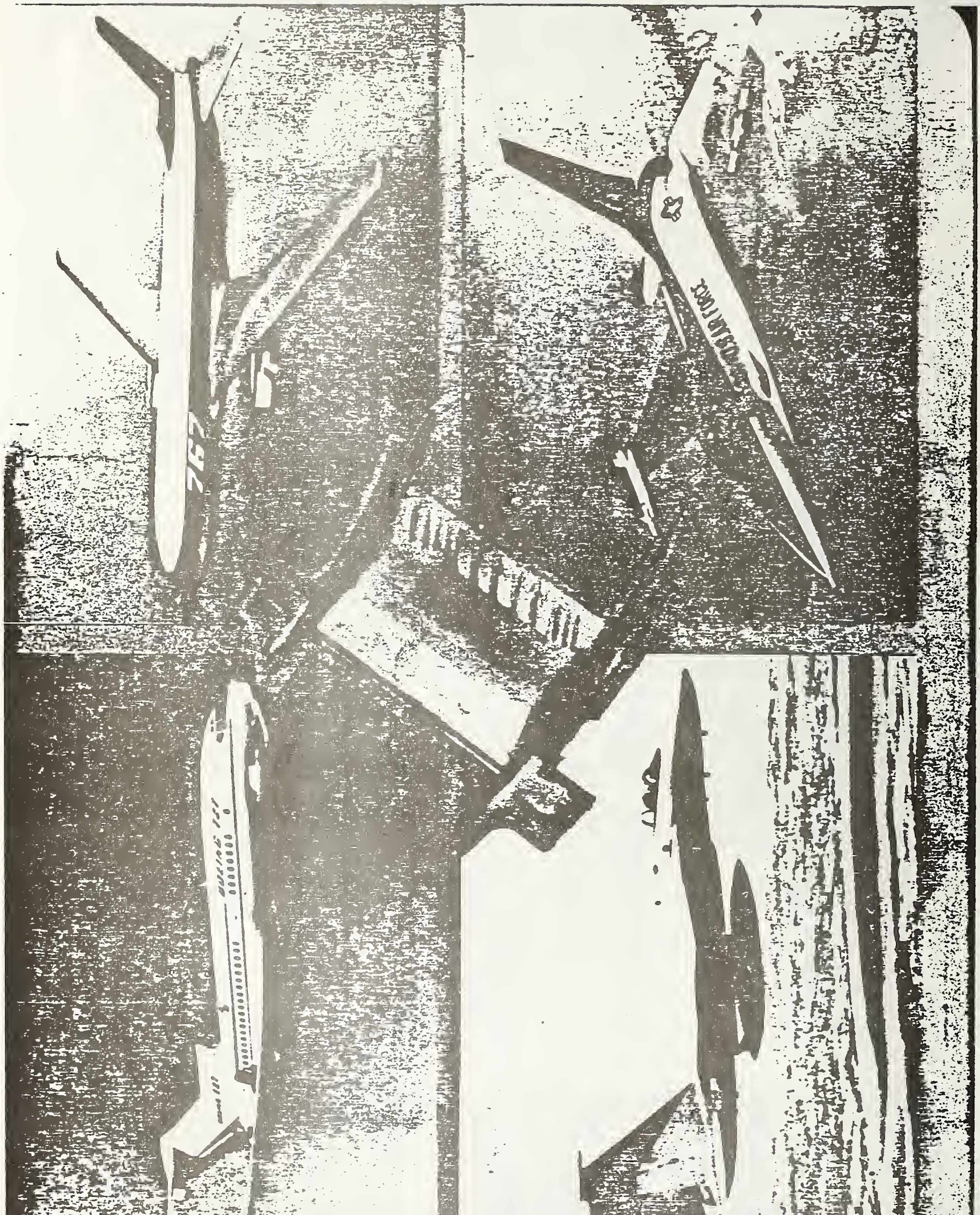


Figure 4

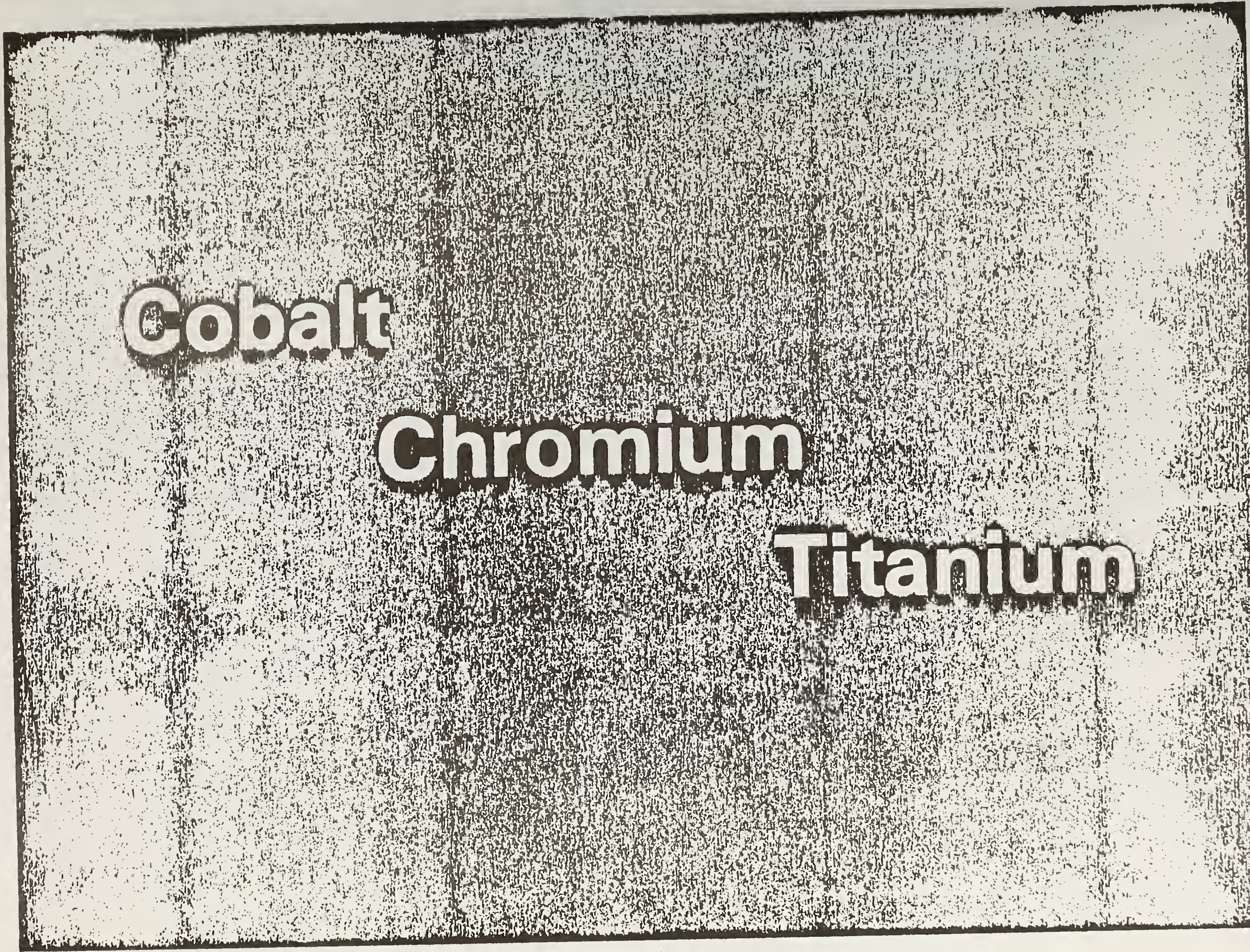


Figure 5

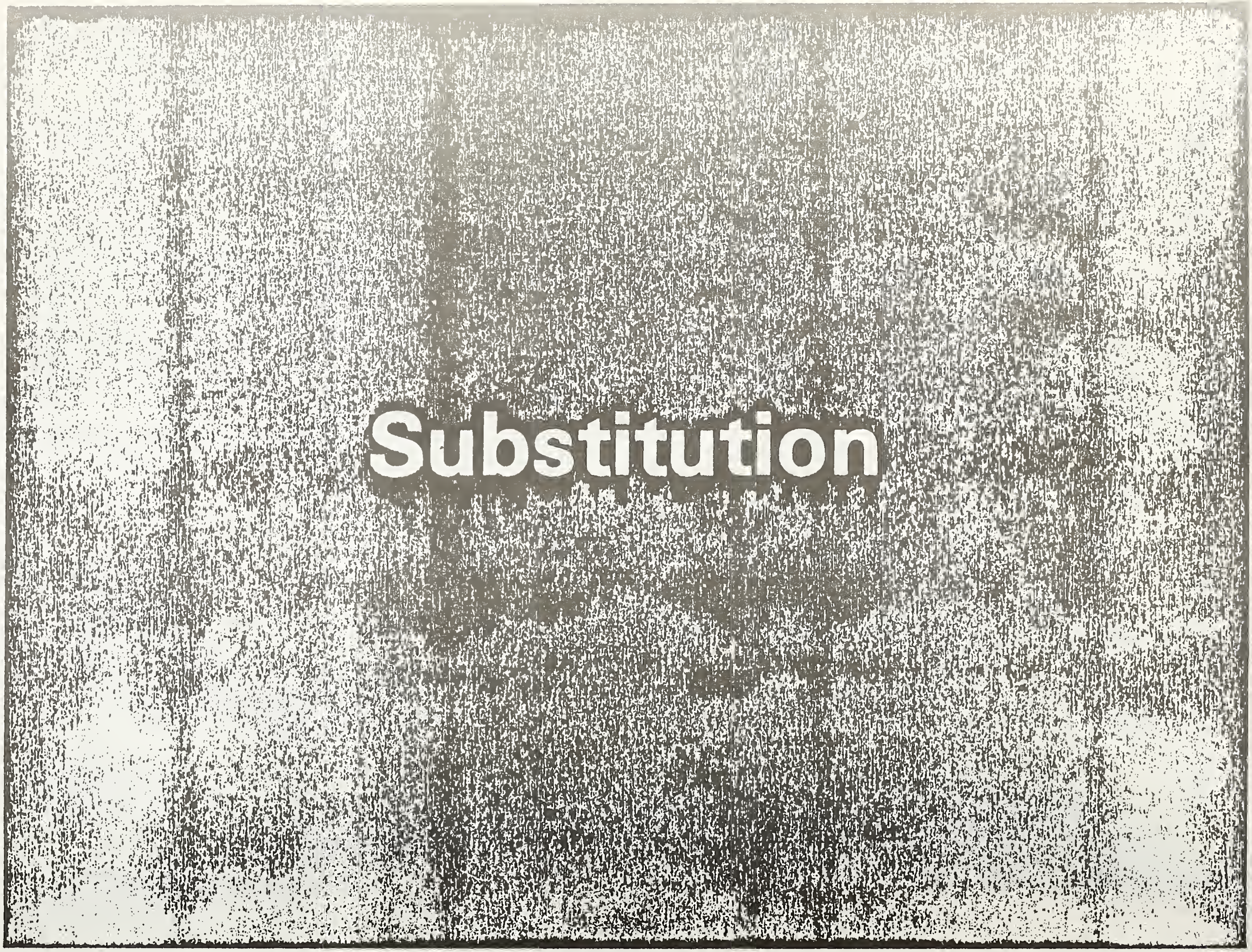


Figure 6

Figure 7

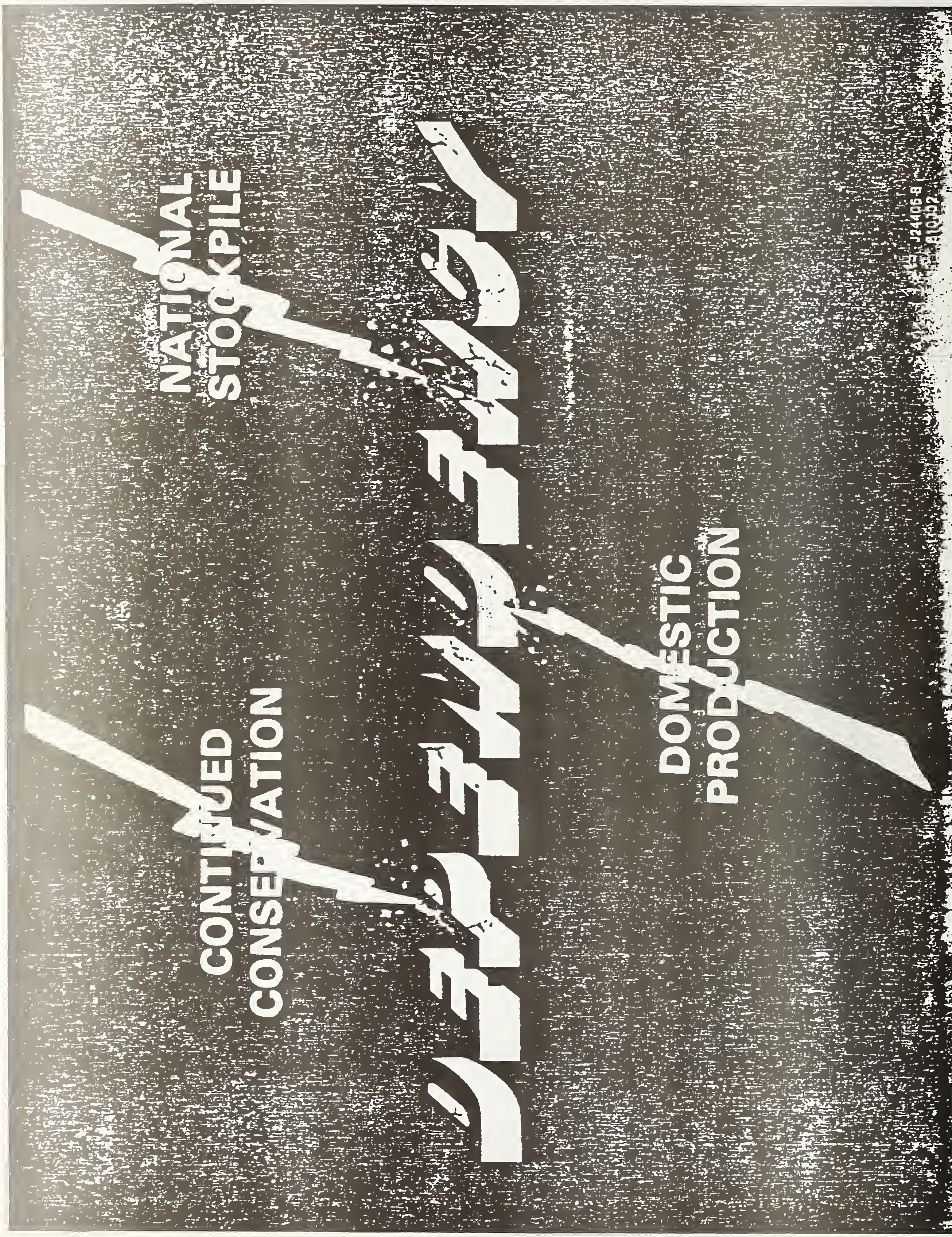

NATIONAL STOCKPILE
CONTINUED CONSERVATION
DOMESTIC PRODUCTION

Figure 8

COBALT AVAILABILITY AND SUPERALLOYS

and

NASA'S ACTIVITIES IN THE CONSERVATION OF STRATEGIC AEROSPACE MATERIALS

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Cobalt Availability and Superalloys

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Cobalt Availability and Superalloys

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SUMMARY

The greatest use of cobalt is in nickel-base superalloys, which are widely applied in such critical high-temperature environments as turbines. Reserves of cobalt ores are diminishing rapidly in the face of accelerating world consumption; furthermore, the greatest reserves are in politically unstable areas, largely in Africa. In light of these serious factors, the occurrence, consumption patterns, and availability of cobalt have been reviewed. The scanty literature dealing with the role of cobalt in superalloys has also been critically reviewed and is discussed. Using data reported in the literature, and previously published analytical techniques, the effects of cobalt content on superalloy microstructural characteristics and mechanical properties have been calculated, leading to the strong suggestion that cobalt in superalloys may not be as crucial as generally believed, and could possibly be reduced significantly.

INTRODUCTION

The current workhorse materials in aircraft, land-based or marine turbines, and other high-temperature, energy production devices are the nickel-base superalloys. Besides nickel, these alloys can contain considerable amounts of cobalt, chromium, aluminum, titanium, molybdenum, tungsten, tantalum, columbium, and vanadium, along with smaller amounts of such elements as carbon, boron, zirconium, and hafnium. Together, these elements accord acceptable mechanical properties in such Dantean environments as the inside of a gas turbine.[1]

Unfortunately, unless considerable resources can be converted into reserves, many of the elements in superalloys will be economically depleted by the first quarter of the next century at the current increasing rates of use.[2,3] Of more immediate concern is that the United States already has no appreciable cobalt, chromium, and nickel reserves of its own. In addition, it imports much of its aluminum, tantalum, and tungsten.[2] Accordingly, the United States, by far the major producer and user of superalloys, is at the mercy of the vagaries of international economics, politics, and stability. This situation is perhaps serious in the case of cobalt.

Of the strategic elements in superalloys, cobalt is unique in that its single largest use is in superalloys.[4-8] Superalloys, however, are not major consumers of chromium, tungsten, or even nickel.[4,9] Much of the world's cobalt supply comes from Zaire;[4-8] the current and past instability of cobalt supply and cost is a direct consequence of production instabilities caused by political instabilities in Zaire and its neighbors. Cobalt prices were stable at about $6/lb through the 1970s, until the mine production disruption in Zaire resulted in a current producer price of about $25/lb, and in even higher dealer prices.

Accordingly, it would be of common, long-term interest to reduce or substitute for cobalt in superalloys without affecting the performance requirements. First, we will review the cobalt use, reserves, and resource situation; then we will review, compact, and extend the knowledge base for the role of cobalt in superalloys. We will show that the technical necessity for cobalt levels of ≥ 10 wt.% in superalloys, especially in nickel-base superalloys, has never been firmly demonstrated and that it would be prudent to understand further the role, if any, of cobalt in nickel-base superalloys.

Table I: Estimated 1979 World Cobalt Mine Production and Cobalt Reserves and Resources,[5,6] Million Pounds*

	Mine Production	Reserves	Resources
North America			
United States	0	0	1,700
Canada	2.0	66	546
Cuba	3.6	240	2,340
Europe			
USSR	4.4	460	500
Finland	3.0	40	50
Africa			
Zaire	29.0	1,000	1,500
Zambia	6.0	250	770
Morocco	4.0	28	30
Botswana	0.4	58	70
Oceania			
New Caledonia	9.2	600	850
Australia	7.6	110	650
Philippines	2.4	420	450
World Total	71.6	3,272	9,456
Seabed Nodules		---	500,000

*Any identified, measured, indicated, or inferred cobalt ore occurring in such form and amount that economic extraction of it is currently or potentially feasible is a cobalt resource. Those identified resources which can be economically mined with current mining and production practices are considered reserves.

AVAILABILITY AND USE

Current Supply

Cobalt is almost always mined and recovered as a byproduct of copper, nickel, and other metals. The estimated world mine production of cobalt in 1979 is shown in Table I;[5,6] Zaire produced almost 41% of the total. Zairian production was up in 1979 after a three-year slump, first triggered by transportation difficulties through Angola as a consequence of unrest in that country and further aggravated by the 1978 war in Zaire itself. New Caledonia at 13%, Australia at 11%; Zambia at 8%, Morocco at 6%, Finland at 4%, and Canada at 3% were also significant producers. No cobalt has been mined in the United States since 1971. Since 1975, U.S. cobalt imports have come mainly from Zaire (41%), Belgium-Luxembourg (19%), Zambia (10%), Finland (7%), and Canada and Norway (5% each).[6] Taking into account the fact that all of the Belgian cobalt originated in Zaire, and including U.S. imports from Morocco, Botswana and South Africa, the total amount of cobalt imported from Africa now stands at about 75%.

Not all of the U.S. cobalt demand has been met by imports or by industry stocks, even after discontinuation of domestic mining in 1971. Until 1976, a significant source of cobalt for the United States was the national stockpile. In 1976, however, to ensure an adequate supply of cobalt in case of national emergency, sales from the national stockpile were halted, and a stockpile goal of 85.4 million pounds was set by the U.S. General Services Administration. As of November

Table II: Total Consumption, Primary Demand, and Average Prices for Cobalt.[5,6]

Year	U.S. Primary Demand (Million Pounds)	U.S. Total Demand (Million Pounds)	Actual Price (US $/lb)	Price Based on 1978 Dollars (US $/lb)
1979*	18.3	20.3	25.00	22.50**
1978	19.3	20.4	11.53	11.53
1977	17.8	18.3	5.58	5.99
1976	19.5	19.8	4.44	5.05
1975	13.7	14.1	3.98	4.76
1974	23.4	23.7	3.46	4.54
1973	21.8	22.0	3.00	4.31
1972	19.3	19.5	2.45	3.73
1971	13.4	13.5	2.20	3.48
1970	16.2	16.3	2.20	3.66
1969	19.2	19.5	1.89	3.31

*Estimated
**Based on 10% dollar inflation over 1978.

30, 1979, the cobalt inventory was 40.8 million pounds.[6] Recycling and reclamation of cobalt has increased dramatically: in 1976, only 333,000 pounds of cobalt were reverted, while in 1979, an estimated two million pounds of cobalt were reverted.[6] However, even with the increase in recycling and reclamation in 1979, U.S. import reliance as a percent of total consumption still stands at a dangerously high 90%.

Current Use

In 1979 the total U.S. consumption of cobalt was estimated to be 20.3 million pounds.[6] Table II lists the U.S. consumption of primary and recycled cobalt, along with the average annual producer's price of cobalt for the last ten years.[5,6] The disruptions in supply and the nearly exponential increases in price since 1976 obviously have not significantly curtailed the U.S. appetite for cobalt. Between 1960 and 1970, the U.S. primary demand increased at an average rate of about 6.25% per year, and since 1970 at about 2.7% per year.[5,6]

Estimated end uses for cobalt in 1979 in the United States are given in Figure 1. As mentioned, superalloys are by far the single largest consumer of cobalt. It is interesting that in 1977, at the beginning of the Zairian production disruptions, the amount of cobalt used in magnetic materials was equal to that used in superalloys, each requiring about 25% of the 18.3 million pounds of cobalt consumed in the U.S. In contrast, only two years later, the amount of cobalt used in magnetic materials was reduced to about 20% of the estimated 20.3 million pounds of total cobalt consumed, whereas superalloys used about 30%.[6] This shows that when alternative systems are available, as in magnetic applications, consumption rates can be somewhat elastic with respect to cost, but apparently this elasticity does not apply to cobalt use in superalloys. Concerted efforts to replace cobalt-containing with cobalt-free superalloys in some turbine applications have resulted in one reported[10] saving of 65,000 lbs of cobalt in 1979. This is roughly a systems substitution savings of 1%.

Table III lists many of the superalloys used in gas turbine engines. Larger turbine components such as discs are usually made of forgeable (hot workable) nickel-base superalloys rather than the cobalt-base superalloys, which are difficult to work. Thus, even though nickel-base superalloys contain only up to about 19% cobalt while cobalt-base superalloys used in turbines contain up to 65% cobalt, most of the cobalt is in nickel-base superalloys. Accordingly, reducing or eliminating the cobalt content in nickel-base superalloys could substantially reduce the primary demand for cobalt in the U.S.

Table III: Cobalt Content in Sample Superalloys Used in Gas Turbine Engines[11]

Alloy	Cobalt Content, Wt.%
Waspaloy	13.5
Nimonic alloy 90	16.5
Nimonic alloy 115	13.2
Rene 41	11.0
Rene 95	8.0
B-1900	10.0
IN-100	15.0
IN-738	8.5
IN-792	9.0
MAR M200	10.0
MAR M247	10.0
Udimet 500	19.0
Udimet 700	18.5
Udimet 710	15.0

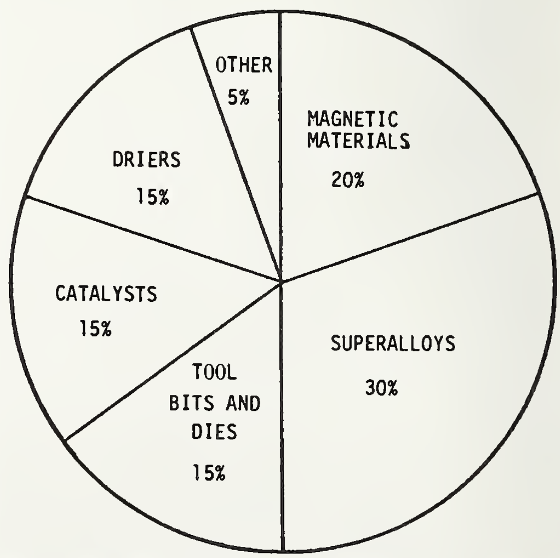

Figure 1. Estimated 1979 U.S. consumption of cobalt (total consumption 20.3 million pounds).[6]

Long-Term Reserves and Resources

The most recent statistics[5] available for world consumption of cobalt show that in 1977 the U.S. accounted for over 37% of world primary demand for cobalt, which totalled 47.8 million pounds. The world primary cobalt demand is forecasted to increase at an average annual rate of about 3.4% to the end of the century. If the U.S. high-technology prominence continues, its primary demand is forecasted to increase at an average rate of 3.3% annually, and to continue to account for about 40% of the total world primary demand. The expected growth in the world demand reflects further development of industries and high technology in Japan, Western Europe and other countries. Production difficulties notwithstanding, it appears that the world's reserves of cobalt (but not its resources) may fast become depleted in the face of increasing global demands.

The identified (and reported) world cobalt reserves and resources are listed in Table I, along with reserve and resource definitions. At present, world cobalt reserves total about 3.3 billion pounds, and almost 31% of that total is in Zaire. New Caledonia, the Philippines, and Zambia also have large reserves, and Cuba and the Soviet Union together have 21% of the reserves. The U.S. stockpiles cobalt, but has no mineral reserves.

At the present rates of mine production, total world cobalt reserves will last for about half a century. If, however, annual mine production increases at a rate that reflects the projected annual increase in world primary consumption (3.4%), then identified reserves will be depleted in about a quarter of a century. If a more conservative cobalt production growth rate is chosen, 2.2% annually, a figure that parallels an estimated global population growth rate, then identified reserves will last 32 years. Of course, unless reserves are replenished by conversion of resources to reserves, by discovery of new ore bodies, or by considerable recycling, cobalt will become a precious metal way before the end of the 32nd year.

Identified world cobalt resources on land can potentially increase identified reserves by a factor of three (see Table I). Cobalt resources total about 9.5 billion pounds. Lateritic ores in Cuba account for about 25% of the resources. Fortunately, the U.S. also has a large cobalt resource (18% of the total). In general, the conversion of resources to reserves depends on economic factors. Price elevations and improved extraction technology can make feasible the mining of low-grade ores currently classified as resources. In the U.S., the extensive cobalt ores classified as resources are basically low-grade ores.

If all currently identified land-based cobalt resources are considered, then at the 1979 rate of mine production, the resources will last over one and a quarter centuries. If, however, cobalt resources are mined at a rate that increases along with the projected increase in world demand (3.4% annually), then the identified land-based cobalt resources will be depleted in half a century. A lower annual increase (2.2%) in mine output would result in virtual exhaustion of output in two-thirds of a century.

The large cobalt resource in the U.S., if entirely utilized, could satisfy U.S. cobalt needs for almost a century at the current rate of consumption. Allowing for increased rates of consumption, the U.S. could still be self-sufficient for about 50 years.

There is also the vast cobalt resource of ocean sea bed nodules. The nodules, typically composed of 35% Mn, 1% Ni, 1% Cu, and 0.35% Co, have been estimated to be a 500 billion pound cobalt resource. Ocean nodules extend the lifetime of our cobalt resources to over 7 thousand years at the current rate of use. Even taking into account an annually increasing consumption rate, total world cobalt resources could last for over two centuries.

Availability — The Problem

Strictly on the basis of global resources, it appears that there is no long-term availability problem if the rich cobalt resources, especially the ocean sources, can be converted to economically feasible reserves. However, economics and technology are not the only considerations in such conversion. For example, ocean mining rights in international waters are currently under active international debate, and many controversial and complex issues still must be settled before significant ocean mining ventures can be undertaken without undue risk by the mineral companies. Indeed, although ocean mining technology has advanced in recent years, it has yet to experience the trials of large-scale and continuous production.

Foreign mineral reliance is not in itself undesirable if the mineral sources are diverse, noninteracting, secure, and elastic to demand. Unfortunately, as discussed earlier, these adjectives do not describe the cobalt situation. On the other hand, international cartel formation by cobalt-producing nations is not likely because the economic driving force for cartel formation may not be strong enough. At $25/lb, the total world trade in cobalt still stands at about $2 billion per year.

Perhaps because of the relatively small market for cobalt, and because it occurs naturally with other metals like copper and nickel, cobalt has by-product status at most producing mines, the exception being Moroccan ores, with a cobalt content of ~1.2%. This general by-product status, in conjunction with current and projected depressed prices for copper and nickel, results in a relatively inelastic situation with respect to cobalt production. This is perhaps the most severe problem governing cobalt supply at this time, since a sudden drastic lowering of production by one major source cannot be easily compensated for by expansions at other sources—unless there are concurrent increasing needs for the associated copper or nickel. This inelasticity in supply is expected to govern even when consumers are willing to pay much higher prices for cobalt.

A mineral availability and pricing problem would be expected to spur efforts to circumvent the problem through elemental or systems substitution. In applications involving other strategic elements, such as chromium, it is known with confidence that the chromium need in the alloys is technically justified. As we will show below, such confidence may not be justified for cobalt in superalloys.

CRITICAL LITERATURE REVIEW

Publications regarding the role of cobalt in superalloys are few.[12-18] This literature, such as it is, is critically reviewed below.

γ' Phase Effect

Nimonic 80A* and 90 differ in cobalt content, the latter having 17 wt.% Co and the former having none. In 1964, Heslop[12] used these alloys to establish that the Ni-Cr-Co matrix has a little less solubility for Al and Ti, which results in a small increase in the volume fraction of the γ' precipitates—the major strengthener in superalloys—and a corresponding increase in the γ' solutionizing temperature. However, in multicomponent complex superalloys, such as those with refractory elements in addition to Cr, Al, and Ti, the influence of Co has not been established. It should be noted that the refractory elements, especially W and Mo, may also reduce Al and Ti solubility in the nickel solid-solution matrix. In fact, the superalloys used in the Soviet Union and China appear to contain more W, Mo, and Nb and far less Co.[14,19,20]

*Inconel, Nimonic, Mar M, René 41, Udimet, and Waspaloy are, respectively, trade names used by the INCO Companies, Martin Marietta Corporation, Teledyne Allvac, Special Metals Corporation, and United Technologies Corporation.

Carbide Phases Effect

The form, morphology, and distribution of carbides, which precipitate at, and strengthen superalloy grain boundaries, have long been known to affect creep and stress rupture as well as fatigue crack initiation and propagation properties.[1] The published information on the effect of cobalt again comes from the comparative study of Nimonic 80A and 90.[12] The conclusion was that cobalt may increase the solubility of carbon in the simpler γ matrix, resulting in fewer carbides.

It was also found that the form of the carbide, i.e., whether M_7C_3 or $M_{23}C_6$ type, can be affected by Co.[18] The carbide situation is often complicated by the presence of the carbide-forming refractory metals. For example, in nickel-base superalloys with Mo and W, the M_6C carbides are the normal type. Some experimental results show cobalt substituting for nickel in the M_6C carbides.[21] Detailed documentation does not exist.

Microstructural Phase Stability Effect

There is some evidence that for long-term service at elevated temperatures, cobalt may influence the microstructural stability of superalloys, especially with respect to formation of the crack-like sigma phase. The role of cobalt on sigma phase formation was studied in Mar-M421. It was found that sigma phase precipitated after long-term aging when there was no Co in this type of alloy, but this susceptibility was eliminated when Co was raised to the 10–30% level.[22] These results were argued through the PHACOMP[23] procedure, in that Co apparently increases the electron-vacancy number for sigma formation. The susceptibility for sigma formation in Inconel 713C, which has no Co, was likewise argued through the electron-vacancy number.[24]

Cobalt need not always be beneficial in terms of microstructural stability since, in René 41 and AF-21D (an Air Force alloy), long-term exposure at elevated temperatures can precipitate another deleterious, topologically closed-packed phase, $(Ni, Co)_7$ $(W, Mo)_6$ or μ phase, in which cobalt participates.[25,26] However, whether Co plays a pivotal role was never established.

Finally, the MAR-M421 study[22] also showed that Co may reduce the coarsening kinetics of γ'. The study by Lund et al.[22] and that by Heslop[12] involving Nimonic 80A and 90 are the major Co studies available in the Western literature.

Solid Solution Strengthening Effect

Heslop also showed, in a limited manner, that Co may decrease the stacking fault energy in Ni-Cr-Co solid solutions,[12] and thereby suppress cross-slip and promote strengthening. However, this interesting study was never pursued in superalloy matrices.

Workability

Again, in a limited way, Heslop showed through hot twist or torsion tests that Co may enhance hot workability. This evidence apparently was generated for the strong Nimonic 115 alloy. However, the evidence was presented without data points. We found no other studies on Co and hot workability of superalloys.

Oxidation and Hot Corrosion Effects

It has been supposed that Co plays a role in improving the oxidation and hot corrosion resistance of nickel-base alloys.[13] However, this conclusion was not based on systematic studies of complex superalloys. In fact, it is often shown that other elements, such as Al and Cr, may play more dominant roles. For example, the oxidation resistance of Co-free Inconel 713C is due to the high Al content.[15] Further, the hot corrosion resistance of Inconel 738 is due to the high Cr content.[1]

Direct Mechanical Properties Information

There has been very little direct experimental investigation of the effect of cobalt on mechanical properties, and no systematic conclusion can yet be drawn. The results of two studies are informative, however. In a Soviet study, it appears that the addition of a substantial amount of Co (at least 10–12%) to a nickel alloy containing Cr, Mo, W, and a fairly high Ti plus Al combined content did not affect the creep properties.[27] In another more recent and more comprehensive study by Mauer et al.,[28] the tensile and stress rupture properties of Waspaloy, a high sales volume alloy, were determined as a function of varying Co content.

At room temperature, reducing the Co content from the normal Waspaloy composition amount (13.5%) to zero by replacing Co with Ni caused only a 4% decrease in the 0.2% yield strength. At 538°C, the Co content had essentially no effect on the 0.2% yield strength. This trend was observed for ultimate tensile strength as well. At room temperature, a small reduction of ~2% was observed as the Co content was reduced from 13.5% to zero. At 538°C, there was little, if any, dependence of the ultimate tensile strength on Co content.

The effect of Co content on the stress rupture of Waspaloy was more significant. At 732°C and 552 MPa, the stress rupture life of Waspaloy changed linearly from about 70 h to about 15 h as the Co content was reduced from 13.5% to zero. It is not known if the cobalt effect on stress rupture increases or decreases with temperature or with applied stress at a constant temperature. The stress rupture ductility was not systematically affected by Co content. Although no fatigue tests were done, it would appear, given the small effect of Co content on tensile properties, that the low cycle fatigue properties of Waspaloy would be little affected by the Co content.

We conclude from survey of the literature that there is no systematic understanding of the role of Co on either the microstructural aspects of nickel-base superalloys known to be important to alloy performance, or directly on the relevant properties themselves. Given this unsatisfying and inconclusive situation, in what follows we seek answers to the questions on the role of Co through an empirical model.

AN EMPIRICAL MODEL OF THE ROLE OF COBALT

Alloy and phase partitioning experimental results and limited information from phase diagrams show that, not surprisingly, Co (atomic number 27) by and large substitutes for Ni (atomic number 28) and therefore rests in the fcc γ phase. However, as with Ni, Co also rests in the γ' precipitate phase.[29,30] A small amount of cobalt may also partition into such minor but important phases as carbide and TCP phases (σ and μ phases, if any).[21,24] How and where Co or any other element partitions basically determines its role in microstructural, chemical, and mechanical behavior. On aspects involving phase stability, such methods as PHACOMP[23,31] and Dreshfield's geometric analysis of phase diagrams[32,33] can predict happenings. However, it is very difficult to calculate γ and γ' compositions in multicomponent alloys, as it is tedious to construct multicomponent phase diagrams.

This information can be obtained empirically, however. Kriege and Baris[29] have published experimental alloy partitioning information for Co for many superalloys, including the leaner Waspaloy and the well-endowed wrought-and-cast alloy Udimet 700. However, no partitioning data exist for different Co levels in any one alloy. Such information is necessary to determine the effect of Co on its own partitioning into the various phases and on its effect on the partitioning of the other key elements, i.e. Al, Ti, C, Ni, and the refractory elements.

Some compiled information does, however, exist in China on empirically determined partitioning ratios in superalloys with levels of zero Co and about 10–17 wt.% Co, and with γ' fractions from about 10–60%.[34] It was found, when the thirty-odd alloys studied were viewed together, that the partitioning ratios (the ratio of the total weight fraction of an element in γ compared to that in γ') of Ni, Ti, and Co in γ and γ', changed with the Co level and also varied monotonically with γ' fraction. For example, the partitioning ratios of Ni and Ti decreased in alloys with higher γ' fraction and with higher Co content (Figures 2 and 3). This implies that more Ni and Ti partition into γ' precipitates in alloys with cobalt than in alloys with no cobalt. In this compilation, no obvious trends were observed for the other elements such as Cr, W, Mo, and Al.

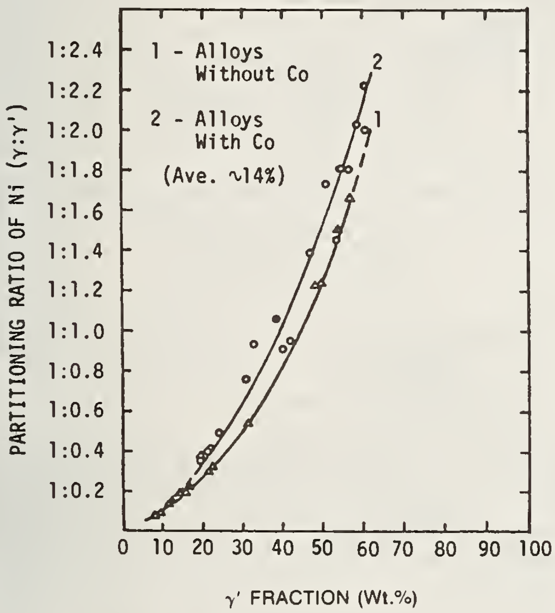

Figure 2. Experimentally determined influence of cobalt and γ' fraction on partitioning ratios of nickel in the γ and γ' phases.[34]

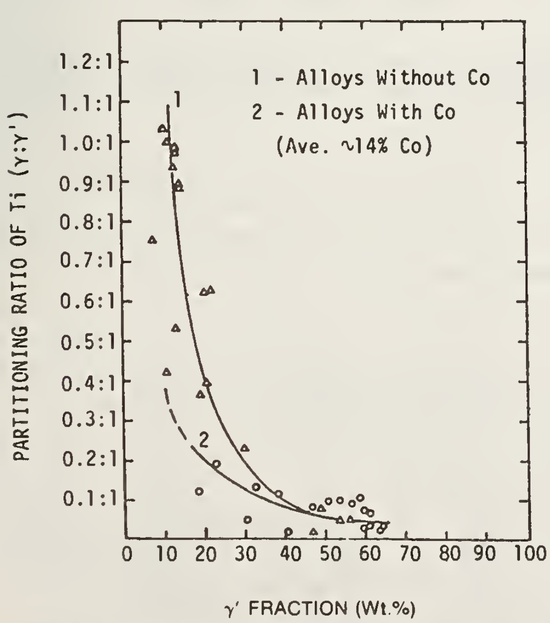

Figure 3. Experimentally determined influence of cobalt and γ' fraction on partitioning ratios of titanium in the γ and γ' phases.[34]

The multiple-matrix results of this study can be applied in a general way through iteration to estimate partitioning effects. The only information needed would be alloy composition and γ' fraction. We decided to undertake such an analysis for the role of Co in sigma-free Udimet 700 and Waspaloy.

Udimet 700 is representative of the stronger class of wrought alloys with a high γ' weight fraction (~45%) and a highly endowed γ matrix. Waspaloy, on the other hand, is typical of the leaner alloys with a lower γ' weight fraction (~19%) and a leaner γ matrix. Both alloys are currently among the higher-volume sales alloys for turbine applications. Udimet 700 is also used in the cast form and, with the appropriate modification, is a candidate powder alloy. Unfortunately, the Co contents in Udimet 700 and Waspaloy are nominally 18.5 and 13.5 wt.%, respectively, (the chemistries of these two alloys are given in Table IV). The partitioning ratios, from Figures 2 and 3, of the major elements in the two alloys, and in the two alloys when Ni is substituted for all the Co on an atomic basis, are also given in Table IV. Partitioning ratios for intermediate Co contents are taken to vary linearly between the values in Table IV.

From simple mass conservation considerations, linear substitution models for lattice parameters,[35] the PHACOMP type procedure[36] and simple strengthening equations,[37,38] and from the chemical compositions of the alloys, one can now estimate the role of Co in γ and γ' composition, γ' fraction, the γ-γ' lattice misfit, σ phase formation potential, and the misfit-modified Orowan strengthening provided by the γ' particles. The results are shown in Figures 4–8. Unfortunately, there are no developed equations relating the chemistries of γ' to anti-phase boundary or ordered strengthening, or to any other mechanical or physical properties, including creep, stress rupture, fatigue, oxidation and hot-corrosion.

It appears that the majority of Co (~95% for Waspaloy and ~72% for Udimet 700) may be in the γ solid solution phase, with the remainder of Co in the γ' phase (~5% for

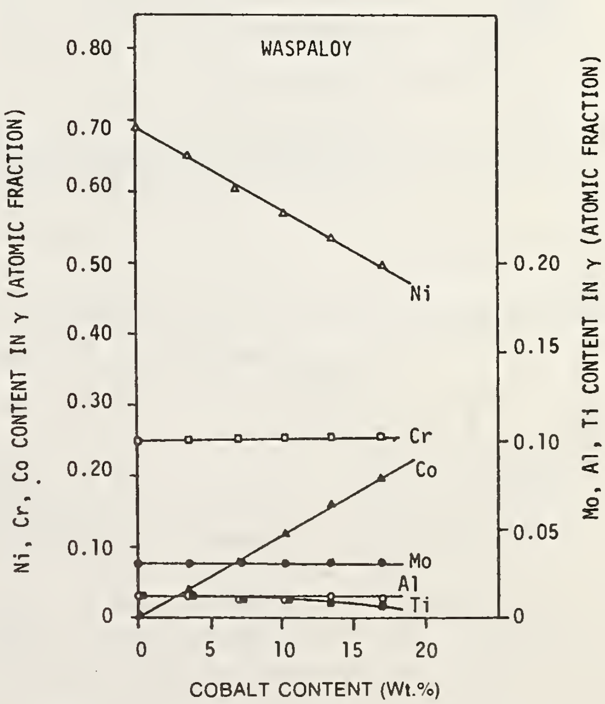

Figure 4. Predicted influence of Co on γ composition in Waspaloy.

Table IV: Calculated Partitioning Ratios of Elements Between γ and γ'

	Co in Alloy, Wt.%	Partitioning Ratios, γ/γ'					
		Ni	Ti	Co	Cr	Mo	Al
Waspaloy	0	1/0.250	0.550/1	0	1/0.039	1/0.040	0.47/1
	13.6	1/0.338	0.238/1	1/0.044	1/0.039	1/0.040	0.47/1
Udimet 700	0	1/1.04	0.07/1	0	1/0.15	1/0.26	0.275/1
	17	1/1.30	0.06/1	1/0.33	1/0.15	1/0.26	0.275/1

Chemical Composition (wt.%) of Alloys Used for Calculations

	Cr	Mo	Al	Ti	Co	C	B	Ni
Waspaloy	19.5	4.3	1.3	3.0	0-13.6	0.05	0.006	bal
Udimet 700	15.0	5.0	4.0	3.5	0-17	0.05	0.025	bal

Waspaloy and ~28% for Udimet 700). Figures 4 and 5 show that in Waspaloy the Co content in both phases increases with increasing Co; simultaneously, the content of Ni in both phases decreases. The same behavior is obtained for Udimet 700. In Waspaloy, Co also lowers the solubility of Ti in the matrix, which results in a predicted slight increase in the γ' fraction in this type alloy with increasing alloy Co content (Figure 6). In Udimet 700, the solubility of Al and Ti in the γ phase is predicted to be only slightly affected, and hence the γ' fraction in the Udimet 700 type alloy with or without cobalt is predicted to be unchanged (Figure 6).

In both superalloys, Co is predicted to increase the γ-γ' lattice mismatch (Figure 7). Accordingly, from the following equation on Orowan-type strengthening modified by the coherency stress field of the γ' phase,[38]

$$\sigma_{CS} = 0.7Gf^{1/2}\,(|\epsilon| b^3/r^3)^{1/4} \qquad b/4|\epsilon| < r < 2b/3|\epsilon| \tag{1}$$

where

G = shear modulus
f = γ' volume fraction
ϵ = γ-γ' mismatch
r = average radius of γ' phase
b = Burgers vector

there can be a positive effect on Co on this component of yield strength (Figure 7). Our calculated results are apparently qualitatively consistent with the aforementioned findings of Maurer et al.[28] on Waspaloy. In the higher strength Udimet 700, APB and not σ_{CS} is expected to determine strength.

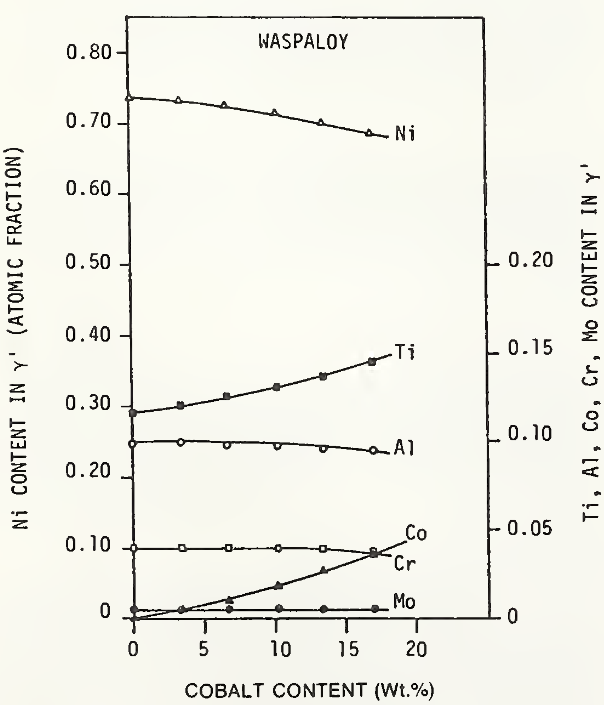

Figure 5. Predicted influence of Co on γ' composition in Waspaloy.

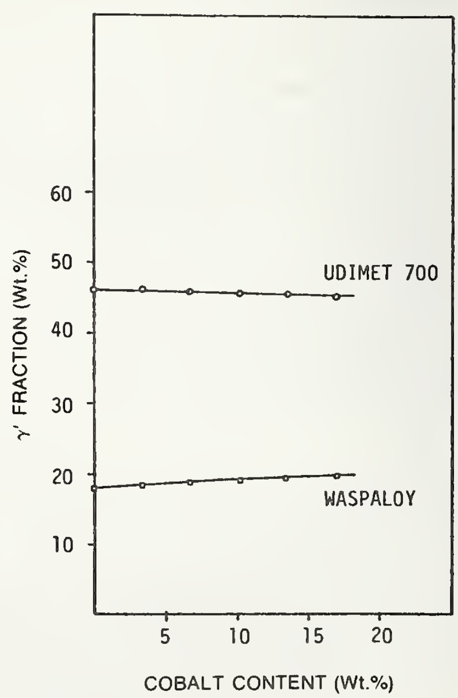

Figure 6. Predicted influence of Co on γ' fraction in Waspaloy and Udimet 700.

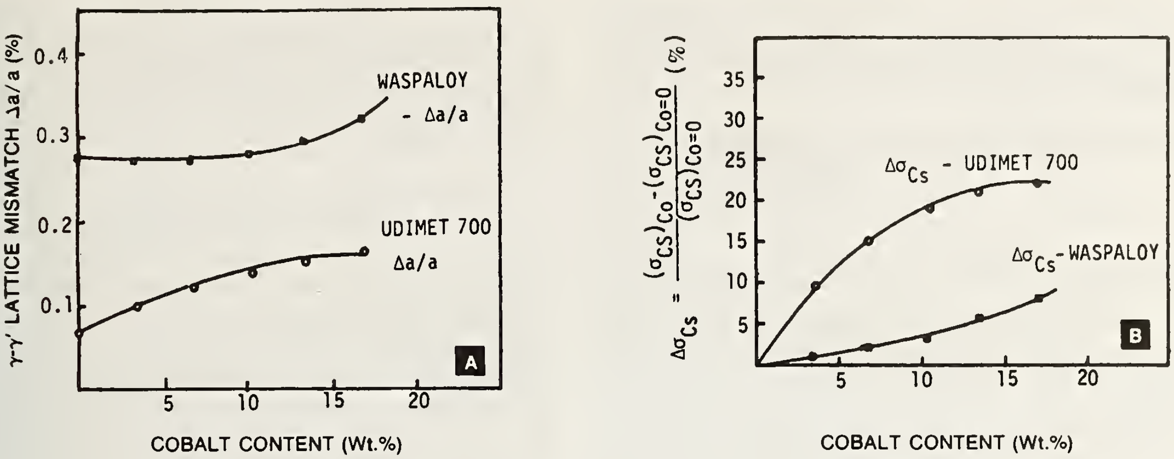

Figure 7. Predicted influence of Co on (A) γ-γ' lattice mismatch, and (B) strengthening by coherency stress field of γ' phase($\Delta\sigma_{Cs}$).

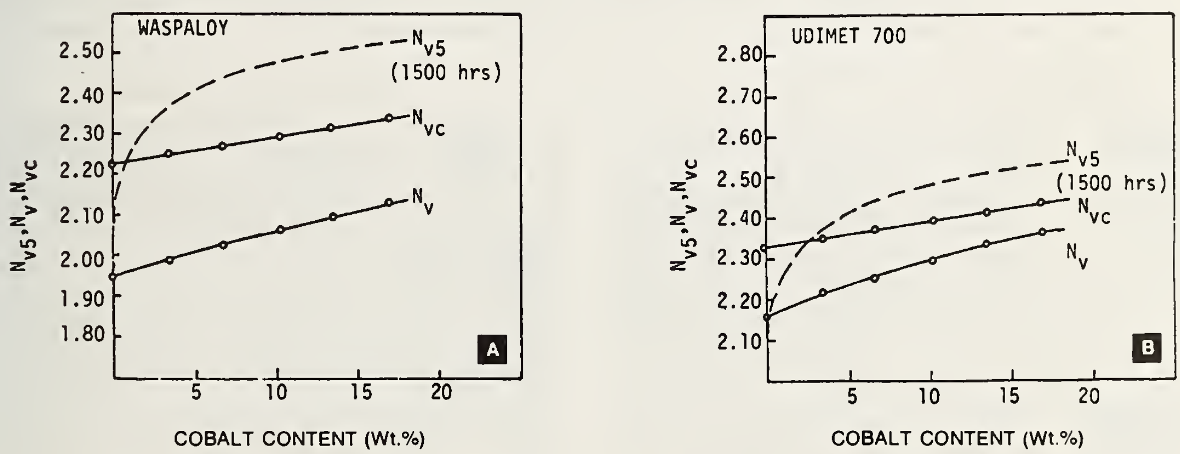

Figure 8. Predicted influence of Co on the σ phase susceptibility in (A) Waspaloy and (B) Udimet 700. If N_{vc}-N_v> O, or N_{vs}-N_v>O, the alloy is not prone to form the embrittling σ phase (see text for parameter identification).

Table V: Relative Effect of Cobalt Content on Creep Rate and Rupture Life

Waspaloy					U-700			
Co%	$\Delta\gamma_s$%	Relative Creep Rate	Relative* Rupture Life	Observed** Relative Rupture Life	Co%	$\Delta\gamma_s$%	Relative Creep Rate	Relative* Rupture Life
0	60.9	8.6	1	~1	0	61.7	100	1
3.4	65.4	5.6	1.25	~1.5	4.6	68.7	48.6	1.4
6.8	69.9	3.5	1.57	~2.1	9.2	75.4	21.1	2.2
10.2	74.4	2	2.1	~2.8	13.8	82.8	6	4.1
13.6	78.9	1	3.0	~3.4	18.4	89.7	1	10
17.0	83.2	0.44	4.4					

* Calculated from $\dot{\varepsilon}^{0.5}t$ = const.
** Cited from experimental creep data of Maurer et al.[28] (732°C, 551 MPa)

The effect of Co on σ_{SH}, the solid solution strengthening component of the yield stress, can be obtained from the following equation which is deduced from the data of Pelloux and Grant[37]:

$$\sigma_{SH} = 0.84 \times 0.024(\text{at\%Co}) + 8.02 \times 0.183(\text{at\%Al}) + 6.99 \times 0.36(\text{at\%Ti}) + 4.93[0.13(\text{at\%Cr}) + 0.421(\text{at\%Mo})] \quad (2)$$

This equation predicts that the effect of Co on the yield stress is not large.

Co rapidly decreases the stacking fault energy γ_s of the γ matrix. This effect can be assessed using the following equation, quoted from Beeston's data[39]:

$$\Delta\gamma_s\% = 2 \times (\text{at\%Cr}) + 1.8 \times (\text{at\%Al}) + 5.83 \times (\text{at\%Ti}) + 1.12 \times (\text{at\%Co}) \quad (3)$$

where $\Delta\gamma_s\%$ is the percentage reduction in γ_s/Gb as compared with pure Ni. If it is assumed that the creep equation

$$\dot{\epsilon} = A\gamma_s^{3.5}D(\sigma/G)^n \quad (4)$$

with $\dot{\epsilon}$ = steady state creep rate
A = constant
D = diffusion coefficient
σ = applied stress
G = shear modulus
n = stress exponent

given by Barrett and Sherby[40] to describe creep in pure metals and solid solutions is applicable to engineering alloys, then using Equations 3 and 4, the relative effect of cobalt content on creep rate can be roughly estimated. The results are shown in Table V, along with calculations of the relative effect of Co on stress rupture life, obtained using $\dot{\epsilon}^{0.5}t$ = const. The calculated relative effect of Co content on rupture life of Waspaloy appears consistent with those found by Maurer et al.[28] Interestingly, we predict (Table V) that the relative effect of Co on creep and stress rupture of the constitutionally more well-endowed Udimet 700 should be greater than that for the leaner Waspaloy. Even though these calculations are qualitative, the result is interesting, for it suggests that an effect of Co on creep in superalloys may be manifested through the effect of Co on the stacking fault energy.

For predicting phase formation we used the method of Barrows and Newkirk,[36] which is based on modifications of previous PHACOMP-type methods[23,31] that involve electron-vacancy correlations. It is presumed that if N_{VC}-N_V>0, the alloy will not be prone to σ phase formation, where:

$$N_{VC} = \sum_i f_i^a(N_{VC})_i \qquad N_V = \sum_i X_i(N_V)_i \quad (5)$$

where

N_{VC} = critical electron-vacancy concentration for γ residual matrix
f_i^a = atomic fraction of element i in the A-element group (where A elements are Cr, Mo, W, V, Nb, Ta, Ti, Zr)
$(N_{VC})_i$ = critical electron-vacancy concentration for pure A-element i
N_V = average electron-vacancy concentration of γ residual matrix
X_i = atomic fraction of element i in the γ residual matrix
$(N_V)_i$ = electron-vacancy number of element i.

Our calculations using these equations show that decreasing Co in both types of superalloys does not appear to influence the structural stability (Figure 8). However, if instead of N_{VC} we use the parameter N_{V5}, as done by Lund et al.[22] for the MAR-M421-type alloys, where

$$\log N_{V5} = (0.0389 + 0.8012/t)\log Co + 0.3553 \quad (6)$$

and t is the long-time exposure in hours, then the prediction is that a possibility of σ phase formation exists only at very low Co levels (Figure 8).

In summary, then, it appears that the empirically-based calculations do result in information that adds to the scant knowledge base on the role of cobalt. The calculations show that Co may effect the partitioning behavior of elements other than Ni (such as Ti), but that this effect appears to have only a small influence on the γ' volume fraction. Co is predicted to increase the γ-γ' lattice mismatch and to thereby affect the yield strength. The Co content is predicted to influence the creep and stress rupture behavior of superalloys, mainly through the effect of Co on the stacking fault energy. Finally, the structural stability is not affected by Co content if the parameter N_{VC} is used; but if the parameter N_{V5} is used then the possibility of structural instability is predicted at low Co levels.

CONCLUDING REMARKS

From our literature survey and the predictive calculations, it appears that (1) systematic information on the role of cobalt in nickel-base superalloys is scanty and not at all comprehensive, and (2) the role of cobalt may not be pivotal, particularly for superalloys less well-endowed with γ', in that superalloys may not require the present levels of cobalt to deliver acceptable performance. However, this last statewhich is itself based on minimal empirical information. Accordingly, systematic research must be undertaken to reassess the necessity of cobalt as an alloying element in superalloys, especially in nickel-base superalloys.*

The substitution of nickel or other elements for cobalt in superalloys could result in a 10% or more reduction in the total U.S. yearly demand for cobalt.[41] As discussed in some detail in this paper, the U.S. is currently 90% reliant on imported cobalt, and current foreign cobalt sources are neither diverse, secure, nor elastic with respect to changes in demand. Furthermore, global cobalt reserves are limited, and conversion to reserves of the world's rich cobalt supply, especially from ocean nodules, awaits international settlement of ocean mining rights as well as further technological developments.

ACKNOWLEDGEMENTS

We are grateful to Teri Huebner for her efforts in the search for cobalt availability information. For enlightening discussions, we thank Drs. John Pridgeon, Steve Reichman, William Boesch, Gern Maurer, Larry Jackman, and John Domingue of Special Metals Corporation, Professor John Radavich of Purdue University, and Drs. Joseph Stephens, Robert Dreshfield, Hugh Gray, and Tom Glasgow of the National Aeronautics and Space Administration at Lewis Field. We are indebted to Dr. Robert Hall of NASA-Lewis for his constructive criticisms which resulted in the section in this paper dealing with the analytical derivations of the role of cobalt.

*At press time, it was learned that under NASA-Lewis sponsorship Columbia University, Purdue University, Special Metals Corp., and NASA itself will undertake a research program to clarify the role of cobalt in superalloys.

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NASA's ACTIVITIES IN THE CONSERVATION

OF STRATEGIC AEROSPACE MATERIALS

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E-623

ABSTRACT

NASA has several activities underway directed at conserving strategic materials used in the aerospace industry. Research efforts involving universities and industry as well as in-house activities at the NASA-Lewis Research Center comprise the current program. These initial research efforts are preparatory to an anticipated much broader program focusing on the "Conservation of Strategic Aerospace Materials - COSAM." The primary objective of the COSAM Program is to help reduce the dependence of the United States aerospace industry on strategic metals, such as cobalt, columbium, tantalum, and chromium, by providing the materials technology needed to minimize the strategic metal content of critical aerospace components with prime emphasis on components for gas turbine engines. Thrusts in three technology areas are planned for the COSAM Program, including near-term activities in the area of strategic element substitution; intermediate-range activities in the area of materials processing; and long-term, high-risk activities in the area of "new classes" of high temperature metallic materials. This paper describes in some detail the projects currently underway and initial results generated to date. Initial emphasis has been placed in the area of strategic element substitution. Specifically, the role of cobalt in nickel-base and cobalt-base superalloys vital to the aerospace industry is being examined in great detail by means of cooperative university-industry-government research efforts. Investigations are also underway in the area of "new classes" of alloys. Specifically, a study has been undertaken to investigate the mechanical and physical properties of intermetallics that will contain a minimum of the strategic metals. Current plans for the much larger COSAM Program also are presented in this paper.

INTRODUCTION

The United States is heavily reliant upon foreign sources for the supply of most strategic metals required by our aerospace industry. With the exception of molybdenum, iron, magnesium, and the rare earths, the United States imports from 50 to 100 percent of such aerospace metals as Co, Cb, Ta, Cr, and Mn (ref. 1). However, the potential for foreign cartels, political unrest, and production limitation is great and is intensified by steadily declining known reserves. Thus, the United States can expect to be faced with supply shortages and price escalation for many strategic metals. Since these metals are vital to the welfare of the nation's economy, their continued availability at a reasonable cost is a national issue which requires cooperative action between the aerospace industry and appropriate government agencies.

The aerospace industry is currently a major factor in the positive inflow of funds from U.S. exports (ref. 2). This industry, and within it the aircraft engine industry in particular, relies heavily upon imports for several key strategic metals including cobalt, columbium, tantalum, and chromium. In order to offset or minimize future disruptions in supply, efforts to develop viable options must begin now, since a new material can take from 5 to 10 years of research and development efforts before qualifying for aerospace service.

NASA currently plans to take a leading role in addressing the aerospace industry's needs to minimize the use of strategic metals for advanced aerospace systems. The materials technology program now being planned by NASA is designated COSAM - Conservation of Strategic Aerospace Materials. The COSAM program has as its broad objective the reduction of the dependence of the U.S. aerospace industry on strategic metals. This objective will be accomplished by providing the materials technology options needed to allow individual companies to trade-off the material properties of critical components versus cost and availability of their strategic metal content. This paper will summarize NASA's current Pre-COSAM activities and broadly outlines the planned COSAM Program.

STRATEGIC METALS

As the basis for what are considered strategic metals, we will focus on the aircraft engine industry's needs. Based on discussions with several aircraft engine manufacturers, four elements emerged that were of particular concern. The alloys used to build the critical high temperature components for aircraft propulsion systems require the use of the four metals - cobalt, columbium, tantalum, and chromium. These metals are contained in steels, stainless steels, and superalloys that are used in engine manufacturing. The location of these metals in aircraft engine compressors, turbines, and combustors is illustrated in figure 1. The need for such metals has increased as the demands have grown for higher durability plus higher performance, fuel efficient aircraft turbine engines. Based on the essential nature of these metals and for the U.S. aircraft industry to maintain its competitive position, it is necessary that supplies be readily available at a reasonably stable cost. To achieve these requirements, domestic sources of key metals are desirable. However, the U.S. has never been self-sufficient in these metals. Today, we are almost totally dependent on foreign sources for these metals as shown in figure 2. In several of the countries listed in figure 2, recent political disturbances have led to supply interruptions. Therefore, the U.S. aircraft engine industry can be seen to be highly vulnerable to supply instabilities of the essential metals for engine manufacturing. Accompanying supply disruptions or increased demand is an accelerated price increase. Escalated prices during the recent few years are evident for tantalum, columbium, cobalt, and to a lesser degree for chromium, as shown in figure 3. These rapid price increases illustrate the vulnerability of the U.S. aircraft engine industry to cost fluctuations. The essential nature of cobalt, columbium, tantalum, and chromium along with their vulnerability to supply instabilities and cost fluctuations combine to cause these metals to be classified as strategic aerospace metals.

OVERVIEW OF THE COSAM PROGRAM

The COSAM Program has as its primary objective the reduction of the dependence of the U.S. aerospace industry on strategic metals. The COSAM Program will further provide the industry with options for making their own property versus availability/cost trade-offs when selecting aerospace alloys. These objectives will be achieved by providing the technology needed to minimize the strategic metal content of critical components in aerospace structures. Initial emphasis will be placed on the aircraft engine industry. The program will initially focus on conservation of the strategic metals cobalt, columbium, tantalum, and chromium. Strategic metals such as titanium, the precious metals, tungsten, and others may be brought into the COSAM Program as it progresses. A three-pronged approach is planned as shown in figure 4, and will consist of strategic element substitution, process technology, and alternate materials. Conservation, as well as reduced dependence on strategic metals, will be achieved in the area of strategic element substitution by systematically examining the effects of replacing cobalt, columbium, and tantalum with less strategic elements in current, high use engine alloys. This will help guide future material specifications if one or more of these metals becomes in short supply. Conservation through process technology will be achieved by advancements in those net-shape and tailored-structure processes that minimize strategic material input requirements. This will lower total usage. And in the longer term, development of alternate materials that replace most strategic metals with those highly available in the U.S. could lead to a substantial reduction in the U.S. dependence on foreign sources. Both of the later two technology areas will help conserve the four strategic metals Co, Cb, Ta and Cr.

PRE-COSAM ACTIVITIES

The COSAM Program has been proposed to begin in FY 1982, i.e., in October 1981. Thus, efforts on planning and organizing the program are currently underway. In addition to the planning activities, several small research activities have already been initiated. These research activities will dovetail in a logical fashion into the proposed COSAM Program. These research activities focus on two of the three major thrusts of the COSAM Program - strategic element substitution and development of alternate materials. Special emphasis of these initial efforts is on developing a fundamental understanding of the role of strategic elements in current aircraft engine alloys so that effective alloying element substitution can be conducted. Similarly, in the development of alternate materials, a basic understanding of materials properties and alloying concepts is being emphasized. Consequently, university grants play a major part in the Pre-COSAM projects. In addition, cooperative programs with industry augmented by in-house research at the NASA-Lewis Research Center comprise the approach used in these initial projects. This cooperative approach will be carried into the COSAM Program where industry, university, and government in-house research will each play a key role. The subsequent paragraphs will describe in some detail the Pre-COSAM research efforts.

<u>Strategic element substitition</u>. - Four metals were mentioned previously as being classified as strategic metals. Cobalt was selected from these four metals for the Pre-COSAM strategic element substitution research. The basis

for selecting cobalt was twofold. First, the largest single use of cobalt in the U.S. is in superalloys for jet engine applications. Figure 5 illustrates that about 30% of cobalt goes into the production of superalloys (ref. 3). Many of the other applications indicated in figure 5 are also important to the nation's economy and security as well. Secondly, the specific roles that cobalt plays in nickel-base superalloy fabrication and performance has not been clearly established. Most superalloys currently in use were developed at a time when cobalt was plentiful and inexpensive. Literature results (ref. 4) are conflicting as to the role that cobalt plays in nickel-base superalloys in important areas such as phase stability, γ' partitioning, strength, fabricability, and oxidation and hot corrosion resistance. Because of these uncertainties, there exists a strong possibility that the strategic element cobalt can be substantially reduced or possibly eliminated from several superalloys without sacrifice of the key properties for which these alloys were selected for engine service.

Four nickel-base and one cobalt-base superalloys have been selected for the Pre-COSAM investigation. The five alloys are listed in figure 6 along with their typical applications in the aircraft engine industry, the forms in which the alloys are used, and remarks as to why they were selected for the Pre-COSAM activity. Applications include turbine disks, low pressure blades, turbine blades, and combustors. A variety of product forms are represented by the applications of the five alloys as noted in figure 6. The selection of the five alloys was based primarily upon the considerations given in this figure. Waspaloy* was selected because it represents the highest tonnage of cobalt in commercial aircraft engines. Selection of Udimet-700* was based on the fact that this alloy is used in the as-cast, as-wrought ingot, as-wrought powder, and as-HIP powder metallurgy fabricated conditions. The potential for determining the impact of cobalt on both conventionally-cast as well as on single crystal turbine blades was the reason for selecting MAR-M247*. Rene' 150* was chosen because it is one of the most advanced directionally solidified alloys. The wrought, sheet alloy HA-188* was selected because it represents one of the largest uses of a cobalt-base alloy in aircraft engines.

The primary purpose of the cobalt strategic element substitution research is to determine the fundamental role of cobalt in a wide variety of nickel-base superalloys and in a high-use cobalt base superalloy. A secondary purpose is to develop the methodology to explore the roles of other strategic elements in similarly chosen alloys so as to have maximum impact on a wide range of users.

Figure 7 shows the participants in the Pre-COSAM activities on cobalt strategic element substitution. These initial research efforts are planned for a three-year period and consist of cooperative programs involving universities, industry, and NASA-Lewis Research Center. Nominal compositions of the

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*Trademarks

Waspaloy	United Technologies Corporation
Udimet	Special Metals Corporation
Mar-M	Martin Marietta Corporation
Rene'	General Electric Corporation
HA	Cabot Corporation

five alloys given in figure 7 indicate that cobalt content ranges from 10% in Mar-M247 to 39% in HA-188. In addition the γ' phase ranges from 20% in Waspaloy to 65% in Rene'-150. The first phase in each research effort will involve substituting the less strategic element, nickel, for cobalt in incremental steps to a zero cobalt content. The effects of this substitution on properties and phases present, such as γ', will make-up the major portion of the research effort in the first year of each program element. Efforts in subsequent years will be directed at identifying and optimizing alloying elements as substitutes for cobalt in the five alloys so as to maintain the key properties of these alloys.

The cooperative nature of the research being conducted on Waspaloy and Udimet-700 is illustrated in figure 8. The role of industry as represented by Special Metals Corporation is outlined. Their primary role is to characterize and optimize fabrication and heat treating procedures for the reduced cobalt Waspaloy and Udimet-700 alloys. The university role in this effort is also shown in figure 8. Columbia University will be involved with mechanical property characterization, structural stability, microstructural features, and theoretical formulations to identify future alloy modifications if required for the second phase of the project. Purdue University will be primarily responsible for microstructural and microchemistry characterization of the reduced cobalt content alloys. To round out the program, NASA-Lewis Research Center will be involved in further mechanical and physical metallurgy characterization of the alloys as shown in figure 8. The output of this cooperative effort is expected to be a clearer understanding of the role of cobalt in nickel-base superalloys.

Some preliminary results on the effects of reducing cobalt in Waspaloy, a 13% cobalt alloy, are shown in figure 9 (ref. 5). Tensile strength appears to be insensitive to the amount of cobalt in the alloy. However, rupture life decreased with decreasing amount of cobalt in Waspaloy. Further testing will be required to better characterize this apparent effect.

The research efforts on MAR M247 and Rene' 150 parallel the previously described efforts on Waspaloy and Udimet-700. It is anticipated that these projects will lead to an understanding of the fundamental role of cobalt in a variety of conventional and directional nickel-base superalloys. These results should provide an improved technical base to develop modified superalloys in the proposed COSAM Program.

Alternate Materials. - Research in this area must be considered to be high risk and long range, but it has the potential of a high payoff in terms of significantly reducing the nation's dependence on strategic materials. As an example of alternate materials, intermetallic compounds are currently being investigated for possible structural applications. Initial efforts are centered on nickel and iron aluminides. Successful development of this type of alternate material offers the possibility of partially or totally replacing all the strategic materials in components where intermetallic compounds can be utilized.

Intermetallic compounds are of interest because of their potential high temperature strength as shown in figure 10 (ref. 6). It can be seen in this figure that nickel aluminides have the strength capability of competing with current nickel-base alloys. However, a possible disadvantage of this type of material is that simple binary aluminide compounds have shown a lack of room temperature ductility (fig. 11). The factors which influence the high ductile-to-brittle transition temperature of nickel aluminide (~600 + ^{o}C) are currently being investigated as part of the Pre-COSAM activities. A NASA grant with Dartmouth University is aimed at understanding the fundamental deformation mechanisms in nickel aluminide. From these investigations, methods of improving the low temperature ductility of nickel aluminide may be suggested. An accompanying in-house research project at NASA-Lewis Research Center is focusing on the high temperature mechanical properties of aluminides. These Pre-COSAM studies will provide a fundamental basis for more extensive research to develop these nonstrategic, alternate materials in the COSAM Program.

COSAM PROGRAM

The proposed COSAM Program is intended to build on the fundamental understanding from the early research for cobalt substitution, as shown in figure 12. Major efforts will be devoted to developing, and if warranted, to scaling-up low or no-cobalt nickel base superalloys for fabrication into various components, and with demonstration of continued promise, to verification in engine tests. Similar efforts will also be conducted for other strategic metals such as columbium and tantalum.

In the area of alternate materials, much more work will be required to develop materials such as intermetallic compounds. As shown in figure 13, initial efforts will focus on fundamental studies aimed at improving low temperature ductility and high temperature strength of FeAl and NiAl intermetallics. Complete property characterization will follow on more promising compositions. Reiterations of these basic steps will be required to further optimize the alternate materials and make them viable candidates as structural materials for aircraft engines. Scale-up and rig testing of promising compositions for blades and vanes will follow. The development of alternate materials will help conserve the strategic metals Co, Cb, Ta, and Cr.

The third area of the proposed COSAM Program involves conservation through improved materials processing technology. Although none of these activities are now underway in the Pre-COSAM effort, they will play a major part in the COSAM Program. Contemplated areas of research are shown in figure 14. Conservation of strategic materials will be achieved from initial melting practices, through component fabrication, and recycling of serviced components. An example of one method of processing technology is tailored fabrication which utilizes strategic metal containing alloys only where required. Figure 15 illustrates the critical placement of strategic metals where conservation of these strategic metals is achieved by using low strategic metal alloys in less critical areas. Technology development requirements will include near-net-shape castings, high temperature joining methods, and repair welding methods. Following component fabrication development and characterization, engine verification will be undertaken. Similar programs are anticipated for other materials processing programs. For example, early efforts on near-net-shape fabrication of a turbine disk (ref. 7) have been shown to be able to reduce input material weight compared to conventional casting/forging practice and further gains appear possible. Processing technology will help conserve the strategic metals Co, Cb, Ta, and Cr.

SUMMARY

This paper has presented NASA's planned COSAM Program and described some of the Pre-COSAM activities that are currently underway. The primary points made about this program are summarized below:

1. Advancements in materials technologies are needed to provide the aerospace industry with alternative materials options in the event of future strategic metal shortages or excessive price increases.

2. The primary role of NASA through its proposed COSAM Program will be to address strategic material problems within the aerospace industry, but the COSAM Program should make contributions to a national data base that will benefit many other domestic industries.

3. The COSAM Program is constructed so as to involve cooperative research efforts in industry from alloy producers, component fabricators, and engine manufacturers along with universities and government research facilities (primarily the Lewis Research Center).

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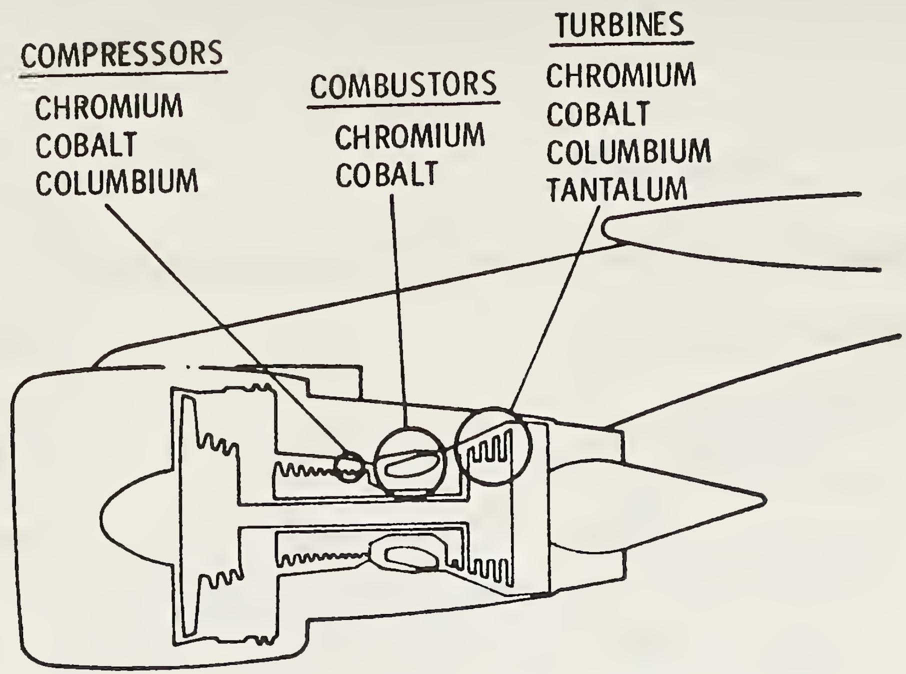

NEEDED FOR PERFORMANCE AND LONG LIFE

COBALT — HIGH TEMPERATURE STRENGTHENER
COLUMBIUM — INTERMEDIATE TEMPERATURE STRENGTHENER
TANTALUM — OXIDATION RESISTANCE
CHROMIUM — CORROSION RESISTANCE

Figure 1. - Current gas turbine engines depend on strategic metals for several major components.

METAL	% IMPORTED	MAJOR FOREIGN SOURCE
COBALT	97	ZAIRE
COLUMBIUM	100	BRAZIL
TANTALUM	97	THAILAND
CHROMIUM	91	SOUTH AFRICA, ZIMBABWE

Figure 2. - Import dependence and major sources of selected strategic metals.

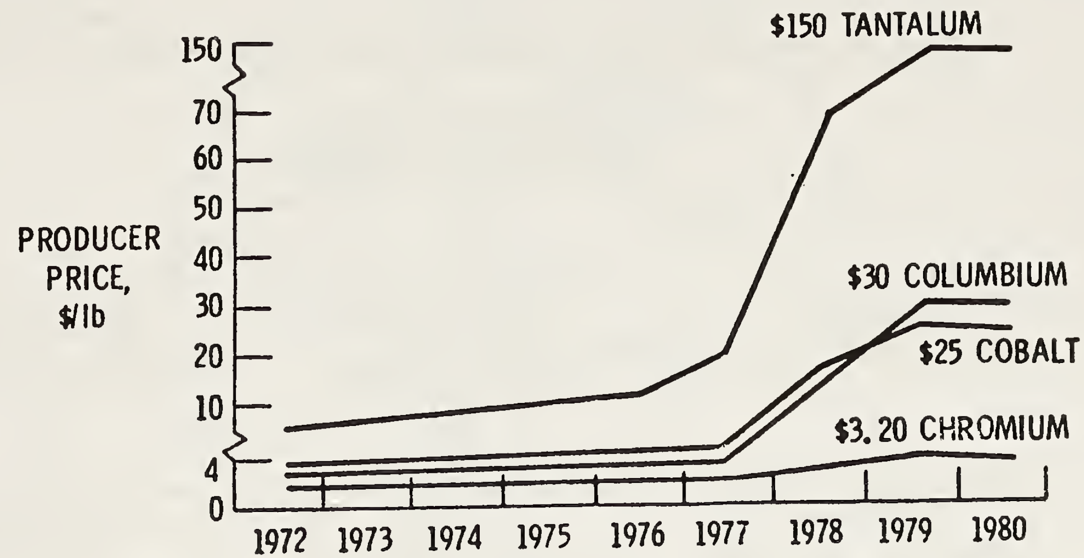

Figure 3. - Cost increase of selected strategic metals over past nine years.

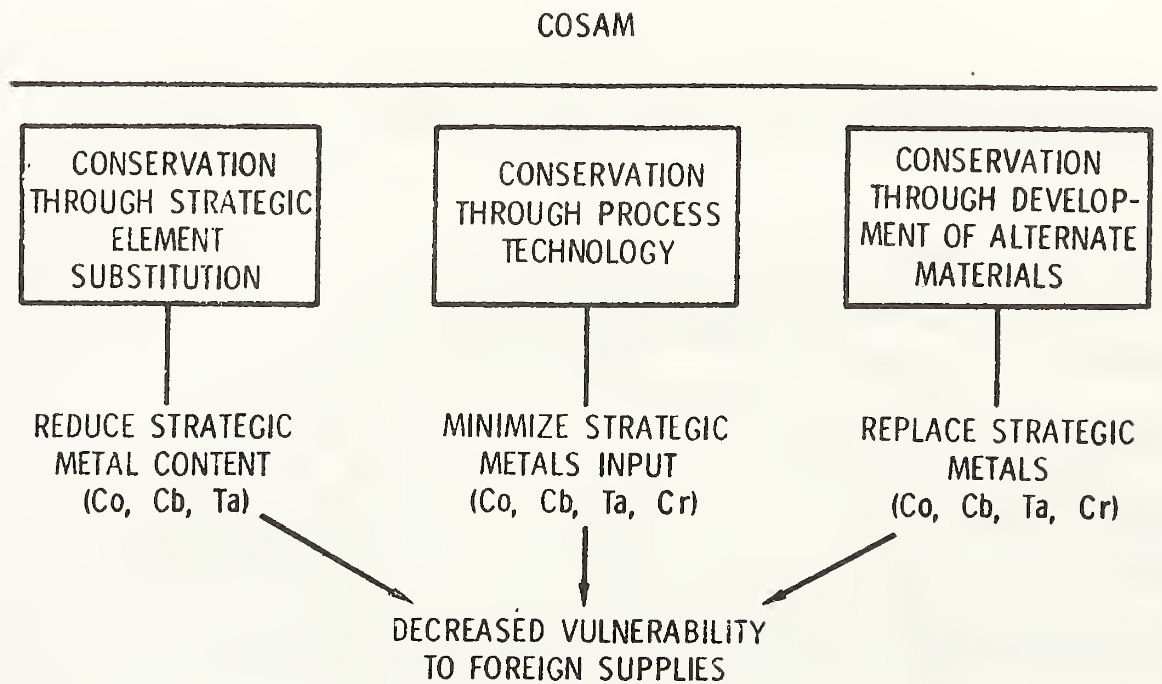

Figure 4. - Conservation of strategic aerospace materials through three major thrust areas.

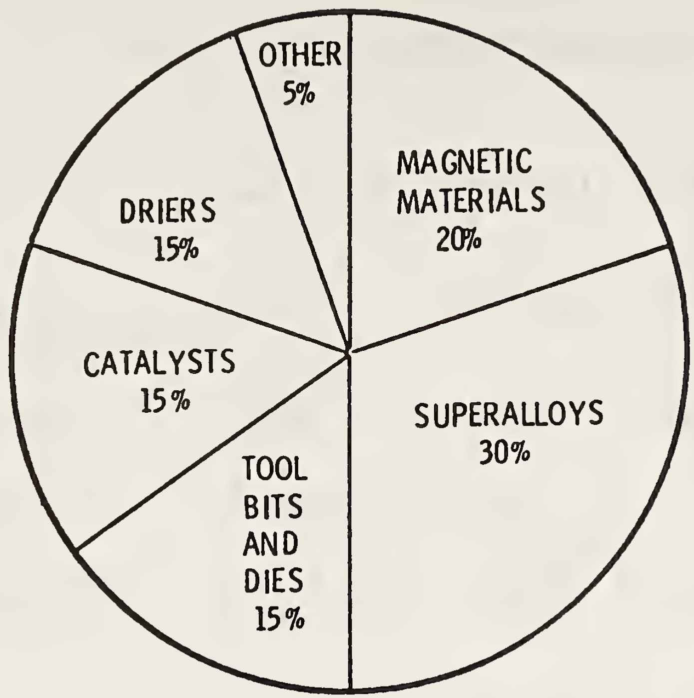

Figure 5. - Distribution of United States 1979 consumption of cobalt (20.3 million pounds total consumption).

ALLOY	TYPICAL ENGINE APPLICATION	FORM	REMARKS
WASPALOY	TURBINE DISK	FORGED	HIGHEST USE WROUGHT ALLOY IN CURRENT ENGINES
UDIMET-700	TURBINE DISK	FORGED	SIMILAR ALLOYS USED IN VARIOUS FORMS AND APPLICATIONS
(LC) ASTROLY	TURBINE DISK	AS-HIP-POWDER	
(RENÉ 77)	LP BLADES	CAST	
MAR-M247	TURBINE BLADES	CAST	CONVENTIONALLY-CAST AND SINGLE CRYSTAL
RENÉ 150	TURBINE BLADES	DS-CAST	HIGHLY COMPLEX DIRECTIONALLY-CAST ALLOY
HA-188	COMBUSTORS	WROUGHT	HIGH USE COBALT-BASE SHEET ALLOY.

Figure 6. - Superalloys selected for pre-COSAM activities.

PARTICIPANTS	ALLOY	NOMINAL COMPOSITION										γ' CONTENT
		Ni	Cr	Co	Mo	W	Ta	Re	Al	Ti	Hf	
COLUMBIA UNIV. PURDUE UNIV. SPECIAL METALS NASA-LEWIS	WASPALOY	58	20	13	4	--	-	-	1.3	3	---	20%
COLUMBIA UNIV. PURDUE UNIV. SPECIAL METALS NASA-LEWIS	UDIMET-700	53	15	19	5	--	-	-	4.3	3.5	---	40%
CASE WESTERN RESERVE UNIV. TELEDYNE NASA-LEWIS	MAR-M 247	60	8	10	.6	10	3	-	5.5	1	1.4	55%
NASA-LEWIS	RENE' 150	59	5	12	1	5	6	3	5.5	---	1.5	65%
(TBD)*	HA-188	22	22	39	---	14	-	-	---	---		---

Figure 7. - Elements of pre-COSAM activities.

*TO BE DETERMINED.

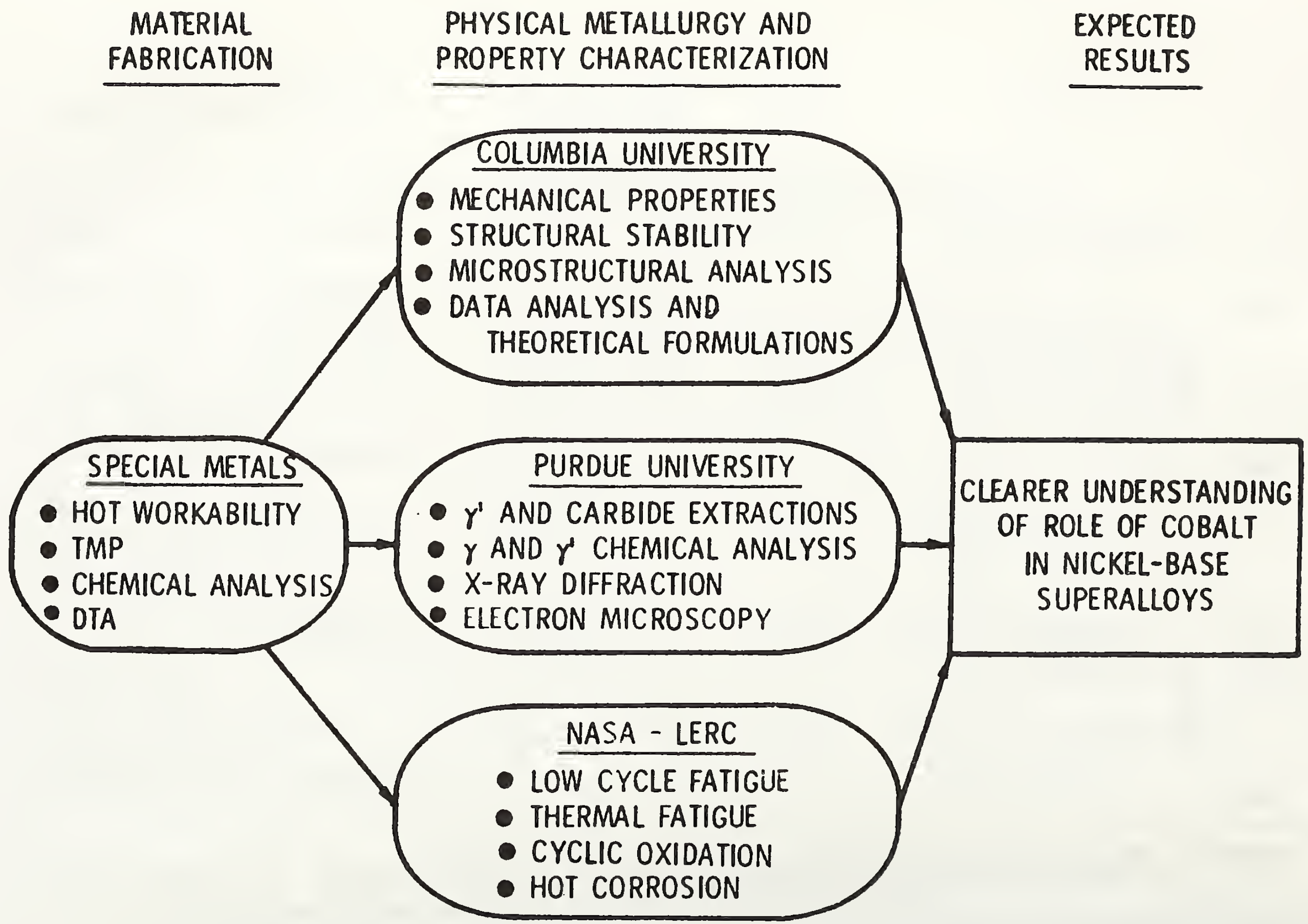

Figure 8. - Cooperative program to determine fundamental role of cobalt in WASPALOY and UDIMET-700.

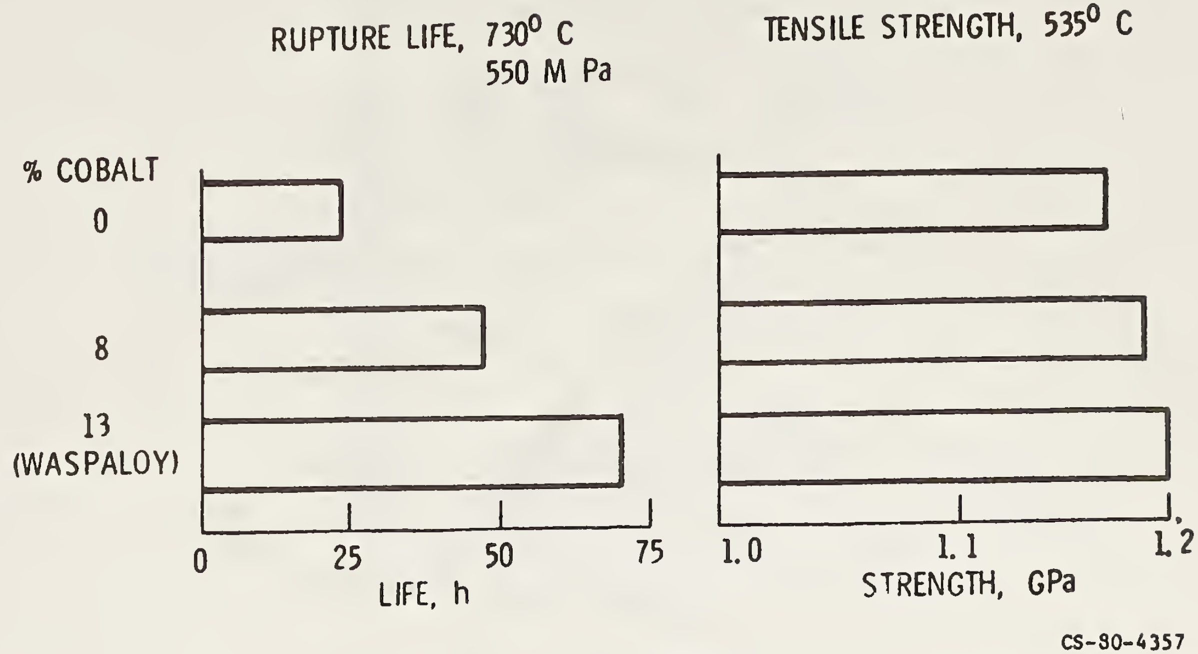

Figure 9. - Effect of cobalt content in WASPALOY on rupture life and tensile strength.

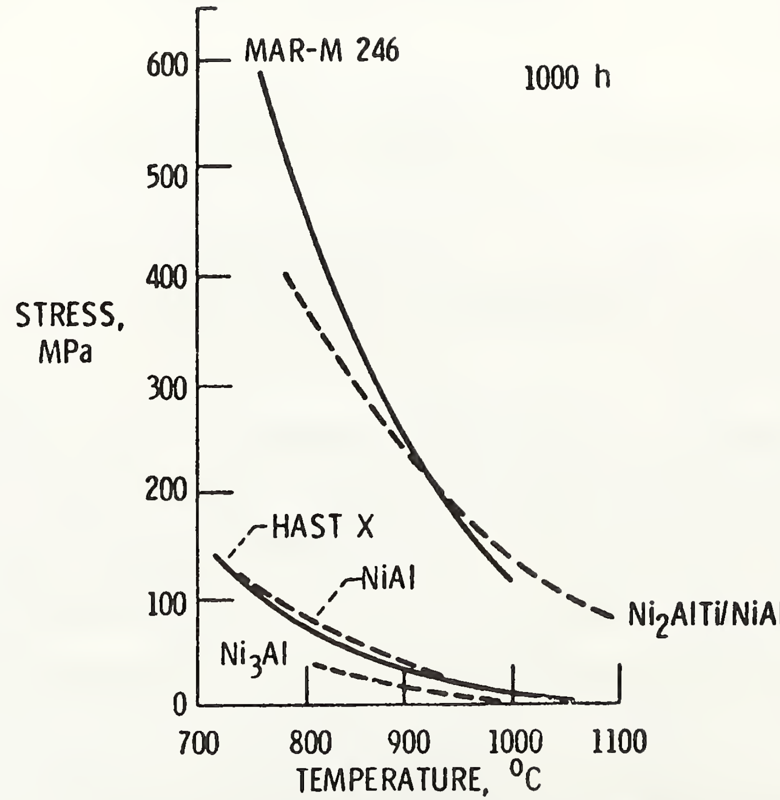

Figure 10. - Comparison of typical 1000-hour rupture strengths of aluminides and superalloys.

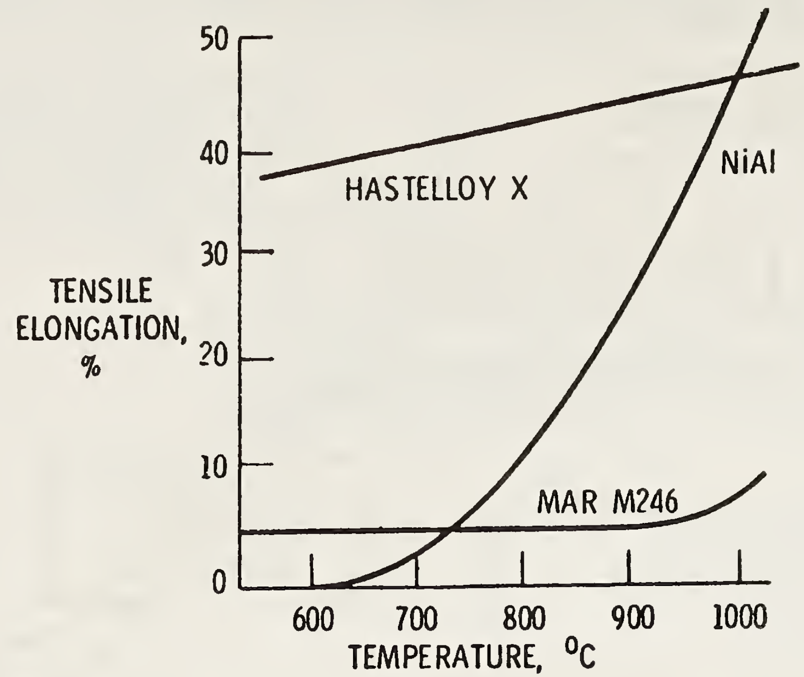

Figure 11. - Effect of test temperature on ductility of aluminides and superalloys.

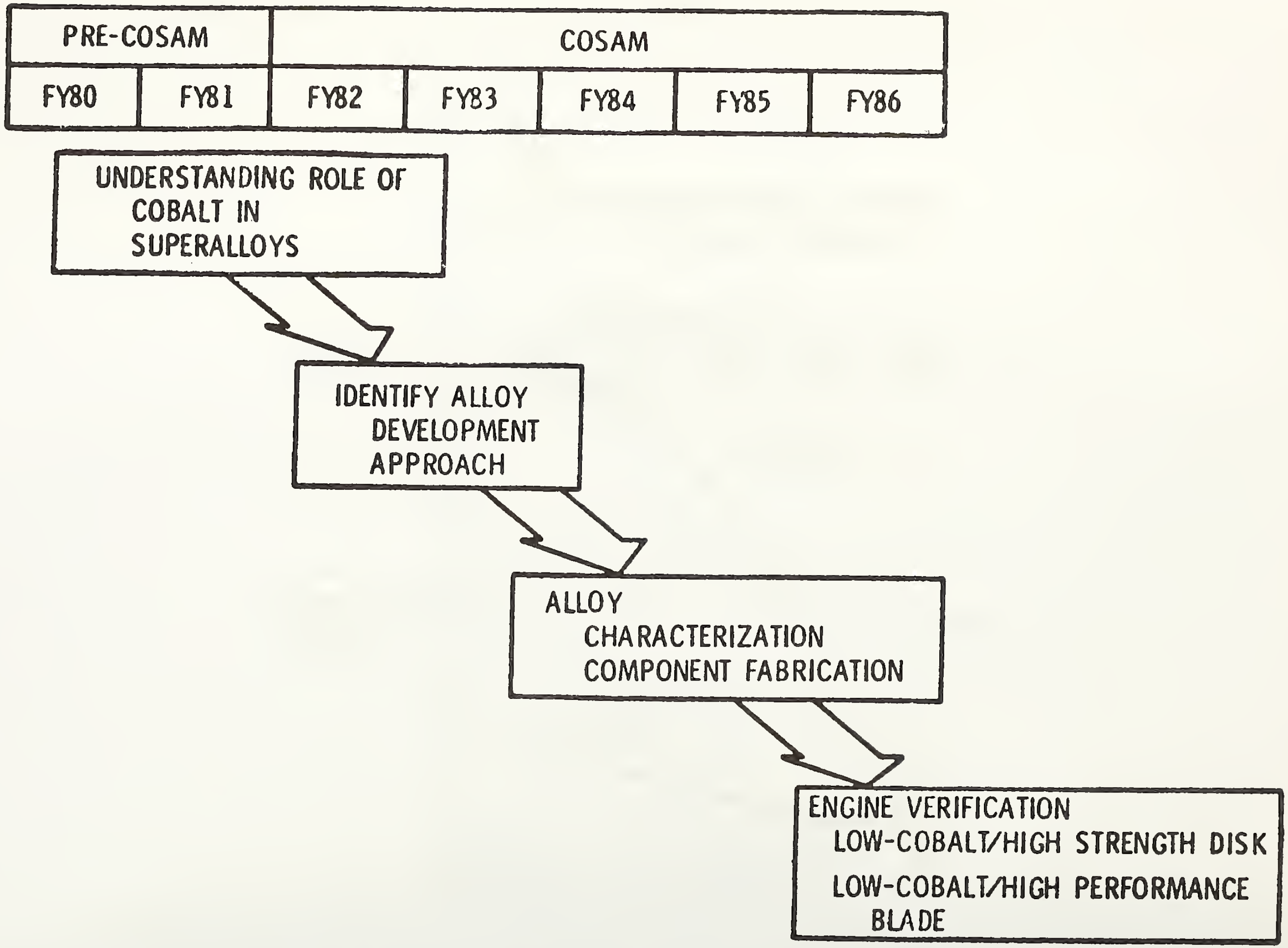

Figure 12. - Relation of pre-COSAM and COSAM programs. Cobalt conservation by strategic element substitution.

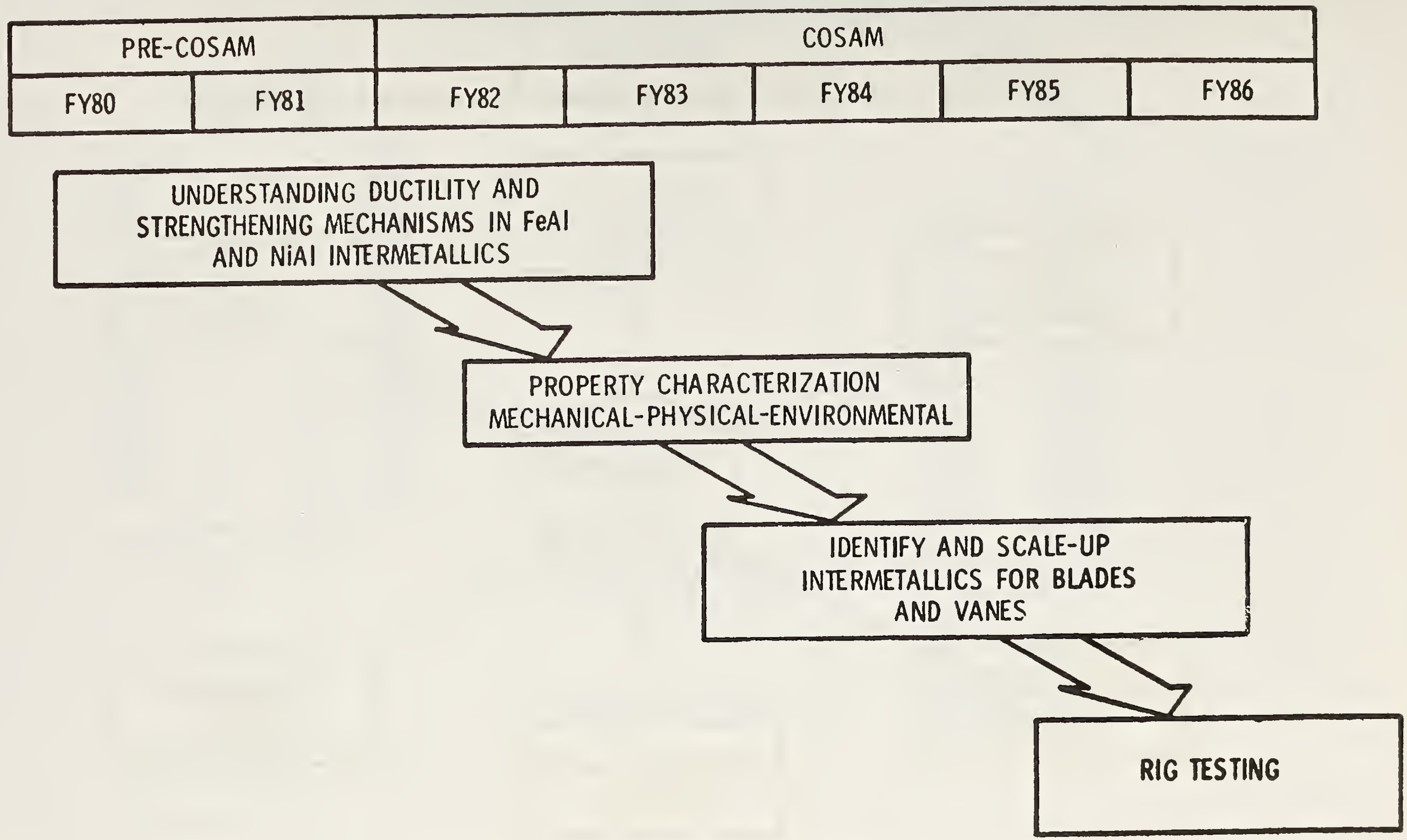

Figure 13. - Strategic metal conservation through development of alternate materials.

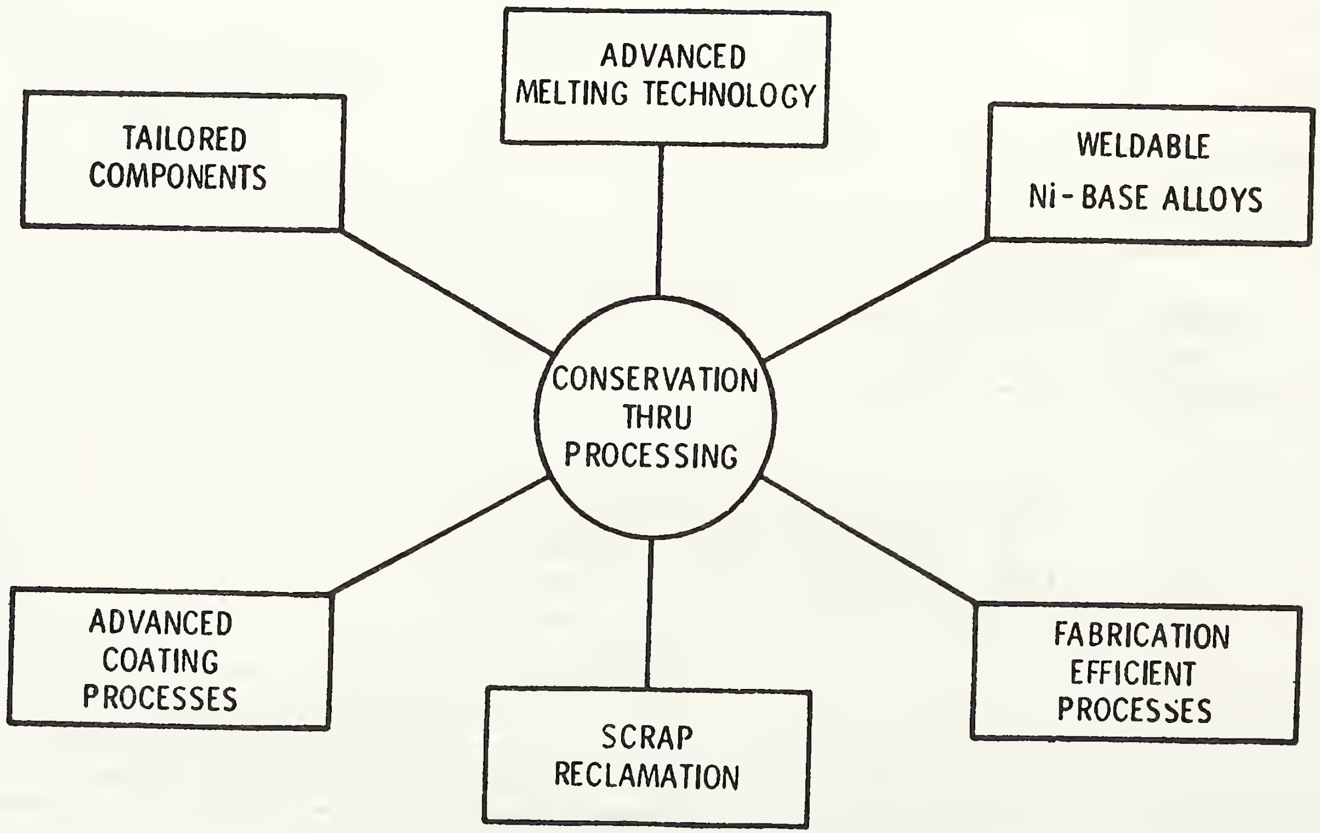

Figure 14. - Conservation of strategic materials through process technology.

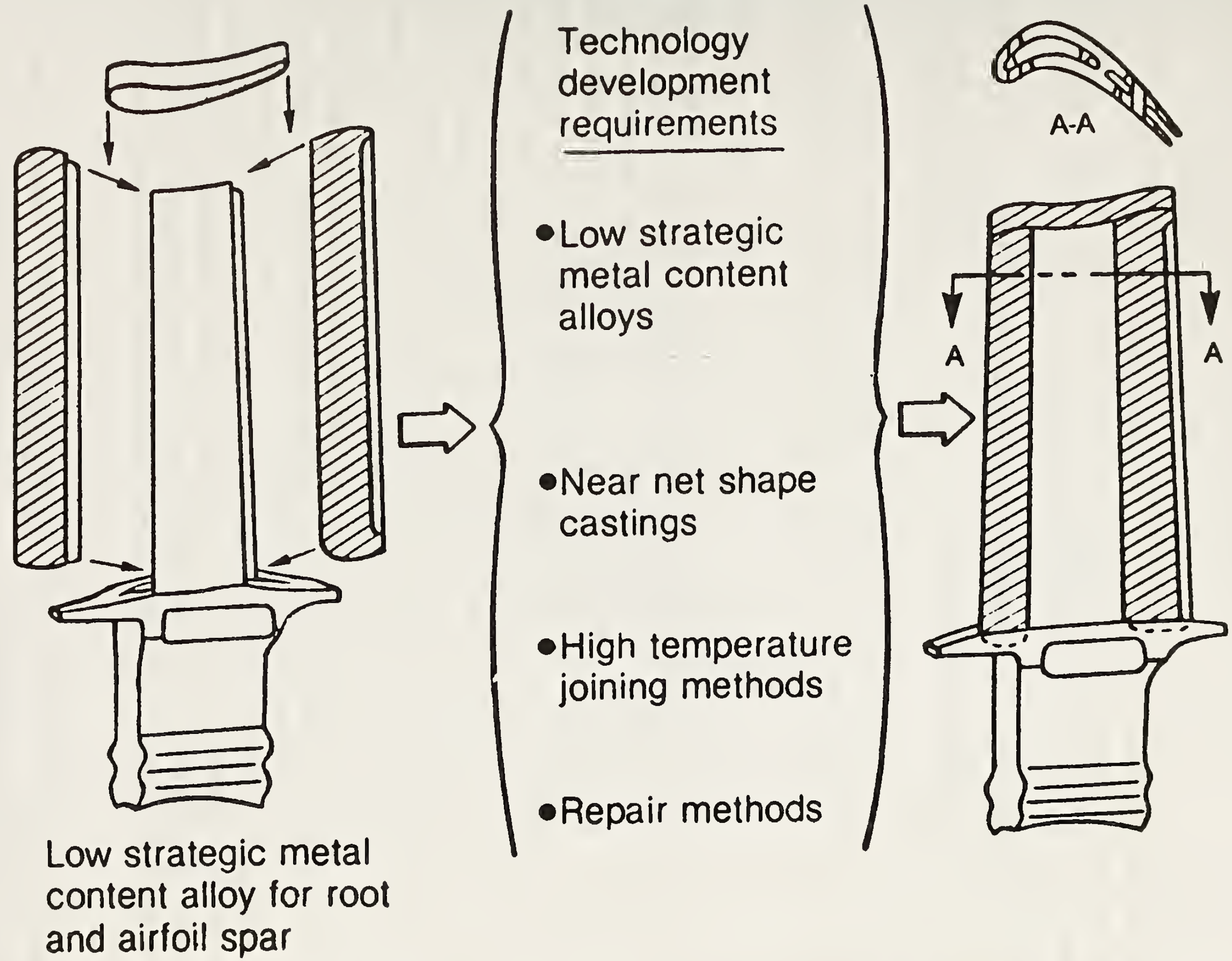

Figure 15. - Tailored fabrication as a process method to conserve strategic materials.

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16. Abstract
NASA has several activities underway directed at conserving strategic materials used in the aerospace industry. Research efforts involving universities and industry as well as in-house activities at the NASA-Lewis Research Center comprise the current program. These initial research efforts are preparatory to an anticipated much broader program focusing on the "Conservation of Strategic Aerospace Materials - COSAM." The primary objective of the COSAM Program is to help reduce the dependence of the United States aerospace industry on strategic metals, such as cobalt, columbium, tantalum, and chromium, by providing the materials technology needed to minimize the strategic metal content of critical aerospace components with prime emphasis on components for gas turbine engines. Thrusts in three technology areas are planned for the COSAM Program, including near-term activities in the area of strategic element substitution; intermediate-range activities in the area of materials processing; and long-term, high-risk activities in the area of "new classes" of high temperature metallic materials. This paper describes in some detail the projects currently underway and initial results generated to date. Initial emphasis has been placed in the area of strategic element substitution. Specifically, the role of cobalt in nickel-base and cobalt-base superalloys vital to the aerospace industry is being examined in great detail by means of cooperative university-industry-government research efforts. Investigations are also underway in the area of "new classes" of alloys. Specifically, a study has been undertaken to investigate the mechanical and physical properties of intermetallics that will contain a minimum of the strategic metals. Current plans for the much larger COSAM Program also are presented in this paper.

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CRITICAL ELEMENTS IN THE AEROSPACE INDUSTRY

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CRITICAL ELEMENTS IN THE AEROSPACE INDUSTRY*

E. P. Whelan
(Climax Molybdenum Company of Michigan)

There can be no question that the aircraft gas turbine industry is heavily dependent on chromium for its successful operation. Despite considerable research, no alternative to chromium has yet been found, either in the form of a single element or a group of elements, that can provide the combination of oxidation and hot corrosion resistance required for high temperature turbine operation. Thus chromium must head any list of elements of critical importance to the aircraft gas turbine industry. The critical nature of chromium in this industry is compounded by its concentration in countries that may well use the availability of this element to further their own interests at the expense of those of the United States. The current price and availability of chromium has induced a false sense of security in this country that historically has been difficult to disturb, and that is overdue for an infusion of realism.

Considerably more attention has been paid recently to the availability of cobalt than to the availability of chromium, due to the effect of supply problems beyond the control of the United States. There is greater potential for substitution for cobalt by other elements than there is for chromium, and therefore the necessity for ensuring a guaranteed supply of cobalt does not have the same extreme degree of urgency as that for chromium. However, some areas will undoubtedly exist where cobalt and cobalt-base alloys will not be open to replacement by, for example, nickel and nickel-base alloys, and therefore some reliance on cobalt in the aircraft gas turbine industry appears inevitable.

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*Text of a presentation made at the Department of Commerce Workshop on Critical Materials Needs in the Aerospace Industry, February 9-10, 1981 at the National Bureau of Standards, Gaithersburg, MD.

The fact that chromium is essential to the achievement of resistance to oxidation and hot corrosion in high temperature turbine applications has been stated frequently. Improvements in the high temperature mechanical properties of superalloys have generally involved some decrease in the chromium content of the alloys, with a consequent loss in resistance to hot corrosion. Thus a decrease in the chromium contents of gas turbine high temperature alloys below certain levels is not a feasible route for minimizing chromium dependency. The use of protective coatings can provide extended corrosion resistant lifetimes to turbine hot components and, therefore, offers some potential for chromium conservation. However, the temporary nature of such coatings demands that the underlying alloy should possess sufficient inherent corrosion resistance to avoid rapid corrosion in the event of coating failure. An alternative to the use of coatings for chromium conservation is the development of clad or composite materials composed of high-chromium alloy envelopes and low- or zero-chromium alloy cores, an approach that has already been given some consideration by gas turbine producers. These techniques of coating and cladding probably represent the extent to which current technology can handle reduced chromium contents in hot components.

Given the essential nature of chromium in high temperature alloys, an adequate GSA stockpile is likely to be the only short term solution to a sudden decrease in the supply of chromium. For superalloy purposes the chromium in the stockpile should contain adequate quantities of high quality electrolytic grade chromium.

Deviating slightly from the high temperature side of the aerospace industry, some mention should be made of the Computer Harmonized Application Tailored (or CHAT) alloy selection system which was developed by Breen and coworkers at International Harvester Company to permit the replacement of nickel in carburizing steels by lower cost alternative elements. The use of this system during the nickel shortage of the late 60's enabled low cost low-nickel or nickel-free alloy compositions to be identified, and a similar approach could be used to minimize or eliminate chromium usage in similar alloys where substitution for this element is feasible.

As mentioned earlier, some substitution for cobalt in superalloys is possible and, as a result of the "cobalt crisis" of 1978, some progress has been made in decreasing the usage of cobalt in gas turbines. To date, replacement of high cobalt alloys by lower cobalt alloys that are already commercially available has been the predominant route taken for cobalt conservation. This situation reflects the fact that considerable expense is involved in qualifying newly-developed alloy compositions for gas turbine applications, which opposes research efforts to identify new zero-cobalt alloys. In addition, the current high cost of cobalt is frequently not a major deterrent to its use in high technology areas, since raw materials costs may form only a minor portion of final product cost. As with chromium, the current availability of cobalt has again tended to obscure our essential dependence on non-domestic sources for the element.

When discussing the need for studies on alloy substitution, due attention must be given to the probability that much relevant work may lie in the unpublished records of alloy manufacturers. Access to this data will obviously be limited on the basis of its proprietary nature, but there will clearly be a need to coordinate research on alloy substitution to avoid unnecessary duplication of work already performed.

Some studies have been performed at the Climax Molybdenum Company of Michigan Research Laboratory on the potential for substitution of cobalt in both wrought and cast superalloys. Our general approach has been to use statistically designed experimentation to identify optimum combinations of elements that yield required properties, and at the same time to assess the potential for replacing cobalt with alternative elements.

In the wrought alloy area, we have compared the properties of experimental cobalt-free nickel-base superalloy compositions with the properties of commercial combustor can alloys such as the cobalt-base Haynes Alloy No. 188 and the nickel-base Inconel 617 which contains 12.5% cobalt. Our work to date suggests that cobalt is not essential to the achievement of stress-rupture properties and oxidation resistance approximating those of Inconel 617, and in fact an alloy similar in composition to an alloy studied at Climax is now available in Europe as Nimonic 86. We have also studied the effect of decreasing the cobalt content of Haynes Alloy No. 188 on its stress-rupture properties and oxidation resistance. An initial study has shown that some reduction of the cobalt content of this alloy is feasible without any loss of these properties being evident, and there appears to be scope for further cobalt reductions.

In the area of cast superalloys, we have studied the possibilities of developing nickel-base compositions as alternatives to the cast cobalt-base alloys FSX 414 and X-40 that are used widely as turbine vane alloys. Using carbide strengthening alone, and avoiding γ' phase formation, it appears probable that nickel-base alloys with stress-rupture properties and oxidation resistance similar to those of FSX 414 can be developed. However, it has become clear that further work will be necessary to duplicate the mechanical properties of X-40.

In contrast to the high technology area, there has been considerable eagerness to replace cobalt-base alloys in applications where rigorous qualification testing is not required. One such area is wear resistant hardfacing alloys. We have recently concluded a cooperative program with Eaton Corporation to develop alloys that can be used to replace the cobalt-base Alloy No. 6 for certain valve wear applications.

The levels of trace elements in superalloys are a matter of concern for gas turbine applications and it is essential that any cobalt in the GAS stockpile should be sufficiently pure for use in superalloys. Current information suggests that the purity level of this cobalt is limited and may be unsuitable for superalloy production. Clearly the composition of this material should be determined immediately if this stockpile is to have any value to superalloy producers.

SUMMARY

Chromium must lead any list of critical elements in the aircraft gas turbine industry, with cobalt being ranked second in importance. Chromium is indispensable for high temperature components, whereas some substitution for cobalt is feasible. The critical nature of these elements tends to be obscured by their general availability. A stockpile source for chromium is essential, with superalloy production requiring electrolytic grade material. A cobalt stockpile may be necessary for superalloy applications for which no substitute alloys can be developed. This stockpile should contain high purity material with acceptable concentrations of trace elements. Research has demonstrated that some cobalt substitution can be achieved readily. A coordinated research and development effort in this area would be valuable.

CRITICAL ELEMENTS IN THE AIRCRAFT GAS TURBINE INDUSTRY

- CHROMIUM
  - ESSENTIAL FOR OXIDATION AND HOT CORROSION RESISTANCE.
  - NO SUBSTITUTES KNOWN.
  - NON-DOMESTIC SOURCES.
    READY AVAILABILITY.
    POTENTIAL FOR DISRUPTION OF SUPPLY.
- COBALT
  - WIDELY USED IN SUPERALLOYS.
  - SOME SUBSTITUTES KNOWN.
  - NON-DOMESTIC SOURCES.
    READY AVAILABILITY.
    POTENTIAL FOR DISRUPTION OF SUPPLY.

CHROMIUM

- ESSENTIAL FOR OXIDATION AND HOT CORROSION RESISTANCE
- LIMITED POSSIBILITIES FOR MINIMIZING DEPENDENCY IN ALLOYS
- PROTECTIVE COATINGS REQUIRE SOME SUBSTRATE RESISTANCE TO OXIDATION, HOT CORROSION
- CLAD COMPOSITE COMPONENTS
- STOCKPILE SOURCE : PURITY

COMPUTER HARMONIZED APPLICATION TAILORED (CHAT) ALLOY SELECTION SYSTEM

- DEVELOPED FOR SUBSTITUTION OF NICKEL IN CARBURIZING STEELS
- POTENTIAL FOR SIMILAR APPROACH TO OPTIMIZATION OF CHROMIUM CONTENT

COBALT

- CONTRIBUTION TO ALLOY STRENGTH.
  SOME CONTRIBUTION TO OXIDATION RESISTANCE.

- CURRENT SUBSTITUTION OF LOW-COBALT ALLOYS FOR HIGH-COBALT ALLOYS USING COMMERCIAL COMPOSITIONS.

- DETERRENTS TO ALLOY DEVELOPMENT:

  QUALIFICATION
  % OF PRODUCT COST
  AVAILABLE SUPPLY
  PROPRIETARY DATA

- STOCKPILE SOURCE : PURITY

COBALT SUBSTITUTION RESEARCH

- STATISTICALLY DESIGNED EXPERIMENTATION
- IDENTIFY OPTIMUM COMBINATIONS OF ELEMENTS FOR REQUIRED PROPERTIES
- ASSESS POTENTIAL FOR COBALT SUBSTITUTION

WROUGHT ALLOYS

- COMBUSTOR CAN ALLOYS:
  HAYNES ALLOY NO. 188 (Co-22Ni-22Cr-14W-0.08La-0.08C)
  INCONEL 617 (Ni-22Cr-12.5Co-9Mo-1Al-0.07C)
- COBALT NOT ESSENTIAL IN NICKEL-BASE ALLOYS
- NIMONIC 86 (Ni-25Cr-10Mo-0.03Ce-0.05C)
- LOWER COBALT IN HAYNES ALLOY NO. 188

CAST ALLOYS

- TURBINE VANE ALLOYS:
  FSX 414 (Co-29Cr-10Ni-7.5W-0.25C)
  X-40 (Co-25.5Cr-10.5Ni-7.5W-0.75Mn-0.75Si-0.5C)
- CARBIDE STRENGTHENED NICKEL-BASE ALLOYS
- STRESS RUPTURE AND OXIDATION RESISTANCE EQUIVALENT TO FSX 414.
- X-40 SUPERIOR TO CURRENT EXPERIMENTAL ALLOYS IN STRESS-RUPTURE PROPERTIES

WEAR RESISTANT ALLOYS

- COBALT-BASE ALLOY NO. 6
  (Co-28Cr-4W-3Ni-3Fe-1Si-1.2C)
- SUBSTITUTE NICKEL-BASE ALLOYS
  (Ni-29Cr-5/9Mo-8/25Fe-1Si-2C)

SUMMARY

- CHROMIUM AND COBALT HEAD LIST OF CRITICAL ELEMENTS
- CHROMIUM - STOCKPILE
PURITY
- COBALT - SUBSTITUTION
STOCKPILE : PURITY
- COORDINATION OF RESEARCH AND DEVELOPMENT EFFORTS

COMAT PRESENTATION

Stanley Fass

Allied Chemical Corporation

January 28, 1981

COMAT PRESENTATION

Stanley Fass

I would like to thank you for inviting Allied Chemical to participate in this workshop on critical materials. It is a distinct pleasure for me to present the innovative developments that are taking place in the Consolidated Metal Products Department of Allied Chemical Corporation in Rapid Solidification Technology and new alloy development. We believe that our efforts represent a major breakthrough in Powder Metallurgy and could
Slide 1 have a significant impact on the critical material shortage.

In the last several years great strides have been made in developing technology, such as Rapid Solidification, that enables us to make high quality powder for aerospace applications. Thus, one will be able to conserve critical materials by consolidating powder to near-net shape and minimize the machining wastes. At Allied Chemical, work is going on that may enable us not only to conserve critical materials but offer a performance effective substitute for these alloys.

Allied Chemical has extended the RST processes developed for Metglas® amorphous alloy ribbon and has produced metal powders of alloys with microstructures that could not be made by conventional casting technology. These alloys are nickel
Slide 2 and iron-based, containing molybdenum and boron but generally do not contain any chromium, cobalt, or tungsten. We believe that some of these alloys will be able to replace cobalt and other strategic metals in certain application areas without

loss of performance and perhaps even improved performance. Although the applications that I will be discussing today are not directly related to aerospace systems, they nevertheless would have an impact in this area.

We have identified a number of application areas that have been chosen for initial field testing and market entry. These

Slide 3 are shown on the next slide. Metal cutting tools, of course, are used extensively in the aerospace industry. Approximately 10% of the cutting tools sold in the U. S. serve that sector. HOT EXTRUSION DIES made from our alloys are being tested in the aluminum and copper industry. Aluminum extrusions play an important part in the manufacture of air frames and surfaces. Plasma spray powders made from Allied Chemical alloys are being evaluated for us as a possible replacement of cobalt-containing superalloy hardfacing powders. Recently, interest has been generated in considering the use of coatings in aerospace applications such as coating turbine blades. Our alloys are also being tested for wear applications. One area where this might impact on the aerospace industry is its use in helicopter gears and bearings. The objective in that case would be to increase performance over conventional gear steels.

Slide 4 The next slide shows some of the typical materials used in the applications we just reviewed. One can see that cobalt, tungsten and chromium are all necessary components of these alloys. Approximately 12% of the cobalt consumption in the U. S. is used in metalwork cutting tools. Similarly,over 50% of tungsten is used in these application areas. Success of our alloys may be able to reduce the consumption of the critical materials.

I would like to spend several moments reviewing some of the data that we have obtained to date that makes us very enthusiastic about our process and alloy systems. The initial cutting tool data was developed for us at Metcut Research, a consultant, in Cincinnati. They recommended that we use M-42, a premium grade HSS containing 8% cobalt, as a standard. They used optimum tool geometry for the M-42 and our material was ground to the same geometry; no attempt was made to optimize it.

Slide 5 The next slide shows the turning test results. As one could see, the M-42 performed optimally in the range of 75-100 SFPM. Allied Chemical's CMP alloys 7007 and 3065 showed the same tool life at approximately twice the cutting speed. Thus, significant increases in productivity or tool life are indicated for our alloys.

Slide 6 The next slide shows the results of the interrupted cut, namely, face-milling tests. The data again shows that the Allied Chemical CMP alloys out-performed the M-42 HSS by over 100% improvement in tool life, at the same cutting speed, or the ability to significantly increase cutting speed and thus productivity while maintaining an acceptable tool life. We realize that these data are still preliminary. However, the potential we have shown to significantly improve cutting tools without the use of strategic materials is enthusiastically supported by a leading HSS cutting tool manufacturer with whom we are embarking on a mutual development program.

CMP alloy 7025 is another alloy that has shown great
Slide 7 promise. The next slide shows the properties of CMP 7025 compared with Stellite 6. The excellent retention of high temperature hardness and the abrasion wear resistance make this alloy look attractive for high temperature applications where

wear and abrasion resistance are important properties. Therefore, we embarked on a program of field testing this alloy in copper and aluminum hot extrusion and aluminum die casting. This program is still underway but the preliminary results look very promising. The next slide presents some of the comments

Slide 8 that the users have stated about CMP 7025. In a report to us, a major aluminum company stated that the CMP alloy "performed very similar to carbide but much better than Hot Work Steel". The user anticipates being able to use our alloy for complex profile dies where carbide proves to be too brittle. In another field test copper alloys were extruded through our die insert, with billet temperatures of 800 to over 900°C. The copper company reported obtaining over twice the die life with our alloy compared to the cobalt-based die they presently use.

At Woodstock Die Casting, which is a subsidiary of Allied Chemical, field testing is still underway. Over 20,000 castings on our die have taken place and the product quality has remained constant and the die has shown no wear. Woodstock also reported that the die gave excellent release even when subject to extremes in temperature variations and molten metal flow. These field tests are continuing and we expect that in the near future several alloys will have been qualified for commercial use.

Our technical people believe that the success of the CMP alloys is based largely on our unique Rapid Solidification Process. Our process is different, and we think better, than conventional PM processes and even other RST processes. For

Slide 9 example, CMP powders have a very consistent and homogeneous microstructure. Thus, each powder particle is essentially identical to each other and this is true because each particle is cooled unidirectionally at over 1 million °C. In atomization processes one obtains aggregates of large crystallites or powders that range from amorphous, to cellular to dendritic structures. The presence and location of ultra-fine grain intermetallic compounds in consolidated CMP materials result in greatly improved chemical and mechanical properties. Our RST process also provides excellent yields without requiring large amounts of recycle or powder classification. The flowability and tap density are good and the process is scalable. For example, Allied has a Metglas casting unit that can process 1 ton/hr of material.

In summary, we believe that Allied Chemical has developed a unique, economic RST process and excellent new alloy systems that could have a significant impact on both improved product performance and a reduction in the use of strategic materials. We have described some of the areas that we are actively engaged in. I would like to show, in conclusion, some areas that we
Slide 10 believe we could make significant contributions. In some of these areas we have already begun discussions with government agencies. We solicit the comments and interest of both the government and private industry to pursue these possible applications as well as any other areas that may be appropriate.

Thank you very much.

SF/amw
1/28/81

ALLIED CHEMICAL CORPORATION

CONSOLIDATED METAL PRODUCTS DEPT.
(CMP)

NEW DEVELOPMENTS IN METALLURGY AT ALLIED CHEMICAL

- UNIQUE ALLOY SYSTEMS
  - IRON & NICKEL BASED
  - CONTAINS MOLYBDENUM & BORON
  - LITTLE OR NO COBALT, CHROMIUM OR TUNGSTEN
- RAPID SOLIDIFICATION TECHNOLOGY

INITIAL APPLICATION AREAS

- METAL CUTTING TOOLS
- HOT WORK TOOLS
- PLASMA SPRAY HARDFACING POWDERS
- WEAR RESISTANCE PARTS

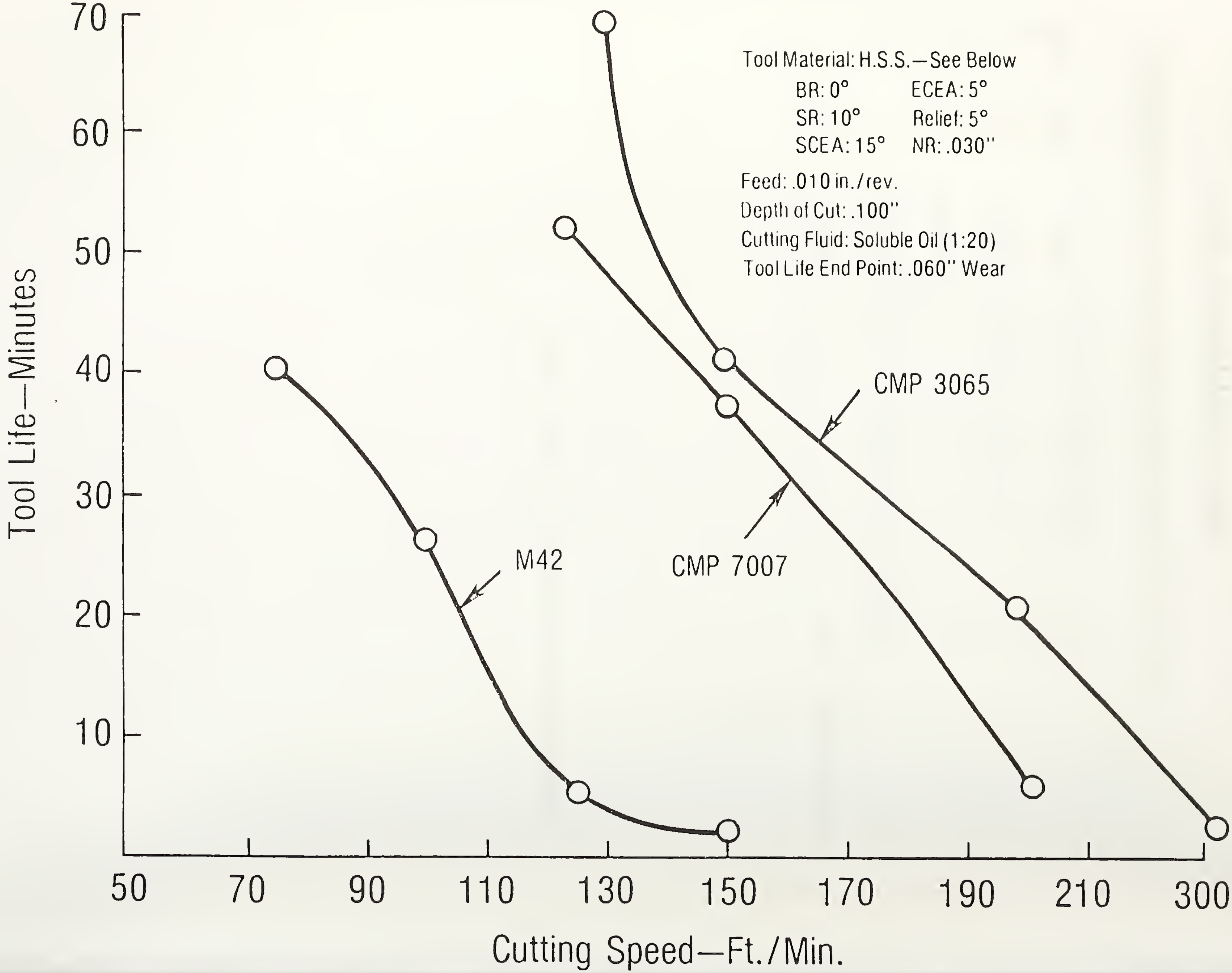
SOME OF THE ALLOYS THAT

CMP ALLOYS ARE BEING EVALUATED IN COMPARISON

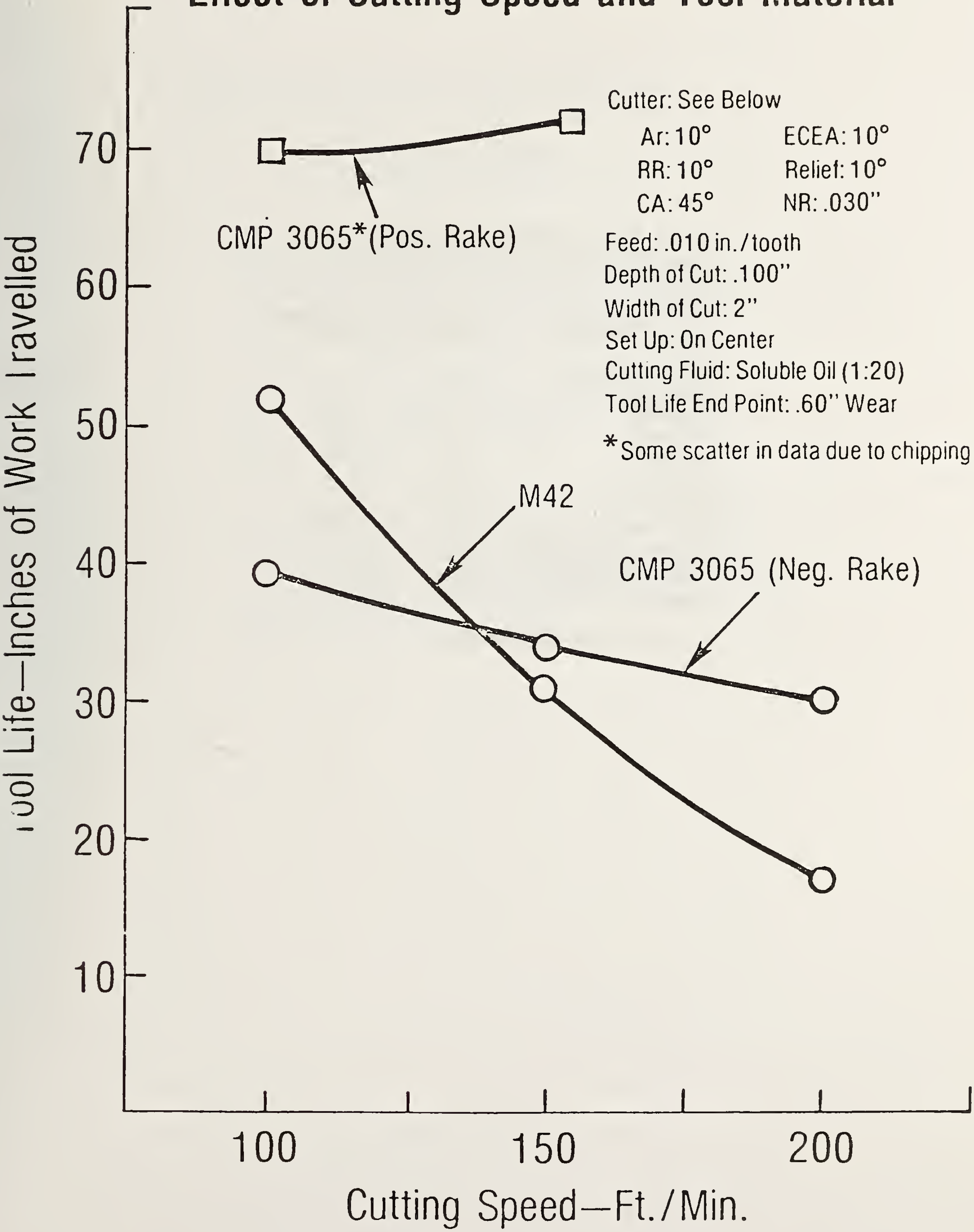
	Cr	V	W	Mo	Co	Fe	Ni
M-42	3.8	1.2	1.5	9.5	8.0	Bal	--
T-15	4.0	5.0	12.0	---	5.0	Bal	--
WC	---	---	85-94	---	15-6	---	--
Stellite*6	29	---	2	5.5	Bal	3	3

*Registered Trademark of Cabot Corp.

Turning 4340 Steel, Quenched and Tempered 302 BHN
Effect of Cutting Speed and Tool Material



Single Tooth Face Milling 4340 Steel
Effect of Cutting Speed and Tool Material



PHYSICAL PROPERTY COMPARISON

STELLITE 6* VS. ALLIED CHEMICAL CMP 7025

Property	Wrought Stellite 6	Allied Chemical CMP 7025
Hardness, Rockwell C		
Room Temp.	45	50
@ 1000 °F	34	50
@ 1200 °F	31	48
@ 1400 °F	26	31
Elongation	0-1%	4-6%
Modulus of Elasticity	28.0 M psi	31.0 M psi
Charpy V-Notched Impact St.	4 ft-lb	3.5 ft-lb
Yield Strength @ 0.2% Offset	92 ksi	205 ksi
Ultimate Tensile Strength	148 ksi	265 ksi
Abrasive Wear, CM^3/Rev	32.5	34

*Registered Trademark of Cabot Corp.

PRELIMINARY FIELD TESTING RESULTS

LOOK VERY PROMISING

ALUMINUM HOT EXTRUSION - CMP ALLOY

"PERFORMED VERY SIMILAR TO CARBIDE
BUT MUCH BETTER THAN HOTWORK STEEL"

COPPER HOT EXTRUSION - CMP DIE OUT
PERFORMED COBALT-BASED DIE BY OVER
TWO TO ONE

ALUMINUM DIE CASTING - CMP DIE GIVES
EXCELLENT RELEASE EVEN WHEN SUBJECT
TO EXTREMES IN TEMPERATURE VARIATIONS
AND MOLTEN METAL FLOW

ALLIED CHEMICAL'S RST PROCESS

- UNIFORM & HOMOGENEOUS MICROSTRUCTURE
- GOOD POWDER PROPERTIES I.E.
  FLOWABILITY, TAP DENSITY
- EXCELLENT YIELD
- COOLING RATE OF OVER 10^{6} °C/SEC
- PROCESS SCALABILITY

POSSIBLE FUTURE APPLICATIONS

GAS TURBINE & DISKS

AIRCRAFT STRUCTURAL COMPONENTS

PENETRATOR & ARMOR

HELICOPTER GEARS & BEARINGS

Report of Working Group on Critical Raw Materials

Chairman: Russell C. Babcock

Bear Creek Mining Company

Prepared at the Public Workshop

on

Critical Materials Needs of the Aerospace Industry

February 9-10, 1981

WORKSHOP ON CRITICAL MATERIALS NEEDS
OF THE AEROSPACE INDUSTRY
February 10, 1981

Final Report of Workshop Working Group on Critical Raw Materials

Russell C. Babcock, Jr.

Following the outline presented by the workshop conveners, this working group discussed the presentations of February 9th and additional factors in the area of critical raw materials. Our response is presented below in outline form:

I. Materials Issues of Primary Concern

A. Overview Issues

Executive Branch

Materials supply has for some time been jeopardized by the lack of coordination of activities within Executive Branch, i.e., inter-relationships of minerals-related actions and decisions between Interior, Defense, Commerce, FEMA, etc.

Foreign Policy

There has been little sensitivity in foreign policy to minerals issues, i.e., raw material supplies, on-shore versus off-shore processing, etc.

Capital Formation and Business Law

There has been a trend away from the stimulation of capital formation to support domestic plant, resource investment, etc., and therefore materials availability.

Labor Productivity

General productivity declines bear on off-shore versus on-shore movement of various stages of raw material supply and processing.

Research and Development

Fiscal, tax and other policies influence the degree of stimulation of research and development, technology expansion, and the retention of developed technology.

B. Particular Issue List

Power Pricing
Tariffs--Import/Export impacts
Processing Facilities
Environmental Controls
Public Lands--Access
Inventory of status, i.e., open vs. withdrawn
Inventory of minerals potentials
Stockpile--Critical: Our existing stockpile--what do we have and what do we need?
Private : Should we have one, and if so, how would we stimulate its growth?
Exploration/Development of Domestic resources--how do we stimulate this initial step?
Tax and Depreciation
Antitrust
DOD procurement policy

Sea Bed Mining Law
Patenting
Balance of Payments
R/D stimulatiuon in areas of "pure" research (vs. applied)

II. Possible Federal Action to Consider

1. Establish a White House Council on Materials and Minerals comparable in size and authority to CEQ. Such a Council should be statutory; i.e. - it will require that a legislative proposal be recommended in the October, 1981, report [sec 5(c)(2) of Act] to Congress.

2. Extend Defense Production Act indefinitely. Full utilization and funding of Title III is recommended, supporting domestic resource development and production through such things as "price floor" supports, which are not likely to be large expenditure items.

3. A private sector Advisory Board to the Council on Minerals and Materials is recommended.

4. Land Use Area
   - Defer further wilderness decisions pending minerals inventory of lands in question.
   - Extend cut-off date for mineral entry into wilderness from the current 1983 date, indefinitely.
   - Inventory land status in order to determine what is open for, versus withdrawn from, mineral exploration and production.
   - Consider establishment of "Areas of Critical Minerals" comparable to the Bureau of Land Management Areas of Environmental Concern.
   - Regulation/administration of minerals exploration/ development/production must be reduced to workable levels.
   - Insist that minerals be addressed in U.S.Forest Service and Bureau of Land Management Planning.

5. Define our critical mineral resource position: that is to say, stimulate the public and private sector inventory of the potential of public lands, including withdrawals, parks, military reservations, etc.

6. Stimulate recovery of minerals from non-conventional or marginal resources through technology development by theBureau of Mines, i.e., on low grade or refractory ores, etc.

7. Promote meetings to discuss state-of-the-art technology across industry-Government-academia lines, and to stimulate technology transfer between these sectors.

8. Develop better control of legal processes to avoid delay and waste, such as those which occur in the present intervenor process.

9. Tax law changes should be considered where possible to stimulate domestic production, domestic processing, capital formation, etc.

10. Review Stockpile for quantity, quality and form (useability), of current stockpiled materials, and consider "barter" method and use of rotating funds as availabile to fill needs.

11. Stimulate private stockpiling through tax incentives or other means, such as low interest loans.

12. In Defense contracts, make interest on borrowed funds an allowable contract cost.

13. Foreign policy should give priority consideration to our foreign mineral supply needs, and insure their availability to us.

14. Law-of-Sea negotiations should be restructured to ensure U.S. corporate participation in deep sea mining and to protect adverse technology transfer.

15. Review in detail the reasons for the off-shore shift minerals processing (Al, Cr, etc.) and make specific recommendation to alleviate this problem. Raw materials will not be developed without processing facilities.

III. Appropriate Materials for Detailed Discussion in Secretary's Report

It was felt that the Issues and actions in Sections I, II above should be considered in the context of the following materials:

A. Principle consideration should be given to Ti, Cr, Co.
Others (Al, Cb, Ta, etc.) should be mentioned where problems, behavior, etc., are different in order to point out the specific aspects of some of these other materials.

The reasons these principle materials should be considered are:

1. Ti - A high volume, low cost item; i.e., 24% of a military aircraft
- possible domestic sources
- imported from friendly countries
- on-shore technology and processing is critical step
- critical to airframe and engine

2. Cr - supply is at risk (South Africa)
- critical engine component
- on-shore technology problem
- a medium volume, low-to-moderately price item

3. Co - a low volume, high cost item
- aerospace use is 40% of U.S. use
- stockpile is 45 MMlb short
- local sources are possible to develop
- local manufacturing a possibility
- very large body of recent data
- Title III application possible
- imported from potentially unfriendly nation

Attendance List

Critical Raw Materials

Jim Owens	U. S. Dept. of Commerce
A. J. Macone	U. S. Dept. of Commerce
Russell Babcock	Bear Creek Mining Co.
Jim Beizer	American Mining Congress
Bob Fabrie	Air Force - Systems Command
W. L. Shafer	House Interior Committee
James T. Dunham	U. S. Bureau of Mines
Harry L. Light	U. S. Bureau of Mines
Walter Lander	U. S. Bureau of Mines
Jack R. Clifford	U. S. Dept. of Commerce
Robert A. Brumwell	Cabot Mineral Resources
Albert Paladino	National Bureau of Standards
John V. O'Conner	Copper Range Co.
Steve Johnson	Anderson & Pendleton (law firm)
George Watson	Ferroalloys Assn.
Gerald Houck	American Iron & Steel Inst.
H. Eugene Frymyer	Carpenter Technology
E. N. Hegge	Fiber Materials, Inc.
Richard Seibert	National Assoc. of Manufacturers
Judith La Drew	Pratt & Whitney Aircraft
Douglas S. Smith	Horanda Mining Inc.
Frank Keckeissen	Lockheed
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Harold E. Goeller	Oak Ridge Nat'l Lab (Union Carbide Corp.)
Claire K. Blong	FEMA
Ken Foster	OSD/DOD
Ken Young	BIE/DOC
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Howard K. Andersen	U. S. Bureau of Mines
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Russell L. Richards	GSA Office Stockpile Trans.
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Scott F. Sibley	U. S. Bureau of Mines
John T. Kummer	U. S. Bureau of Mines
Leonard L. Fischman	Central Intelligence Agency
Thomas L. Asche	G. E. Aircraft Engine Group
Roger C. Maples	McDonnell-Douglas
Dennis Browne	Canadian Embassy
David J. Latzke	Sundstrand Aviation
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Walter T. Joyce	Freeport Minerals Co.
Gene Kingsbury	Dept. of Commerce
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William J. Kaestner	Consultant - Metals/Minerals
Armondo J. Lopex	U. S. Dept. of Commerce
John McKinley	National Bureau of Standards
Paul Helton	RMI Titanium
Laszlo Pasztor	Dravo Corp.
Marylyn Biviano	Federal Emergency Mngmt. Agency
Frank J. Kelly	U.S. Bureau of Mines
Jerome Persh	OSD
Anna C. Fraker	National Bureau of Standards
Tatiana Roodkowsky	Chamber of Commerce of the United States

Report of Working Group on Critical Engineering Materials

Chairman: F. E. Akin

The Boeing Company

Prepared at the Public Workshop

on

Critical Materials Needs of the Aerospace Industry

February 9-10, 1981

Report of Workshop Working Group on Critical Engineering Materials

Group No. 2 was assigned the responsibility for Critical Engineering Materials. At the outset I want to mention that our group made no attempt to identify all critical aerospace materials. Those materials discussed are considered to be examples only. They are, however, probably the most critical materials we have encountered. Our discussion further centered primarily on conversion from raw materials state into mill product form. We left the question of available raw material to Group No. 1 and the question of conservation and substitution to Group No. 3. Since no other usage criteria was provided we considered the past two years' experience to be the base upon which our discussions were predicated. The first engineered material item to be discussed in detail by our group was titanium mill products. Among the many concerns that we had were the user's inability to accurately forecast on a timely basis the extent of his need. Next was our concern about the ability to melt adequate quantities and convert the melted titanium sponge into ingot form. Following that was the concern about large press capacity where the ingot in turn would be formed into large forgings. Further, we felt that the consistent application of Title I of the Defense Production Act had the opportunity to create problems. And finally, the potential withdrawal of Japan from exportation of sponge appeared to leave a potential shortfall in sponge total supply.

Potential actions we recommend to correct the above problems included the extension of the Defense Production Act, establishment of a suitable multi-year funding program within the military services, a Government guaranteed market to the limit of current stockpile authorization, examination of current Government stockpile policies, perhaps to include a broadened applicability which would allow economic and commercial usage rather than strategic usage only, and the provision of incentives for commercial expansion and for the creation of commercial stockpiles.

Our next items for discussion were cobalt and chromium. We concluded it proper to combine the two because the comments that were generated seemed to apply equally to each of them. We found no known problems of fabrication regarding either of these two materials. Rather, the problems as we foresaw them had to do with the availability of cobalt and chromium in their elemental forms. The actions as we saw it fell to Group 1 relative to availability of the materials, under Group 3 concerning additional conservation and/or development of substitute actions. Again we felt the Government stockpile policy should be examined and perhaps adjusted in the same manner as recommended for titanium.

It was the consensus of our group that the next item for consideration be tantalum. This conclusion was reached because titanium is a fundamental item used in the development of an airplane. Cobalt and chromium seem to apply mostly to usage by power plant developers, whereas the third major portion of any weapon systems and most commercial applications include significant electronics; and tantalum is necessary to the timely and satisfactory development of electronics as we now know them. We didn't find a significant problem in the conversion of tantalum to mill products and in that sense we considered it to be in approximately the same category as cobalt and chromium. However, in the actions discussed we felt the emphasis on the development of timely substitutes to be even more important and more urgent than in the other instances because of the question relative to the amount of tantalum currently in reserve. We also felt that here again, Government policies relative to the availability of Government stockpiles for commercial and economic use and also the advocation of previously recommended incentives for commercial organizations to develop and maintain commercial stockpiles of tantalum would be equally applicable.

The last item of material that our group thought worthy of inclusion in this group was graphite fibers. The reason for inclusion of graphite fibers is the greatly increased demand that we currently anticipate. While industry responsible for supplying graphite in fiber and tape cloth form has indicated that they can and will increase their capacity to support needs; that is, as the needs are presently perceived. We had reason to believe that needs will develop faster than industry currently anticipates and therefore there could be a gap between demand and available supply. We suggest that this product requires very close monitoring in the future and some attempt to anticipate what forward usage may amount to compared to what we have experienced in the past.

A review of our earlier deliberations left us with the impression that our biggest single problem was the conversion of titanium into mill product form. While this includes plate and extruded sections fundamentally the problem seems to lie in availability of large presses. It was therefore our final conclusion that the supply of raw material, rather than known or anticipated fabrication problems are our chief concern.

Attendance List

Critical Engineering Materials

Name	Organization	Position
Leon N. Karadbil	Commerce-OIM	Dir., Industrial Resourc Division
John Geron	Aerospace Industries Assn.	Dir. for Materiel
Choon K. Quan	Bureau of Mines	Physical Scientist, Deputy Director
Ron Heitzmann	Grumman Aerospace Corp.	Mfg. & Matls. Engr.
Greg Barthold	Alcoa	Mgr., Tech. Progress
Ken Stalker	General Electric Co.	Consulting Engineer
Harris Burte	A.F. Nateruaks Kab	Dir., Metals & Ceramics Division
R. L. Jaffee	EPRI	Director, Materials
Jack Odell	Wyman Gordon Co.	Marketing Mgr.
Sally I. Couluris	Grumman Aerospace Co.	Economic Spealist
William V. Ward	INCO Alloy Products, Co.	Market Analysis
Wm. A. Owczarski	Pratt & Whitney Aircraft	Mrg. Tech Planning
Kenneth W. Mlynarski	Bureau of Mines	Physical Scientist
Jim Kerr	Rockwell Int.	Director, Material
C. J. Beigle	Rockwell Int.	Mgr. Material
Wm. A. O'Donnell	Sperry Gyroscope, Sperry Corp.	Mgr. Materiel
Jim D. Martin	General Dynamics Corp.	Corporate Mgr., Procurement
Virgil Ketterling	Dept. of Commerce	Senior Economist
F. E. Akin	AIA, MMC (Boeing)	Vice chairman, AIA, MMC
Bob Parsons	Dept. of Commerce	Dir., Tech Staff
Stan Channon	Institute for Defense Analysis	Tech. Staff
C. G. Scofeld	Forging Industry Assoc.	Mktg. Director
John Cremeans	Bureau of Ind. Econ., DoC	Dir., OIERA
Robert Hemm	Nat. Materials Adv. Board	Ex. Secretary, Acting Ex. Director
M. A. Steinberg	Lockheed	Dir., Technology
W. L. Hodge	McDonnell-Douglas	Br. Mgr. - Purchasing
R. C. Maples	McDonnell-Douglas	Dir. Gen. Proc.
Robert J. Hensberger	Dept. of Commerce/BIE	Program Material, Metalworking Equip.
Robert A. Ricciuti	Dept. of Commerce/BIE	Industry Specialist
S. V. Radcliffe	National Forge Co.	Vice Pres., Corp. Dev.
W. W. Minkler	TIMET	Vice President

Substitution, Conservation, Specialized Recycling, and Higher Performance Materials

Chairman: Professor Ellis D. Verink, Jr.
University of Florida

Prepared at the Public Workshop
on
Critical Materials Needs of the Aerospace Industry

February 9-10, 1981

WORKSHOP ON CRITICAL MATERIALS NEEDS OF THE AEROSPACE INDUSTRY

February 9-10, 1981

Workshop Comments and Recommendations
Regarding Substitution, Recycling, High Performance Materials

I. Driving Force

The driving force behind an interest in Substitution, Recycling and High Performance Materials derives from several types of threats.

(a) Economic Threats

Domestic manufacturers must contend with competitive technology from abroad. The ready availability of critical materials to non-USA based manufacturers could permit greater latitude in design and may result in the ability to achieve higher performance as the result of being able to use critical materials. US manufacturers may also feel competitive pressures to the extent that local pricing concessions on critical materials are given to non-USA manufacturers by local agencies and/or governments.

(b) Geopolitical Threats

The geopolitical threat resides primarily in the import dependence of the USA for supplies of critical materials, particularly Co, Cr, Ta, Cb and Ti.

(c) Regulatory Threats

The host of regulatory restrictions imposed by US government agencies such as OSHA, EPA, CPA, etc., poses a significant threat to the ability to discover and exploit potential domestic reserves of critical minerals and to recover and/or reprocess scrap economically. Such threats already have forced closing of significant US productive capacity.

II. Responses

The need to obtain critical materials for use dictates several levels of response. These include (a) a physical stockpile of critical materials of the proper quantity, composition and form to accomodate stockpile goals, (b) the development of an "intellectual" stockpile of research and development information as well as the accompanying manufacturing technology to permit rapid substitution for unavailable critical materials should the need exist, (c) a positive industrial effort to seek suitable substitute materials and/or develop designs, etc., which permit use of less critical materials or alloys using smaller quantities of critical materials, (d) an informed but aggressive effort to alter regulations, tariffs, taxes, patent laws, etc., to unblock the discovery, extraction, production and recycling use of domestic materials.

The alternative to these scenarios is to retain the status quo, do nothing, and trust to the good nature of the rest of the world!

III. Substitute Materials

(a) Definition

The term "substitute materials" as used herein includes (1) alloys containing small amounts (down to zero content) of critical materials, (2) alternate materials including non-metallic materials such as carbon/carbon composites, (3) higher performance materials such as RST materials, (4) dual structure/ dual property materials such as turbine discs with the hub designed for fracture toughness and the rim designed to resist creep, (5) materials which may have somewhat less than optimum life or properties, but which could be expected to provide useful service until critical materials become available.

(b) Comments

(1) Materials considered to be particularly critical include Co, Ta, Cr, Cb and Ti. In the case of Ti the critical aspect is lack of domestic productive capacity rather than lack of mineral reserves.

(2) There is need of a means to "qualify" alternate materials for use without jeopardizing the patent interests of producers or suppliers.

(3) Financial support is needed to assist producers and users in developing confidence in substitute materials. This is particularly important to potential second and third tier manufacturers concerned with new prototypes.

(4) New alloy research and development should focus on systems based on available minerals (e.g., Ni, Fe, Ti, Al, Mo, W) as well as on alloys containing only small additions of the designated critical materials (particularly Co, Cr, Cb, Ta).

(b) Opportunities

Several research and development opportunities are available which would reduce the overall need for critical materials. These include:

(1) Composite materials (e.g., graphite/polyimide);
(2) Rapidly Solidified metals (RST products);
(3) "Forgiving" ceramics (i.e., ceramic materials with enhanced ductility);
(4) Use of new alloys which are strengthened by intermetallic compounds (e.g., Fe-Al and Ti-Al);
(5) Aluminum powder metallurgy products;
(6) Special coatings (perhaps containing critical materials) which can be used over substrates not containing critical materials thereby reducing the total requirement for critical materials;
(7) Use of computerized methods for alloy and hardware design as well as for control of manufacturing.

IV. Reclamation

(a) Definition

Reclaimable material includes such mechanically cleanable materials as shop floor scrap and sludges such as are generated in electrochemical or chemical machining as well as non-revertible scrap materials such as contaminated scrap, used parts, etc.

(b) Comments

(1) To optimize the processes, it will be necessary to identify and track scrap through all stages of manufacture and collection to maintain "pedigree."

(2) Regardless of item 1 above, there will be build-up of trace elements. The techniques of extractive metallurgy should be employed to purify such materials.

(3) Designers and users must be persuaded to avoid unnecessary demands for virgin or super-purity material.

(4) A national commitment to recycling and conservation is required which includes the non-export of scrap considered critical.

(5) The aerospace industry now uses approximately 3% of the chromium supply. The purity requirement for aerospace needs are extremely high (require vacuum-melt grade). Research should be encouraged aimed at devising methods to produce the equivalent of vacuum-melt grade from reclaimed material.

(6) Because of the potential usefulness of such procedures, government activities in support of private industry should be enhanced with regard to extractive metallurgy technology.

V. Life Extension

The total requirement for critical materials can be reduced by extending the life of existing structures. This may be accomplished by (1) refined repair and maintenance procedures and (2) by use of special coatings as noted above. Efforts at life extension should receive high priority in order to make optimum use of existing hardware thereby softening the need for critical materials.

VI. Processing

(a) Definition

Processing techniques which minimize the total amount of critical materials in process will extend the available supply. Such techniques include those which produce parts "near net shape (NNS)." Included are:

(1) Investment castings;
(2) Powder metallurgy products, including RSR powder techniques;
(3) Stepped extrusions;
(4) Inertial welding;
(5) Etc.

Every encouragement should be given to adopt the NNS philosophy in manufacture.

VII. Generic Recommendations

There are a number of concepts which, if incorporated, would provide broad support to the accomplishment of the aims of conservation of critical materials. These include:

(a) Institution of multi-year procurement practices;
(b) Development of new ways of doing business with the government;
(c) Expansion of development efforts in the field of manufacturing technology (MANTECH);
(d) Involve second and third tier suppliers in development of prototype components and provide financial incentives as appropriate;
(e) Encourage government/industry/university interaction;
(f) Encourage technology transfer;
(g) Emphasize incentives. These need not always be direct financial incentives, but may take the form of credits, patent implications, etc.

CRITICAL MATERIALS FOR THE AEROSPACE INDUSTRY

Summary of Workshop on Substitution,
Recycling and High Performance Materials

Drivers

Economic Threats

- Technology
- Availability of Critical Materials
- Design for Performance

Geopolitical Threats

- Availability

Regulatory Threats

- EPA, OSHA, CPA, etc., etc.

Responses

Physical Stockpile

"Intellectual" Stockpile

- Research and Development
- MANTECH

Industrial Involvement

- Legal
- Regulatory
- Etc.

Alternative

- Status Quo

Substitutes

Definition

- Low to Zero Critical Materials Content
  - low cobalt alloys
- Alternate (non-metallic) Materials
  - carbon/carbon
- High Performance Materials
  - RST, etc.
- Limited Life
  - acceptably reduced capability
- Dual Structure/Dual Property
  - duplex turbine discs

Substitutes (continued)

Comments

Targets: Co, Ta, Cr, Cb, Ti (productive capacity for Ti)
Need means to qualify alternative materials while preserving patent integrity
Need funds for developing confidence
Focus on new-base alloys from available materials (Ni, Fe, Ti, Al, Mo, W) with restricted amounts of critical materials

Opportunities

Composites
RSP
"Forgiving" ceramics
Intermetallics
Powder metallurgy aluminum alloys
Coatings
CAD/CAM

Reclamation

Definition

Shop floor scrap/sludges, non-revertible scrap/used parts

Comments

Identification and tracking of scrap
Trace element build-up
Unnecessary demands for virgin material
National commitment to recycling and conservation (and non-export) of scrap
Upgrading recycling methods using extractive metallurgy technology (e.g., produce vacuum-melt grade Cr from scrap)

Life Extension

Definition

Repair, coatings

Processing

Definition

Near Net Shape Concepts

Generic Recommendations

- Multi-Year Procurement
- Innovative Methods of Dealing with Government
- Expanded MANTECH
- Involve Second and Third Tier Manufacturers
- Government/Industry/University Collaboration
- Technology Transfer
  - Extractive metallurgy technology
- Emphasize Incentives

Attendance List

Substitution, Conservation, Recycling, High Performance

Name	Affiliation	Office Phone
Ellis D. Verink, Jr.	Univ. of Florida	(904) 392-1454
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Robert L. Caton	Carpenter Technology Corp.	(215) 371-2281
S. W. Palmer	Union Carbide Carbon Products	(203) 794-3757
Jim Gardner	BIE	(202) 377-1218
Jack Knox	Cemented Carbide Producers Assn.	(502) 589-3781
P. H. Butler	Commerce/ITP./OIM	(202) 377-2322
Skip Jones	Commerce/ITA/OCP	(202) 377-5124
E. P. Whelan	Climax Molybdenum Co.	(313) 761-2300
R. V. Jarrett	Columbia Univ.	(212) 280-2915
Randy Myers	Commerce Dept.	(202) 566-7416
Diana Friedman	Commerce/BIE/OBI	(202) 566-7732
John de Barbadillo	Inco Res. & Dev. Center	(914) 753-2761
Louis Ianniello	U.S. DOE	(301) 353-3428
A. W. Ruff	National Bureau of Standards	(301) 921-2966
Joseph E. Hunter	General Motors Research	(313) 575-2951
James S. Grichar	Bureau of Mines	(202) 634-1093
Ted Lynch	Versar, Inc.	(703) 750-3000
Arden L. Bement	TRW	(216) 383-2762
Mel Siegel	Pratt & Whitney Aircraft	(305) 840-5060
Renice Kerr	UTRC	(203) 727-7172
Chet Sims	General Electric-GTD	(518) 385-9481
Stan Siegel	Aerospace Industries Assn.	(202) 347-2315
Saul Isserow	Army Materials & Mech. Res. Ctr.	(617) 923-3501
Murray A.Schwartz	Bureau of Mines	(202) 634-1147
Stan Margolin	Arthur D. Little, Inc.	(617) 864-5770
Michael A. Greenfield	NASA	(202) 755-2364
G. Dana Brabson	USAF/AFWAL/MD	(212) 764-8363
Dale A. Weiler	Arthur D. Little	(617) 264-5770

ABRAHAM HURLICH

Consulting Metallurgist
Registered Professional Engineer

7467 Mission Gorge Road, Sp. 247
Santee, Ca 92071
Phone: 714/448-2440

December 8, 1980

Dr. John B. Wachtman, Jr.
Director, Center for Materials Science
National Bureau of Standards
Room B308, Bldg. 223
Washington, D.C. 20234

Dear Jack:

In reply to your request for a listing of "materials needs cases" related to national security, I have contacted a significant number of materials experts in the aerospace industry, both airframe and engine, to obtain their viewpoints on current and anticipated materials problems. While a number of isolated materials and materials related problems were described, there were several which seemed to be common to much of the industry. These are the following:

1. Long delivery times are presently being encountered in procuring aluminum, steel and titanium alloy forgings and extrusions. It is feared that this problem will become particularly acute during the 1982-83 time period if presently anticipated aircraft production requirements eventuate.

2. Concern was expressed regarding the inability of the present largest U.S. forging presses (50,000 tons) to produce the larger forgings that the aerospace industry would like to design. New presses of 75,000 - 100,000 ton capacity are desired. Concern was also expressed that the present two 50,000 ton presses, one at Wyman-Gordon and the second at Alcoa, are now approximately 25 years old, may possibly be near the end of their useful lives and may encounter more frequent breakdowns.

3. Long delivery times are experienced in procuring consumable vacuum arc melted steel and nickel base alloys. This was attributed to the limited number of such melting furnaces presently available within the industry.

To: Dr. John B. Wachtman, Jr.
December 8, 1980
Page 2

4. Many companies encounter difficulties in procuring required quantities of specialty aluminum, steel and titanium alloys, and have had to change designs to accommodate less desirable alloys. For example, a company may switch to the 2024 aluminum alloy in place of the more desirable 2124 alloy because the supplier quotes a much longer delivery time for the latter alloy or else refuses to take less than a mill order which may be much larger than the required quantity. The same problem is encountered in the procurement of extrusions.

5. While no immediate problem exists, concern was expressed about the uncertain future availability and price of cobalt. Attention was called by the airframe people to the increasing use of high strength cobalt bearing steels such as 9 Ni-4 Co for landing gear components and to cobalt bearing high speed tool steels used for drills and cutters. The engine people are worried about the high temperature turbine blade alloys. The latter are also concerned about the availability of chromium, columbium and tantalum for high temperature alloys. The development of substitute alloys containing lesser amounts of critical and strategic materials requires extremely costly and time-consuming experimentation involving both laboratory and engine testing, and this will not be done without government support.

The general viewpoint throughout the aerospace industry is that there are no constraints at present on any of the materials used by the industry, and none are foreseen before 1982. Due to the expected pickup in production of both civilian and military aircraft during 1982-83, materials shortages and very long lead times will be experienced. This could be very severe in the case of forgings and extrusions.

Aerospace materials people see the need for forging presses of larger capacity than currently exists in the U.S. It is felt that no single forging company can afford the huge capital outlay necessary to design and manufacture such equipment. If any are to be built, the Air Force would probably have to do it, as was done in the case of the 50,000 ton presses.

Opportunities exist for the research and development of alternative means of producing large shaped parts by powder metallurgy, hot isostatic pressing, superplastic forming and other lower energy methods. In view of problems experienced in obtaining forgings, extrusions and vacuum melted materials, it appears that an increased effort in R&D on materials processing is warranted.

Few of the problems listed above are materials problems per se. When discussing specific metals and alloy ingredients, I got generalized rather than specific comments. Everyone is concerned about possible future problems in the availability and price of cobalt, chromium, columbium, tantalum, titanium, etc. Some concern was even expressed about aluminum since its ores are largely imported from abroad. The titanium industry has been characterized by sharp ups and downs as major programs requiring large amounts of titanium are started up and then cancelled. The industry is understandably reluctant to embark upon large expansion programs without some guarantee that their products find a market. More Japanese and Soviet titanium sponge is now reaching the U.S. market and Chinese sponge is becoming increasingly available. This has eased the sponge shortage which existed a year or two ago.

While stockpiling of cobalt, chromium, tantalum and other alloying elements can solve the problem of materials availability for military products, the aerospace industry is very concerned about their commercial products. They feel that their non-military products will become increasingly vulnerable to fluctuations in materials availability and prices.

The names of the people I contacted during my telephone survey are listed in the enclosure. Most of them head up the M&P groups of their respective companies and have had long experience in the aerospace industry.

Very truly yours,

Abe Hurlich

A. Hurlich

cc: N. E. Promisel

Enclosure 1

Aerospace Industry Contacts

Name	Company	Position or area of interest
Dr. Morris Steinberg	Lockheed	Corporate staff asst.
Rodney Simmons	Lockheed-Burbank	Materials & processes
Donald Goehler	Boeing	" "
Dr. Robert Gassner	McDonnell-Douglas	" "
Roger Maples	McDonnell-Douglas	Head, materials procurement
Larry Korb	North American-Rockwell	Materials & processes
Alan Hauser	Pratt & Whitney	" "
William Owzarski	Pratt & Whitney	Mgr, Technical Planning
Dr. Ray Wojcieszak	General Electric	Materials & processes

CANNON-MUSKEGON CORPORATION

BOX 506 MUSKEGON, MICHIGAN 49443
616/755-1681 TWX 510/394/4620

Dr. Allen G. Gray
Technical Director
American Society for Metals
Metals Park, OH 44073

Dear Allen:

Your letter of 3 December 1980 invites suggestions as to possible activities or areas of involvement for consideration by the newly formed ASM Critical Materials Committee. One area of concern to me is the increasing involvement of the Government into the basic foundation of American success, the Free Market System. Whenever the nation suffers from material shortages, some segments of private industry actually seek and encourage more Government action through economic manipulation of the Stockpile supplies. If this Committee can serve any useful purpose, it can represent private industry and the basic American system of free enterprise. A free market, if left to operate, will be self correcting. It is happening today in the Cobalt market and will happen elsewhere also if left alone to function.

One of the initial charges in the new Public Law 96-479 is a specific materials need case related to national security, to be prepared by the Commerce Department. The initial study will be cobalt as a possible threat to security. Pursuant to this case, Dick Quigg and I met with the Commerce Department last 14 November 1980 and presented our thoughts relative to the Free Market, cobalt substitution, and specific recommendations relative to the application of the cobalt Stockpile. Subsequent to the meeting, our thoughts were summarized in writing. A copy of this summary letter is attached for your perusal. Perhaps this might stimulate an area for fruitful involvement of this ASM Committee.

Sincerely,

CANNON-MUSKEGON CORPORATION

Roger F. Schwer
President

RES/jm

Enclosure

CANNON-MUSKEGON CORPORATION
BOX 506 MUSKEGON, MICHIGAN 49443
616/755-1681 — TWX 510/394/4620

14 November 1980

U. S. Department of Commerce
International Trade Administration
Washington, D. C. 20230

Attention: Mr. Frederic W. Siesseger
Director
Resources Policy Division

Dear Fred:

Dr. Quigg and I appreciated the opportunity to meet with you and Mssrs. Todd and Jones on Thursday, 30 October 1980, regarding your study of U.S. dependence on cobalt imports at the direction of the National Security Council. The overall subjects of critical materials, National Materials Policy, and stockpile application are of particular interest to us at Cannon-Muskegon. Cobalt has relatively recently tended to receive most attention and is generally considered to be of great strategic importance. It should not be assumed, however, that cobalt is the only critical metallic element with which we should be concerned. Our nation is dependent upon foreign sources for many raw materials, several of which are more critical than cobalt and less easily substituted. This is a broad problem and there are no quick or easy answers. It is amazing, however, how relatively neatly the free market system, if allowed to operate, will sort things out and prioritize those key applications where the short supply material is required and cannot be readily substituted. This is happening in the cobalt market today; and, if allowed to operate, the market will balance itself.

I'll attempt in the subsequent paragraphs to organize and condense our comments relative to cobalt. Hopefully, this summary may be helpful and assist in clarification of some of our thoughts.

<u>Supply Considerations</u>

The combination of the relatively depressed state of the economy has reduced cobalt usage; however, more significant is the impact of inventory adjustment. As business cycles mature, inventories become imbalanced and recycle material assumes a greater share of the total usage, causing the requirement for virgin material to decline at an accelerated rate. These economic factors, combined with the significant substitution which has occurred, has resulted in an over-supply condition. This short term over-supply is expected to correct itself once inventory adjustment is completed...expected in early 1981. The long term outlook is for the over-supply condition to short term develop as additional new supplies come into the market from new and expanding producers.

Price Considerations

The historic price for cobalt has been two times (x 2) the price of nickel; cobalt's most competitive metallic element. At the present time, cobalt is over seven times (x 7.3) the price of nickel, which has caused significant economic dislocation and substitution to occur. The former balance will not be restored until the price is permitted to move freely. It should be assumed that over the long term, cobalt is largely interchangeable with nickel in nickel-base superalloys.

The two major producing countries (Zaire & Zambia) have, in my opinion, little to gain in the short term, which would encourage them to reduce the established price of $25 per pound. The governments of both countries have very serious and immediate cash income problems. The income from the copper and cobalt mines represent 95% of Zambia's export income and a similar share in Zaire. This income is needed to finance the countries' needs for basic commodities such as food and essentially all manufactured goods. These needs are immediate and, hence, the producer countries have little concern for long term market impact or deterioration. It was observed during my recent visit to Zambia that the most concerned people are the ex-patriots, or the minority white population. This small minority of technological experts are treated as temporary residents and are not regarded as permanent citizens. They are not entitled to citizenship nor will they ever be regarded as Zambians. The black Zambian population tend to be predominantly concerned with immediate needs of their country.

The existing over-supply is considered to be temporary, primarily a result of inventory adjustment by the market and secondarily a result of substitution successes. However, the artificially supported $25 per lb. price will economically justify expansion of worldwide cobalt production and eventually a cobalt glut will develop. This is perhaps five (5) years in the future.

In brief, I believe that the primary producers will strive to hold the $25 per lb. price level until the long term supply excess develops and price erosion occurs naturally. Meanwhile the two producing countries will have maximized their export incomes and bought additional time to develop the domestic agricultural industries and reduce dependency on the mining industry.

Substitutions

Significant substitution has occurred in all industrial segments, including aerospace and high temperature superalloys. Markets lost or significantly reduced include:

- automotive radio speaker magnets
- paints and dryers
- tool steels
- hard facing and coating
- wear resistant alloys

The major aerospace market for high temperature alloys is the turbine engine disc application. Several nickel-base alloys containing cobalt have been traditionally used in this heavy application, including Waspaloy (13% Co), Rene' 41 (11% Co) and Astroloy (17% Co). The engine designers are gradually changing the disc alloy to an established cobalt free nickel-base Alloy 718 (0% Co). This single substitution at Pratt & Whitney alone will reduce cobalt usage by an estimated 600,000 lbs./year starting about now. As years pass, the impact of this substitution will continue to grow as the smaller and older engines are phased out and newer designs utilizing cobalt free or reduced cobalt containing alloys are selected. It is considered feasible that superalloy cobalt usage could be reduced by 50% over the long term.

All substitution programs should be considered on a short, medium, and long term basis. Aerospace tends to be medium and long term in nature and also rather difficult and slow to switch back should cobalt price drop and availability become assured.

Research and Development

We know of no active research, alloy or market development programs which are targeted toward expanding cobalt base alloy usage. The only known exception to this statement is the rare earth (sumarium) cobalt magnet development which will potentially help to retain a market share (albeit reduced) for cobalt in the developing miniature electric motor requirement for automotive and appliance markets.

If the dearth of cobalt R & D expenditures continues, markets will continue to slip away and nothing will be developed to replace them. Cobalt usage could predictably slip to half of the previous usage level.

Stockpile Inventory Level

It is our understanding that the Federal Preparedness Agency is authorized a three year emergency inventory of critical materials. The present 40 million pound cobalt inventory is estimated to be about four (4) times the total present U.S. cobalt usage. In 1977, the agency increased the cobalt goal to 85 million pounds, a sum which would be about eight (8) times the present total usage. This increased stockpile goal does not appear to be justified by any measure of market usage.

Stockpile Purpose

The stockpile is intended to "meet the needs of National defense only and is not intended for economic and budgetary purposes,"....as apparently occurred in the 1970-76 period. It is my opinion that no regulatory agency can equitably judge market needs and control product prices better than the free market system. All previous attempts to adjust the stockpile and effect economic price influence has resulted in a "sell low and buy high" policy. Regulatory agencies should not, I believe, attempt to effect economic price control by adjusting the supply and demand balance. It creates an artificial imbalance and fails to shake out the less critical needs for the material in short supply.

Stockpile Quality

The cobalt which is in the current stockpile inventory is not suitable for the production of high temperature superalloys. The alloys of today require only vacuum grade electrolytic cathode cobalt metal which was not even being commercially produced when the stockpile was collected. The analytical methods of the time were not well established to identify and quantify the low level traces which could be disaster to the performance of a superalloy.

As we discussed, two recommendations were proposed:

1. Accurately analyze each lot of cobalt material, using a well respected analytical facility which is experienced in the determination of trace levels of the following important elements (very few laboratories in the U.S. have this capability):

   Pb; Bi; Sb; As; Se; Th; Cd; Zn; S; Hg; Ag

2. Once the trace and tramp element content is determined, a refining procedure could be established and the stockpile could be gradually upgraded to present day requirements. An ongoing program which would continually upgrade 10 to 15% of the inventory would assure that a portion of the stockpile would be available for immediate emergency use should the need develop. At this time, the Country is ill-prepared to meet any sort of emergency requirement from the stockpile inventory.

   Cannon-Muskegon has the capability to vacuum induction refine some grades of substandard cobalt and has demonstrated performance with the Chambishi brand material. This technique may not, however, be the best technique to refine all impurities which may be present in the stockpile cobalt. Until the exact quality is established, determining the best refining procedure would be speculation, at best.

In summary, our recommendations are as follows:

1. Do not increase the present stockpile quantity. Readjust the goal back to the present 40 million lb. level.

2. Upgrade 10 to 15% of the existing stockpile. It would first be necessary to accurately analyze the individual lots to determine what refining procedures might be most suitable. Some experimentation may be necessary.

3. Establish an on-going upgrading program to assure that a certain percentage of the stockpile is always of current superalloy quality and available should an emergency develop.

4. Encourage domestic development of cobalt mining capacity, if the product and process can be economically justified on projected cobalt prices of $10/15 per pound. In other words, remove environmental and ecological constraints but do not guarantee market economics.

5. Ignore the present economic imbalance created by the controlled prices established by Zaire and Zambia. The market will correct itself if left alone.

6. Do not use the stockpile for economic price control and market regulation. The free market will do this more efficiently.

Hope our comments were helpful. Please call if we may be of further assistance.

Sincerely,

CANNON-MUSKEGON CORPORATION

Roger E. Schwer

Roger E. Schwer
President

RES/jm

cc: Honorable James D. Santini, U.S. House of Representatives
Honorable Guy VanderJagt, U.S. House of Representatives
Honorable Carl Levin, U.S. Senate
Honorable Don Fuqua, U. S. House of Representatives
Mr. Tom Harkins, Special Metals Corporation
Mr. Don Furman, Howmet Turbine Components Corporation
Mr. Martin Smith, Cabot Stellite Corporation

ASARCO

Simon D. Strauss
Director

December 16, 1980

Dr. John B. Wachtman, Jr.
Director, Center for Materials Science
National Bureau of Standards
United States Department of Commerce
Washington, D. C. 20234

Dear Dr. Wachtman:

In response to your letter of December 11, I am setting forth on behalf of the Minerals Availability Committee of the American Mining Congress some concepts in relation to the National Materials and Minerals Policy, Research and Development Act of 1980. You point out that the Secretary of Commerce is required to identify and submit to the Congress "a specific materials need case related to national security, economic well-being and industrial production which will be the subject of the report." You then state that a Department of Commerce task group believes that the aerospace industry would be a good choice for the first study.

I should like to suggest a different approach -- one that would focus on a materials supply situation rather than a specific industrial needs component. My suggestion is that the case be focused on the problems arising from a group of essential industrial materials that are at present chiefly obtained by the United States either from southern Africa or the Soviet Union. These materials are chromium, cobalt, platinum metals, and manganese. Southern Africa and the Soviet Union are also dominant factors in the world production of vanadium, asbestos and gold. For these materials, however, industry in the United States is well protected through Canadian or domestic sources (in the case of asbestos and vanadium) and in the event of an emergency would have access to the U. S. Treasury's huge stocks of gold.

I attach a tabulation which is based on the most recent published information from the General Services Administration with respect to the strategic stockpiles of chromium, cobalt, platinum metals and manganese. From these figures it appears that holdings of chromium and manganese in the aggregate are in line with stockpile goals -- although the breakdown of individual categories shows deficiencies in such items as ferrochrome and ferromanganese.

ASARCO Incorporated 120 Broadway New York N Y 10005 (212) 732 9500

The picture is quite different for cobalt and the platinum metals. The stockpiles held are far below present goals. Under current market conditions the cost of bringing stockpiles up to the targets would be substantial. For example, cobalt is currently selling in the range of $20 to $25 a pound. Any attempt to purchase as much as 45,000,000 pounds might well cause prices to rise. Similar consequences would result from endeavors to acquire the platinum metals.

Serious efforts by major corporations are currently under way to develop cobalt resources in Idaho and platinum resources in Montana. In both instances work is being hampered and costs increased because of stringent environmental restraints. Whether these deposits will prove viable is not yet known. However, in both instances the private sector approaches might be encouraged and stimulated if the government would use existing authority under the Defense Production Act to offer long-term contracts to acquire stipulated quantities of materials at firm prices. Because of the volatile nature of both the cobalt and platinum markets, a major uncertainty facing a new producer of these commodities is a matter of price. In World War II, in the Korean War, and again to a limited extent in the Viet Nam conflict the government succeeded in expanding domestic capacity to produce materials through such floor-price contracts.

Domestic resources of both chromium and manganese were activated in World War II through the construction of government-owned plants operated at cost by the private sector. These resources are of poor grade and doubtful viability. Nevertheless should political or military developments make African and Russian resources unavailable, as a fall-back position the Departments involved under the 1980 legislation referred to should up-date information on these resources. They should have an emergency plan for reactivation on the drawing boards -- but not implemented.

There may be opportunities to identify resources of some of these materials in Alaska, where exploration to date has been limited. Alaska was a producer of platinum metals during World War II. Special attention should be given to these possibilities in the light of the restrictions on Alaskan land embodied in recent legislation.

Because of the limitations of time, I have not been able to clear this letter with my colleagues on the AMC committee. I am arranging to have a copy of this letter and of your letter to me circulated to the committee with the request that if the members have supplementary comments they forward them to the AMC, which in turn will pass them on to you.

Sincerely yours,

Simon Strauss

SIMON D. STRAUSS

Enclosure

cc: Mr. J. Allen Overton, Jr. - encs.

Table 1

FEMA's STOCKPILE GOALS AND (Desired Inventory Mix), May 2, 1980.
Compared to March 31, 1980, Inventories.

	5/2/80 Goal	3/31/80 Inventory
uminum Metal Group	7,150,000 ST Al	3,444,064
(Alumina)	0	0
(Aluminum)	700,000 ST	1,732
(Bauxite, Metal Grade, Jamaica Type)	21,000,000 LDT	8,858,881
(Bauxite, Metal Grade, Surinam Type)	6,100,000 LDT	5,299,596
uminum Oxide, Abrasive Grade Group	638,000 ST Abrasive Grain	263,292
(Aluminum Oxide, Abrasive Grain)	0 ST	50,904
(Aluminum Oxide, Fused, Crude)	0 ST	249,864
(Bauxite, Abrasive Grade)	750,000 LCT	0
timony	36,000 ST	40,730
bestos, Amosite	17,000 ST	42,534
bestos, Chrysotile	3,000 ST	9,958
uxite, Refractory	1,400,000 LCT	174,599
ryllium Metal Group	1,220 ST Be Metal	1,061
(Beryl Ore 11% BeO)	18,000 ST	17,987
(Beryllium Copper Master Alloy)	7,900 ST	7,387
(Beryllium Metal)	400 ST	229
smuth	2,200,000 LB	2,081,298
dmium	11,700,000 LB	6,328,729
stor Oil Group	22,000,000 LB	5,009,697
romium, Chemical & Metallurgical Group	1,353,000 ST Cr Metal	1,173,230
(Chromite, Chemical Grade Ore)	675,000 SDT	242,414
(Chromite, Metallurgical Grade Ore)	3,200,000 SDT	2,488,043
(Chromium, Ferro, High Carbon)	185,000 ST	402,696
(Chromium, Ferro, Low Carbon)	75,000 ST	318,892
(Chromium, Ferro, Silicon)	90,000 ST	58,355
(Chromium, Metal)	20,000 ST	3,763
romite, Refractory Grade Ore	850,000 SDT	391,414
balt	85,400,000 LB Co	40,802,393
lumbium Metal Group	4,850,000 LB Cb Metal	2,510,549
(Columbium Carbide Powder)	100,000 LB Cb	21,372
(Columbium Concentrates)	5,600,000 LB Cb	1,780,463
(Columbium, Ferro)	0 LB Cb	930,911
(Columbium, Metal)	0 LB Cb	44,851
pper	1,000,000 ST	29,048
rdage Fibers, Abaca	155,000,000 LB	0
rdage Fibers, Sisal	60,000,000 LB	0
amond, Industrial Group	29,700,000 KT	43,713,510
(Diamond Dies, Small)	60,000 PC	25,473
(Diamond, Industrial, Crushing Bort)	22,000,000 KT	23,692,702
(Diamond, Industrial, Stones)	7,700,000 KT	20,007,992
athers & Down	1,500,000 LB	0
uorspar, Acid Grade	1,400,000 SDT	895,983
uorspar, Metallurgical Grade	1,700,000 SDT	411,738
aphite, Natural - Ceylon, Amorphous Lump	6,300 ST	5,498
aphite, Natural - Malagasy, Crystalline	20,000 ST	17,911
aphite, Natural - Other than Ceylon & Malagasy	2,800 ST	2,802
line	5,800,000 LB	8,013,074
wel Bearings	120,000,000 PC	67,625,096
ad	1,100,000 ST	601,051
nganese Dioxide, Battery Grade Group	87,000 SDT	258,089
(Manganese, Battery Grade, Natural Ore)	62,000 SDT	255,078
(Manganese, Battery Grade, Synthetic Dioxide)	25,000 SDT	3,011

	5/2/80 Goal	3/31/80 Inventory
Manganese, Chemical & Metallurgical Grade Group	1,500,000 ST Mn Metal	1,974,247
(Manganese Ore, Chemical Grade)	170,000 SDT	221,044
(Manganese Ore, Metallurgical Grade)	2,700,000 SDT	3,379,342
(Manganese, Ferro, High Carbon)	439,000 ST	599,764
(Manganese, Ferro, Low Carbon)	0 ST	0
(Manganese, Ferro, Medium Carbon)	0 ST	28,920
(Manganese, Ferro, Silicon)	0 ST	23,574
(Manganese, Metal, Electrolytic)	0 ST	14,172
Mercury	10,500 Flasks	191,391
Mica, Muscovite, Block, Stained & Better	6,200,000 LB	5,203,930
Mica, Muscovite Film, 1st & 2nd Qualities	90,000 LB	1,270,845
Mica, Muscovite Splittings	12,630,000 LB	19,580,866
Mica, Phlogopite Block	210,000 LB	130,745
Mica, Phlogopite Splittings	930,000 LB	2,217,898
Molybdenum Group	0	0
(Molybdenum Disulphide)	0	0
(Molybdenum, Ferro)	0	0
Nickel	200,000 ST Ni + Co	0
Opium Group	130,000 AMA LB	71,303
(Opium Gum)	0 AMA LB	31,795
(Opium, Salt)	130,000 AMA LB	39,508
Platinum Group Metals, Iridium	98,000 TrOz	16,990
Platinum Group Metals, Palladium	3,000,000 TrOz	1,255,003
Platinum Group Metals, Platinum	1,310,000 TrOz	452,640
Pyrethrum	500,000 LB	0
Quartz Crystals	600,000 LB	2,423,036
Quinidine	10,100,000 Av Oz	1,800,343
Quinine	4,500,000 Av Oz	3,246,164
Rubber	850,000 LT	119,207
Rutile	106,000 SDT	39,186
Sapphire & Ruby	0 KT	16,305,502
Silicon Carbide, Crude	29,000 ST	80,537
Silver (fine)	0 TrOz	139,500,000
Talc, Steatite Block & Lump	28 ST	1,092
Tantalum Metal Group	7,160,000 LB Ta Metal	2,392,072
(Tantalum Carbide Powder)	0 LB Ta	28,688
(Tantalum Metal)	0 LB Ta	201,133
(Tantalum Minerals)	8,400,000 LB Ta	2,551,446
Thorium Nitrate	600,000 LB	7,146,327
Tin	42,000 LT	200,477
Titanium Sponge	195,000 ST	32,331
Tungsten Metal Group	50,666,000 LB W Metal	82,515,773
(Tungsten Carbide Powder)	2,000,000 LB W	2,032,942
(Tungsten, Ferro)	0 LB	2,025,361
(Tungsten Metal Powder)	1,600,000 LB W	1,898,911
(Tungsten Ores & Concentrates)	55,450,000 LB W	89,952,484
Vanadium Group	8,700 ST V Metal	541
(Vanadium, Ferro)	1,000 ST V	0
(Vanadium Pentoxide)	7,700 ST V	541
Vegetable Tannin Extract, Chesnut	5,000 LT	17,210
Vegetable Tannin Extract, Quebracho	28,000 LT	145,794
Vegetable Tannin Extract, Wattle	15,000 LT	16,398
Zinc	1,425,000 ST	375,946

Source: FEMA

CHROMALLOY AMERICAN CORPORATION WEST NYACK, NEW YORK 10994 · TELEPHONE 914 358-5900
TELEX 131490

RICHARD P. SEELIG
VICE CHAIRMAN EMERITUS

December 17, 1980

Dr. John B. Wachtman, Jr.
Director, Center for Materials Science
United States Department of Commerce
National Bureau of Standards
Washington, D. C. 20234

Dear Dr. Wachtman:

In order to respond effectively to your letter of 20 November and our prior telephone conversation, I have communicated with three members of the Critical Materials Committee. The purpose of this task force is to formulate a response to your requirements in an effective and accurage manner. Unfortunately, because of the holiday season and other factors, there has been some delay in obtaining the necessary data. I will communicate with you as soon as I have the information needed.

We are most anxious to cooperate with you on this project and appreciate your interest.

Very truly yours,

Richard P. Seelig

RPS:ms

CHROMALLOY AMERICAN CORPORATION WEST NYACK, NEW YORK 10994 · TELEPHONE 914 358-5900
TELEX 131490

RICHARD P. SEELIG
VICE CHAIRMAN EMERITUS

December 9, 1980

Dr. John B. Wachtman, Jr.
Director, Center for Materials Science
United States Dept. of Commerce
National Bureau of Standards
Washington, D. C. 20234

Dear Dr. Wachtman:

As per your request on the telephone with Mr. Seelig today, we are enclosing herewith a list of the names and addresses of the members of the Critical Materials Committee.

Very truly yours,

Marie Slinn

(Mrs.) Marie Slinn
Secretary to Mr. Seelig

Enclosure

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PRATT & WHITNEY AIRCRAFT GROUP

East Hartford, Connecticut 06108

18 December 1980

Mr. John B. Wachtman, Jr.
Director
Center for Material Science
U.S. Department of Commerce
National Bureau of Standards
Washington, D.C. 20234

Dear Mr. Wachtman:

The Pratt & Whitney Aircraft Group, United Technologies Corporation, would be most happy to assist in the case study required by the National Materials and Minerals Policy Research and Development Act of 1980. Our Company is one of the largest consumers of cobalt and titanium in the country and we could not build either military or commercial engines without these and a number of other materials such as chromium and tantalum.

Because of our absolute dependence on these materials, this subject has received considerable attention by our top management. I have enclosed three papers which provide a brief description of our views; one by Harry Gray to the House Committee on Armed Services, and one by Alexander Haig to the Mines and Mining Subcommittee. The third enclosure is my testimony to the Senate Science, Technology and Space Subcommittee in support of HR-2743.

We support the selection of the aerospace industry for the case study because it is dependent on all of the critical materials. Dr. William Owczarski, (203) 565-3508, who has Group-wide responsibility for all materials and manufacturing technology, will be our focal point if we can assist you in this study.

Sincerely,

PRATT & WHITNEY AIRCRAFT GROUP

R. C. Mulready

R. C. Mulready
Vice President, Technology

RCM:apm
Enclosures

UNITED TECHNOLOGIES

Industrial Capacity and Mobilization

Testimony by

Harry J. Gray

Chairman and Chief Executive

United Technologies Corporation

before

The House of Representatives

Committee on Armed Services

Washington, D.C.

September 17, 1980

Mr. Chairman and members of the Committee. Thank you for the opportunity to appear before you. I am Harry J. Gray, chairman and chief executive officer of United Technologies Corporation. In total contract volume, our company is the nation's third largest defense contractor. We provide the Defense Department with such products as jet engines, helicopters, advanced radar and command and control systems, and solid rocket boosters.

If there were a national emergency today, I seriously doubt that our nation could mobilize its industrial base in time to make an appreciable difference in sustaining a war effort. It might take as much as two years before we'd see any real increase in production of war materiel. And that's an optimistic estimate.

America's defense industry -- particularly the aerospace segment of it -- already is working at virtually full capacity. Factories are full and backlogs in many cases are at record levels. We're putting out just about all we can, right now.

Increasing capacity in times of national need does not mean simply switching from commercial to military production, or building new factories and filling them with workers, much as we did when we mobilized for World War II.

Many complex factors affect our ability to gear up military production, or production of any kind today.

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New manufacturing facilities are certainly one of the keys to increasing production. Today, it takes a company three and a half to five years to build a new factory of any size and get-it to full production.

If you're fortunate enough to find an existing facility to buy, it takes about a year to convert that facility, get machines in, train people, and produce just the first parts. It can take another year to two years to bring that factory to full capacity.

Building the plant and getting the equipment are only part of the job. During the Second World War, we brought in people who never before had worked in a factory -- farmers, clerks, housewives. They were trained -- in a matter of weeks -- to build aircraft engines. And they built thousands of them.

Today, however, you can't just take someone off a farm or out of a kitchen and expect him or her to build aircraft engines. The technology is too advanced, the tolerances too tight, the equipment too sophisticated. It takes three years for a machinist apprentice to complete his rigorous course. It takes the better part of a year to retrain someone from producing autos, for example, to work on high technology aerospace parts. The schools aren't turning out enough of these young people as it is.

If we were under full mobilization, with all the advantages the government can place, we <u>might</u> be able to squeeze 18 months out of the longest time it takes to get to full production in a new plant. But it wouldn't be possible to build a factory, train the people, and get the required high technology manufacturing tools we need in anything less than three years.

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One obvious answer is to convert commercial production to military production. Use materials for military products that would have been used for commercial products. Pull production workers off commercial jobs, and put them onto military jobs.

This is only a partial solution. Take as an example our Pratt & Whitney Aircraft Group, whose production of jet engines is split about equally between the commercial and military markets.

By turning off our commercial production, we'd be able to process the military material we had in hand much faster and produce the engines ahead of schedule. Initially, the Air Force and the Navy would see a surge in the number of engines they'd receive.

The same priorities that affected us would affect our suppliers, and material and parts for military engines would come into our plants more rapidly than currently scheduled.

We'd all be looking at raw material already ordered and in the pipeline, and we'd determine what could be converted from commercial parts to parts for the military engines. In some cases, that material is common to both. If the raw material hasn't already been converted into billets, say, for a commercial engine, it could be made into billets for a military powerplant. But if the billets have been made, it's too late to convert.

In addition, a large number of parts for high technology military engines contain material that isn't used in commercial powerplants.

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Even though there would be an initial surge in military production, as soon as the material in the pipeline was used up, military engine production would drop -- because of lead time.

In 1978, normal lead time for one of our military jet engines was 19 months. Today the Air Force has to order that engine 41 months before delivery. Certainly not all parts of the engine take more than three years. But critical parts, made from large titanium forgings, do. It doesn't take us any longer to build the engine than it did in 1978. All of the increase results from the availability -- and lead time --of certain critical materials, such as titanium.

Before 1978, there had not been any significant increase in lead time for that particular engine in at least four years. Since April of this year, though, its lead time has increased by five months.

Long lead time is an industry-wide problem. Our competitors feel it. Our suppliers feel it, and ultimately our customers feel it. Our ability to respond to national emergency suffers from it.

The availability of critical materials is one of the most crucial parts of the puzzle.

It is obvious that the United States does not have a rational non-fuel minerals policy. The threat is that we will be faced with a "materials OPEC" in certain metals. The first place we're likely to see the results of the squeeze is in national defense.

When it comes to certain critial materials the United States is a have-not nation. We are frighteningly vulnerable to overseas producers.

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For certain materials, such as chromium and cobalt, we are close to 100 percent dependent on overseas sources. Without chromium and cobalt, we couldn't build high-performance military aircraft engines. And remember that our primary sources of these critical metals are unstable or unfriendly nations. We don't mine any chromium ore in the United States.

Pratt & Whitney Aircraft is the largest single user of titanium in the world. The raw material that yields titanium is abundant on the earth's surface. But the industrial capacity to convert that raw material to what we need -- titanium alloys -- is woefully short. As a result of supply and demand, prices have shot up, and lead times have increased two-fold since 1977.

Another problem we face: the supplier network that forms the base of our country's defense industry is shrinking at an alarming rate. Since 1967, the number of companies involved in aerospace production has declined by more than 40 percent. In 1967, there were approximately 6,000 companies in the industry. Today, there are only about 3,500.

As a result of this drastic shrinkage in the number of suppliers, there have been dramatic increases in prices in this sellers' market.

To make matters worse, high costs in terms of capital and technological expertise are real barriers keeping new companies from entering such critical areas as closed die forgings of superalloys, sheet metal weldments, and the mining, smelting and production of critical raw materials.

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We are trying to ease our dependence on suppliers through material substitution, new processes, and long-term purchasing commitments. We're also entering agreements for new sources in other countries who are pushing to develop their own aerospace capability. But we can't be dependent on foreign suppliers in a time of national emergency.

You are all well aware that industrial productivity improvement in the United States is not keeping pace with that of other industrialized countries, such as Germany and Japan. Our plant and equipment are aging. We're not seeing innovation in new manufacturing processes at home that we're seeing abroad.

Increasing production to meet the requirements of a national emergency is a complex problem. It is not just affected by our ability to build new plants and equipment for production and to staff them with highly-skilled workers. It also is affected by political and economic forces outside of the United States over which we have no control.

The United States should move to meet these problems without delay.

First and foremost, I think, there must be mobilization planning at the government level. It's been tried before, but it seems that people lost interest.

Back in 1975, the military services and defense industry made some preliminary studies. Our company spent 18 months on a study of critical engine production. We determined how quickly we could deliver with, and without, industrial preparedness measures. We looked at mobilization planning costs and schedules, and what future mobilization work we'd have to do.

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Our report was submitted to the government, and virtually nothing has been done by the government since then.

Perhaps it's time to re-establish an office of mobilization planning, headed by a cabinet level officer, working closely with the Department of Defense and with industry. Such an office, at such a level of government, would be able to operate independently. It wouldn't have to face the conflict that could occur, say, in the Department of Defense, over whether to spend funds on procurement or on industrial reserves.

Second, it's imperative that we develop and implement a national minerals policy that will release this country from dependence on non-U.S. sources.

This policy should do all it can to encourage extensive exploration at home for sources of critical materials.

The government owns one third of the nation's land. These lands contain an estimated total of 85 percent of our oil reserves, a significant share of gas, timber and scarce minerals. We don't know for sure how much of these resources are being considered for wilderness designation. But we do know that if this land is closed to exploration, we'll never find out.

Third, we've got to increase our stockpiles of critical material. The Soviets are doing it, and the results can be seen in the marketplace. Equally important, we've got to cycle material in and out of our stockpile, so material will be kept up to date and it will become an integral part of the working defense production system.

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It's clear, too, that we need reserve capacity to produce the materiel we'd need in an emergency. But it would be counter-productive to have plants, machine tools and workers idle and waiting for the emergency that would put them to work.

Why not build up that capacity, train the workforce, and put it to work, building today what the military would need in an emergency tomorrow. Give the Air Force the planes it would need, man them with pilots, and support them with mechanics. In the long run, the costs of such a program might even be lower than that of holding capacity in reserve. And the nation would be prepared. I believe private industry would make the necessary investment in plant and equipment and in people. The reward would be worth the risk.

Finally, we must change the way we purchase defense hardware. As it is now, the procurement system penalizes investments for cost reduction, new process development, stockpiling of critical materials, and for productivity increases. Long-term profit incentives should be provided for industry to make the capital investments that improve productivity and lower the cost of government products. The current practice of negotiating from a lower cost base, after cost improvements, must be discontinued.

Industry loses its rights to proprietary processes used in government business. Government regulatory reporting requirements inhibit our operational decision-making. We are inadequately funded for long lead items. We are financially at risk for contractual coverage before contracts have been initiated.

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The Department of Defense should have some leeway in spending future dollars on high-priority items like spare parts. They shouldn't be tied to the one-year budget cycle, particularly now that lead times are pushing out to three years.

Finally, if America wants an adequate level of preparedness capable of reacting to a national emergency, there must be improved tax incentives now for business investment associated with the defense industry -- such as rapid accelerated depreciation for new plant and equipment.

The question of mobilizing our industrial base is a complex one. And there isn't any easy answer. But we must recognize now that we have a serious problem in the erosion of our defense industrial base. We must find the resolve to face up to it. As a nation, we simply can't afford to wait any longer.

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TESTIMONY by

Alexander M. Haig, Jr.

President and Chief Operating Officer

United Technologies Corporation

Mines and Mining Subcommittee

Committee on Interior and Insular Affairs

U.S. House of Representatives

September 18, 1980

Mr. Chairman and Members of the Committee. I am grateful for this opportunity to appear before you and to offer my views on our national plight on strategic materials. These views will reflect not only my limited recent experience as President and Chief Operating Officer of United Technologies Corporation, the nation's third largest defense contractor, but perhaps more importantly, some thirty-five years of public service in the national security area. The latter experience included 4 years duty with the National Security Council and almost five years as the Commander of NATO forces in Europe.

At the outset, Mr. Chairman, I should like to compliment you for the way you have drawn attention to the gravity of a problem of fundamental significance not only to the United States but also to those industrialized states worldwide sharing our values.

Personally, I have long been troubled by what is rapidly becoming a crisis in strategic and critical materials -- a crisis rooted in our own and our allies' dependence on imports for key materials.

The United States is inordinately and increasingly dependent on foreign sources of supply for many of the raw materials critical to our defense and our economy. In 1950, only 4 of the 13 basic industrial raw materials were imported in quanties of 50% or more. Today, we have reached that level of import for 9 of the same 13 materials. But as serious as the problem is to us, it is far more so to our industrialized allies and friends around the world. For example, the nations of the European Economic Community have total import dependence on ten strategic minerals and metals -- including manganese, cadium, cobolt and chromium. Japan imports 100 percent of 11 so-called strategic materials.

In the same context, it is significant to note that the Soviet Union has a comparable dependency -- (approximately 50 percent) -- for only three such materials and metals -- bauxite/alumina, barium and flouride. Conversely, the Soviets are net exporters of 20 materials, among which is chromium, platinum group metals, and manganese. The fundamental observation to be drawn from these strategic realities is that Russia is nearly self-sufficient in materials for which we and our allies must turn to external sources, many of which today are either unfriendly or unstable. Should future trends, especially in Southern Africa, result in alignment with Moscow of this critical resource area, then the USSR would control as much as 90 percent of several key minerals for which no substitutes have been developed and the loss of which could bring the severest consequences to the existing economic and security framework of the free world.

As one assesses the recent step up of Soviet Proxy activity in the third world -- in Angola, Ethiopia, Southern Yemen, Northern Yemen, Southeast Asia, Central America and the Carribean, and the December 1979 unprecedented invasion of Afghanistan by regular Soviet forces -- then one can only conclude that the era of the "resource war" has arrived.

The question of how best to deal with the ominous increase in direct and indirect illegal Soviet interventionism in the third world is clearly one for consideration in other venues. Nevertheless, our foreign policy in the Near and Middle East, and Africa, and elsewhere, has not adequately followed the new reality of free world raw material dependency.

Notwithstanding, in the realm of strategic materials there is an urgent need for the United States to provide "a natural resources leadership" both within the NATO alliance as well as among other friendly non-NATO nations. With respect to NATO, our leadership would emphasize that whether or not the alliance chooses to formally expand its boundaries to the areas of third world resource conflict, it will be increasingly and profoundly influenced by events within these areas.

If we are successful in this effort, the result will be expanding coordination within the Alliance leading to concerted assessments and policies beyond NATO's boundaries. The threat to NATO, our principle security framework, demands that if the Alliance is to continue as an effective organization, it must broaden its horizons. While it need not extend its mandate formally, improved coordination between its most seriously affected powers is an essential minimum. In this process, Washington must inspire, persuade, urge and cajole its partners to make the "hard decisions" free of bullying insensitivity.

But a favorable response from our allies depends on order in the American House. If we continue to appear impotent in dealing with our own resource problems, pretensions of international leadership will be derided.

Thus, we must also look within our own borders for part of the answer. We must seek domestic sources for non-fuel materials. There is simply too much at stake for America and the rest of the free world to rely heavily on overseas sources, many of them volatile, others with political systems inimical to ours.

From the standpoint of our national and international strategic interests, it strikes me as inconceivable that we would shut off opportunities to seek our domestic deposits of the strategic materials we need. Yet precisely that has been the effect, whether intended or not, of our federal land management policies. By the actions of our own government, fully two-thirds of our mineral lands have been withdrawn from possible exploration.

The government owns one-third of the nation's land. It is estimated that federal lands contain about 85% of our oil reserves and a large share of gas, timber, and scarce minerals. We do not know for sure how much of these resources actually exist on lands being considered for wilderness designation within the 50 states. One thing is certain: If this land is cordoned off from exploration, we'll never find out what minerals it can yield.

Many of us in industry were elated by passage of the Idaho Wilderness Legislation, providing for development of any cobalt resources discovered in the West Panther Creek area. We at United Technologies are appreciative, Mr. Chairman, of your leadership in this important legislative issue. This is truly landmark legislation. It recognizes for the first time that we can strike a balance between the need for domestic supplies of critical materials and for preserving and protecting our wilderness. This legislation could lead to production of cobalt in the United States for the first time in three decades.

We are also encouraged by the progress of the California Wilderness Bill, H.R. 7702, which has just cleared the House. The lands involved in California could provide potentially rich deposits of cobalt, nickel, and chromium. We strongly support this legislation. I hope most earnestly that it will be passed by the Senate during this session.

Sources of the strategic materials America needs have been developed so fully overseas because of the low labor costs and rich ore deposits found in those countries. But that doesn't mean such materials aren't available right here in the United States. The fact is, they do exist. And we should go after them.

To be sure, it will take huge capital investments to explore for and develop our own domestic deposits. The costs will be high -- for the same reason that it costs much more to extract oil from our shale deposits in the

West than it does to withdraw crude oil from the ground in the Mid East. But the price we will pay if we do not go ahead will be great indeed, striking at the very heart of our national security interests and our economy.

Another aspect of our domestic resource efforts should focus on conservation and substitution. Industrial users are bending substantial efforts to design strategic or critical materials out of their products. Take, for example, our company's Pratt & Whitney Aircraft Group, the world's leading builder of jet engines. Design in one of our military engines has been modified to replace a cobalt superalloy used for turbine blades with a cobalt-free nickel alloy. This change resulted in the saving of 65,000 pounds of cobalt last year in just one spare parts order. For our most widely used commercial engine, we are projecting that work in progress will reduce the need for cobalt by 30 to 35 percent starting next year.

Through stepped up conservation and reclamation, we are reducing our raw materials requirements considerably. With conventional forging practices, as much as 75 percent of the material is machined away into chips. Today, however, chips of alloy containing cobalt, titanium, nickel and chromium are carefully segregated and recycled.

But, while domestic substitutes and conservation are important, they cannot in the foreseeable future reach to the heart of the problem faced by the United States and its allies who must continue to rely excessively for essential materials from the third world "resource battlegrounds."

Mr. Chairman and Members of the Committee: There is no easy solution. There is no single route to the answers we seek. A non-fuel mineral policy for ourselves and our allies is long overdue. It must be built on a comprehensive, all embracing resource program whose essential elements include formulation of a non-fuel minerals policy of domestic and international scope and involving:

- Revitalized United States leadership within NATO and other industrialized states seeking concerted free world resource management.
- Stepped up exploration and development of domestic deposits in a way that achieves a balance between our vital resource needs and the necessity to preserve and protect our environment and wilderness areas.
- Accelerated efforts in conservation and substitution through the application of technology.

Thank you, Mr. Chairman

Draft Testimony for Science Technology and Space Subcommittee
Senate Commerce, Science and Transportation
July 2, 1980

Mr. Chairman and Members of the Committee...I am Richard C. Mulready, Director of Technical Planning for Pratt & Whitney Aircraft Group, a division of United Technologies Corporation. Pratt & Whitney Aircraft is pleased to have this opportunity to present its views on HR-2743, The Materials Policy, Research and Development Act. We strongly support HR-2743 and applaud the Committee's interest in acting on a Materials Policy Bill this year.

Pratt & Whitney Aircraft manufactures military and commercial jet engines powering our front line F-14, F-15, and F-16 fighters and most of the free world's commercial aircraft. Production of these engines requires significant quantities of materials such as cobalt, titanium, and chromium. Without adequate and stable supplies of raw materials, our production lines would shut down with serious employment, economic, and national security implications. HR-2743 will help to provide part of the answer to the nation's critical materials dependency.

Until OPEC got our attention in 1973, not many of us were consciously aware of our critical dependence on foreign sources for many of the raw materials on which our defense and the economy of the country are based. President Truman was worried about it, and the Paley Commission report in 1952 detailed the problem and recommended specific actions, but not much has been done in the three intervening decades. The problem is now even more acute, as the recent disturbances in Zaire and the Russian withdrawal from the titanium sponge market have demonstrated.

Of all of the critical materials, cobalt is probably the one for which the risk is greatest. As recently as last Thursday, an article in "The Wall Street Journal" described the continuing unsettled conditions in Zaire. Zaire provides about 55% of the cobalt consumed in the United States. The second largest supplier, Zambia, has, according to other articles in the press, recently agreed to trade cobalt to Russia for weapons. An interruption in the supply of cobalt would have a major impact on both our military and commercial engine and spare parts deliveries.

To illustrate the nature of our concern, let me outline for you the impact of a cobalt supply cut-off on U.S. airlines. To simplify the illustration, I'll limit the case to one part in one engine type.

> A major part of the world's airlines use our JT8D engine. In 1979, some 83 percent of the commercial flights in the United States were in aircraft equipped with the JT8D engine. On the average, these engines operate about 2,500 hours per year in these aircraft and the first turbine vane, which is about 60 percent cobalt, has a useful life of 10,000 hours before it is replaced.
>
> The pipeline for replacement parts is about twelve months long between our melting suppliers and delivery of spare vanes to the airlines. If we assume that the cobalt supply was suddenly

CUT OFF TO OUR MELTING SUPPLIERS, WE SHOULD BE ABLE TO CONTINUE SUPPLYING SPARE PARTS TO OUR AIRLINE CUSTOMERS FOR ABOUT A YEAR. AT THE END OF THAT TIME, THE JT8D FLEET WOULD START TO BE GROUNDED AT THE RATE OF 25 PERCENT PER YEAR.

THIS ILLUSTRATION HAS BEEN LIMITED TO ONE PART IN ONE ENGINE TYPE. THE FIRST TURBINE VANES IN ALL MANUFACTURERS' ENGINES ARE HIGH COBALT ALLOYS. IN FACT, ALL ENGINES WOULD BE AFFECTED, AND BOTH THE COMMERCIAL AND MILITARY AIRCRAFT PROGRAMS WOULD SUFFER.

RATHER THAN HAVE THIS HAPPEN IN THE REAL CASE, AN ACCELERATED EFFORT WOULD BE LAUNCHED TO USE LESS SATISFACTORY ALTERNATIVE MATERIALS, BUT THIS SUBSTITUTION WOULD TAKE TIME. IN ANY EVENT, A SIGNIFICANT DISRUPTION WOULD OCCUR TO THE NATION'S MAJOR TRANSPORTATION SYSTEM.

THE DEPARTMENT OF INTERIOR'S OFFICE OF MINERALS POLICY AND RESEARCH ANALYSIS PUBLISHED A STUDY LAST YEAR ENTITLED, "DEVELOPING A CRITICAL MINERALS INDEX: A PILOT STUDY," WHICH INDICATES THAT "COBALT IS THE MINERAL OF GREATEST RELATIVE CONCERN DURING THE 1979-84 PERIOD, BEING MOST SUSCEPTIBLE TO DISRUPTION IN 1980 AND 1981 AND HAVING A PROBABILITY OF DISRUPTION EXCEEDING 0.6 (60 PERCENT) IN BOTH YEARS."

THE STUDY ALSO ADDRESSES THE ECONOMIC IMPACTS OF SUPPLY DISRUPTION, LISTING SUCH FACTORS AS A NET RESOURCE LOSS, DIMINISHED REAL INCOME OF U.S. CONSUMERS, AND REDUCTION IN TOTAL CONSUMPTION. ACCORDING TO THE DEPARTMENT OF INTERIOR, DISRUPTION CAN BE MEASURED IN TERMS OF "THE COSTS OF LOST PRODUCTION RESULTING FROM REDUCED IMPORTS, INCREASED COSTS FROM EXPANDING LESS EFFICIENT U.S. PRODUCTION, THE COSTS OF SUBSTITUTING LESS COST-EFFECTIVE MINERALS, AND THE TRANSFER

OF U.S. WEALTH TO FOREIGN PRODUCERS BECAUSE OF HIGHER PRICES FOR REMAINING IMPORTED SUPPLIES."

IMPORT DEPENDENCY ALSO REPRESENTS A LARGE DRAIN ON OUR BALANCE OF PAYMENTS. IN 1979 WE SPENT ALMOST HALF A BILLION DOLLARS FOR IMPORTED COBALT ALONE. THE FEDERAL PREPAREDNESS AGENCY REPORTED IN 1978 THAT THE TOTAL COST OF ACHIEVING GOALS FOR THE STRATEGIC AND CRITICAL MATERIALS STOCKPILE WOULD BE OVER 11 BILLION DOLLARS. SINCE THEN THE GOALS HAVE BEEN INCREASED AND PRICES FOR NUMEROUS MATERIALS HAVE SKYROCKETED. THUS, THE FULFILLMENT OF STOCKPILE GOALS AND ANNUAL U.S. DEMANDS MET BY FOREIGN SUPPLY WILL CLEARLY FURTHER AGGRAVATE OUR NEGATIVE BALANCE OF TRADE.

A VARIETY OF PROGRAMS IS NECESSARY, IN OUR VIEW, TO DEAL WITH THE IMPORT DEPENDENCY. LOGICALLY, ONE OF THE FIRST STEPS IS TO ENCOURAGE DOMESTIC PRODUCTION OF STRATEGIC MATERIALS CURRENTLY IMPORTED IN LARGE QUANTITIES.

THE UNITED STATES GOVERNMENT OWNS AND CONTROLS OVER 55 PERCENT OF THE MINERALLY-RICH WESTERN STATES AND ALASKA. IN THE PAST, 90 PERCENT OF THE FEDERAL LANDS WERE AVAILABLE FOR MINERAL EXPLORATION AND DEVELOPMENT. TODAY--DUE MAINLY TO THE GROWTH OF THE WILDERNESS PRESERVATION SYSTEM--TWO-THIRDS OF FEDERAL LANDS NOW HAVE SIGNIFICANT RESTRICTIONS ON MINERAL ACTIVITIES. OVER 90 MILLION ACRES ARE CURRENTLY INCLUDED IN THE WILDERNESS SYSTEM OR ARE UNDER CONSIDERATION FOR DESIGNATION AS WILDERNESS AREAS IN LEGISLATION PENDING BEFORE THE CONGRESS.

We are most encouraged by the recent House/Senate Conference action on the Idaho Wilderness Bill (S-2009). This Bill is a landmark in that it recognizes for the first time the necessity to balance the need to develop domestic supplies of critical materials, with the desire to preserve Wilderness Areas.

Intelligent Government stockpile management is another key element in encouraging domestic production. The history of almost every Administration since World War II would indicate that this will be very difficult to achieve. Properly managed, the stockpile should act like an accumulator in a hydraulic system, storing material during slack demand to provide extra flow for the peaks.

To carry the analogy further, the line connecting this accumulator to the user is far too long, and it currently may not be useful at all. It could have been used to smooth the peak demands for titanium last year, but it was not. Properly managed, it can provide the incentive for domestic production which might not otherwise occur.

Substitution of less critical materials is an obvious partial solution to the problem. New designs which eliminate or reduce cobalt are already underway. For engines now in service, opportunities exist to replace cobalt-base alloys such as X40 or Stellite 31 with INCO 713 or a low cobalt alloy. However, even when a suitable substitute exists, an extensive program involving laboratory, rig, and engine testing is required to provide the needed substantiation for safety, durability, and performance requirements. This process

REQUIRES 30 TO 36 MONTHS, DEPENDING UPON THE SPECIFIC APPLICATION. WORK IN PROGRESS IN THIS AREA ON OUR JT8D ENGINE THAT POWERS THE BOEING 727 AND 737 AND DOUGLAS DC-9 FLEET WILL REDUCE COBALT REQUIREMENTS BY 30 TO 35 PERCENT PER ENGINE BY 1981.

IN ADDITION TO THESE SUBSTITUTION PROGRAMS, WE ARE ALSO CONDUCTING PROGRAMS TO REDUCE RAW MATERIAL REQUIREMENTS THROUGH IMPROVEMENTS IN MATERIALS PROCESSING, AND TO CONTROL AND RE-USE SCRAP WITHIN OUR INDUSTRY. AN EXAMPLE OF IMPROVED MATERIALS PROCESSING IS FORGING CLOSER TO FINISHED SHAPE TO REDUCE RAW MATERIAL INPUT. IN A CURRENT APPLICATION IN THE F100 ENGINE THAT POWERS THE F-15 AND F-16 AIRCRAFT, INPUT MATERIAL WEIGHT FOR NINE KEY PARTS IS BEING REDUCED BY A FACTOR OF TWO, FROM 1200 POUNDS TO 600 POUNDS BY NEARER NET SHAPE FORGING. YESTERDAY'S PRACTICE USED A 500 POUND FORGING TO PRODUCE A 116 POUND FINISHED DISK. TODAY THIS TURBINE DISK CAN BE HOT ISOSTATIC PRESSED USING ONLY 270 POUNDS OF INPUT MATERIAL. WITH CONTINUED DEVELOPMENT, THIS CAN PROBABLY BE CUT IN HALF AGAIN. I WOULD ALSO LIKE TO POINT OUT THAT TO MAKE THE KIND OF RAW MATERIAL SAVINGS I'VE DESCRIBED, A SIGNIFICANT CAPITAL INVESTMENT HAS TO BE MADE. A SINGLE HOT ISOSTATIC PRESS, FOR EXAMPLE, COSTS $8 TO $10 MILLION TO PUT INTO OPERATION.

CONSERVATION AND IMPROVED SCRAP RECLAMATION PROGRAMS ARE SIGNIFICANTLY REDUCING INPUT REQUIREMENTS. WITH CONVENTIONAL FORGING PRACTICES, AS MUCH AS 75 PERCENT OF THE METAL INPUT IS MACHINED AWAY INTO CHIPS. TODAY THESE CHIPS OF TITANIUM, COBALT, AND NICKEL BEARING ALLOYS ARE CAREFULLY SEGREGATED AND RECYCLED, REDUCING THE VIRGIN METAL REQUIREMENTS BY AS MUCH AS 65 PERCENT IN SOME CASES.

Over the long term, it now appears possible to develop complete new families of alloys for jet engines which contain neither chromium nor cobalt. This work is in an early research phase and is known as RSR, which stands for rapid solidification rate. Powder is produced in a system with cooling rates in the order of a million degrees per second. In this rapid cooling process, it has been possible to produce true alloys of nickel, molybdenum, and aluminum, for example, and that material is the one that Dr. Perry talked about. It looks like a very good candidate for some turbine blades in the future.

With conventional practice, these elements would remain segregated. These new alloys show promise for hot section application. Significant use of these new materials is probably ten years away, so it is not a short term solution to our material shortages.

The materials crisis is like a jig-saw puzzle. Land withdrawal, conservation, recycling, stockpiling, research and development are all pieces of the puzzle. They must be dealt with in a coordinated, integrated manner or the puzzle will never be solved. The Materials Policy R&D Act is the outline of the puzzle. Once in place, it will provide a framework for future materials legislation and greatly aid efforts to address long-range materials needs.

Pratt & Whitney Aircraft and the United Technologies Corporation endorse HR-2743 and hope that it will be enacted this year. Prompt and positive action by the Science Technology and Space Subcommittee, the full Commerce Science and Transportation Committee, and the Senate will put the long-awaited process into effect.

Thank you.

United States Council of the International Chamber of Commerce Inc *1212 Avenue of the Americas New York NY 10036*

United States Council

December 23, 1980

Mr. John B. Wachtman, Jr.
Director
Center for Materials Science
United States Department of Commerce
National Bureau of Standards
Washington, D.C. 20234

Dear Mr. Wachtman:

Confirming our telephone conversation, I would like to take this opportunity to convey the comments of members of the U.S. Council's Natural Resources Committee on the proposed materials needs case study being conducted by the Department of Commerce.

A majority of those with whom I spoke concurred in the selection of the aerospace industry as the first sector to be studied. One member suggested that this study be broadened to encompass those energy-related industries which produce turbine blades (e.g. for gasoline refining) which require the same type of cobalt as that used in jet engines.

As for future studies, our members suggested the following possibilities:

(1) the automotive industry
(2) the shipbuilding industry

Several individuals expressed an interest in further cooperation with the Commerce Department, and in this regard, we look forward to receiving additional information on the study, as well as an indication of more specific areas where we could be of assistance.

Sincerely,

Jacqueline A. Keith
Manager
Energy/Consumer Affairs

JAK:cr

Telephone: (212) 354-4480

Telex: USCOUNCIL 14-8361 NYK

ASARCO

Simon D. Strauss
Director

January 21, 1981

Dr. John B. Wachtman, Jr.
Director, Center for Materials Science
National Bureau of Standards
United States Department of Commerce
Washington, D. C. 20234

Dear Dr. Wachtman:

Assistant Secretary Jordan J. Baruch has written me regarding the notice recently published in the Federal Register announcing the workshop planned for February 9-10. He has suggested that I write you in regard to the questions posed for the workshop and also that I may wish to take part in the workshop itself.

Due to prior commitments I will not be able to be in Washington on February 9-10. I am, however, pleased to add to the comments in my letter to you of December 16 written in my capacity as chairman of the Minerals Availability Committee of the American Mining Congress.

I have noted with interest press reports of the testimony of Secretary Baldrige before the Senate Commerce, Science and Transportation Committee at the time of his confirmation hearings. He is quoted as regarding the strategic minerals problem facing the United States as "very serious". He added that the issue has been "studied sufficiently" and is calling for action to ensure that sources of supply are stabilized.

These comments are quite applicable to your workshop. Most of the questions you have posed were dealt with in the Non-Fuel Minerals Policy Review. The Bureau of Mines individual commodity summaries contain the needed basic information. The Commission on Supplies and Shortages in 1976 made a detailed evaluation of these problems.

Rather than consume time and effort in once again collecting well-known facts, I would think that the Commerce Department should already have the capability to submit a defined program to the Secretary now. For example:

ASARCO Incorporated 120 Broadway New York, N. Y. 10005 (212) 732-9500

Cobalt is obviously a problem. It is essential for the aerospace industry since it is used in the production of jet engines. The cobalt stockpile now contains less than half the objective. The present major sources of cobalt are two African countries -- Zaire and Zambia -- faced with major political and economic problems. There is a potential for production of cobalt from a domestic source -- Idaho. The Defense Production Act contains authority to create or expand domestic materials capacity.

Should not the government therefore now proceed to discuss with the potential Idaho cobalt producers what they need in the way of encouragement to equip their deposits for production? At a guess, they might well respond favorably to a contract establishing a "put" or floor price for their expected production over a period of several years -- say, two to five.

If money is needed to facilitate such a program, then the Secretary should so report to the Congress. Why wait until October 21? Would not the Congress be impressed by a quick response?

Your workshop will not develop any facts in regard to cobalt that differ from the above. I suggest action rather than study.

Sincerely yours,

Simon Strauss

SIMON D. STRAUSS

cc: The Honorable Jordan J. Baruch

ASARCO

Simon D. Strauss
Director

January 30, 1981

Dr. John B. Wachtman, Jr.
Vice Chairman
Department of Commerce Task Force on PL 96-479
National Bureau of Standards
Department of Commerce
Washington, D. C. 20234

Dear Dr. Wachtman:

In response to your letter of January 26, I will not be able to attend the Department of Commerce Workshop on Critical Materials Needs of the Aerospace Industry to be held in Gaithersburg on February 9 and 10.

I believe Mr. James Beizer of the American Mining Congress staff has advised you that David Swan, Vice President of Kennecott, a member of the AMC Committee on Minerals Availability, will participate and will be prepared to make supplementary remarks on behalf of the mining industry.

Sincerely yours,

Simon Strauss

SIMON D. STRAUSS

cc: Mr. David Swan
Mr. James Beizer

ASARCO Incorporated 120 Broadway New York, N. Y. 10005 (212) 732-9500

DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
WASHINGTON, D.C. 20590

JAN 23 1981 REFER TO:

Dr. John B. Wachtman, Jr.
Director, Center for Materials Science
United States Department of Commerce
National Bureau of Standards
Washington, D.C. 20234

Dear Dr. Wachtman:

In reply to your letter of January 13, 1981, I have reviewed the Notice, Definition of Aerospace Industry Materials Needs, and would like to suggest that consideration be given the following points:

1. A generic problem in this country today is the lack of processing capability for highly advanced materials and composites. It is not the lack of the basic materials themselves that causes (or has the potential for causing. . .) material short falls. A few examples will illustrate this point: (a) In the processing of titanium forgings for critical aerospace components, it is the lead time associated with part design, master forge development, and associated industry capacity to deal with such problems economically, (b) processing technology for rapidly solidified powder metal alloys is not yet capable of producing sufficient volumes of powder to be considered economically feasible, (c) high-strength components such as the parallel continuous glass fiber epoxy composites are not yet commercially available owing to the lack of high-production rate processing equipment.

2. Consideration should be given to developing an understanding of the problems that tend to inhibit the growth of critical process technology and the rapid commercialization of such processes. National policy must be able to accommodate rapid development of critical processes. Emphasis should be placed on accelerated support for such critical processes in both the defense industry and the transportation industry.

Sincerely,

Gregory T. Haugan

Gregory T. Haugan
Director
Transportation Programs Bureau

(The following was dictated telephonically by Dr. James Boyd on January 29, 1981.)

Dr. John B. Wachtman, Jr.
Director, Center for Materials Science
National Bureau of Standards
Washington, DC 20234

Dear Jack:

This is in response to Secretary Baruch's letter of January 15 regarding the Materials and Minerals Policy Act of 1980, PL 96-479. By way of a brief background, I have served as Chief of the Minerals Branch, Commodites Division of the Army and Navy Munitions Board, 1941-42. I chaired the interagency committees on aluminum and copper aside from my regular duties involving strategic minerals. On the reorganization of Army in 1942, I became the Army's representative to the predecessors of the War Production Board and that Board's Program Adjustment Committee dealing with all materials. Concurrently, I sat on WTB international committees on copper, etc.

Following World War II as Director of U.S. Bureau of Mines, I sat on the interdepartmental committee on stragegic materials. For the following 20 years as an executive in two copper companies, I served on several Government committees involving minerals. Since retirement from industry in 1971, I have served on NRC committees and boards; as Executive Director of the National Commission on Materials Policy reporting in 1973, and Chariman of OGA's Minerals Advisory Committee, etc. I have had experience with many aspects of materials policy over a 40-year period.

The following are general comments put together in a hurry; however, I did not get Dr. Baruch's letter until January 20, and I have been traveling on materials matters since then. I trust they will be of value to you. I regret that previous commitments prevent me from attending your meetings.

A. The minerals cycle is a highly complex resource, economic and political system in constant state of flux. This requires policies which are flexible enough to react quickly to change in any obvious phases. Policy adopted by Government must therefore be such that the system can react quickly to changes in political, scientific, and economic conditions. In other words, to the marketplace and strategic plans. This system is so complex that it cannot be handled satisfactorily by bureaucratic decision making. Such guidance tends to slow down the process and distort the markets. Even in states of national emergency, the decisions must be left up to those operating its details as they are the first to see changes coming and can take immediate action.

B. In regard to the areas for discussion at the meetings:

1) There is a tendency to put too much effort into fine-tuning supply and requirements data. Important as it is to know orders of magnitude, market conditions and technological developments are so volatile that policy tied to detailed estimates can do more harm than good.

2) This is even more true for engineered materials and forms. Effort needs to be focused on producing an economic and regulatory climate in which the materials system can operate more satisfactorily.

3) R&D in materials and publication of results is the source of material information for those who must make adjustment to potential shortages or changing technological needs. Attempts to dictate substitutes are a waste of time. The Bureau of Mines' development of processes to bring titanium, zirconcum, and electrolytic manganese to the threshold of economic development are the best examples. A running catalog of material characterization would be a better policy.

This includes processes as well as material specifications. Processes need demonstration. Such things can sometimes but not always be done by Government.

C. Concerns to be addressed:

1) Fine-tuning requirements in this context is a waste of time. It diverts attention from the policy and planning efforts. It is time-consuming and short-lived as the figures will change before the ink is dry. A catalog of material properties and processes, constantly advancing and available to planners in and out of industry, would support the policy more effectively than attempts to identify and meet specific needs. There are innumerable examples of bad timing and errors in judgement in the current stockpile program of accummulation and disposal which have damaged the achievement of long-range goals.

2) Up-to-date published documents such as the "Minerals Yearbook" and "Minerals Facts and Problems" properly staffed is essential to this need. This is not an expensive operation. It needs to have its presence through mineral attaches in the embassies augmented. World statistics brought up to the level of those produced by the Bureau of Mines is an important element if our information base is to be made clearer. The trade is capable of detecting weaknesses in supply before they become serious.

3) Disruptions to any link in the supply chain are difficult to discover if the observer is not directly involved. The U.S. commercial system through customers or the Government agencies if they are the customer is better able to detect pending shortages than any other Government agency. If the market for a specific

item is too small to warrant the private construction of the facility and the item is vital strategically, the Government must provide the market for that material or material form by negotiation. This is no different from that which is done every day in the market place. Uninhibited by Government interference, these things get done by one means or another and more surely than they do through Federal planning. The materials industries provide examples of this every day. Government policy should be directed in all of those phases to create the climate in which this system works. The Government should itself use the economic system rather than resort to long-range planning.

D. Specific Materials: The aerospace industry is a good example of an industry which has the Government as a major customer and in which the most supply problems arise. This is largely due to limited markets for technologically sophisticated items and specifications for those items which have limited sources both of materials, forms, and shapes. No one is better able to detect shortages or long-range bottlenecks than the constructing agencies. Policy should give them the tools to make corrections to cure specific needs and not make general unfocused policies and programs.

I shall not attempt to get into the specifics of which materials to study. Your committee will be more knowledgeable.

E. Potential Action Policies

1) Improvement in the materials production base: If this must be done by the private sector, improvement can be stimulated by Government by improving the economic climate within these industries and involve:

a) A tax structure that does reflect risks as a cost.

b) Detailed regulation of processes and procedures.

c) Regulation that puts the burden on regulatory agencies and away from the ultimate responsibility of management and labor.

d) Encouragement of capital formation.

e) Environmental regulations which depend on individuals to enforce and does not leave it to management and the courts. Fining for violations of specifics are the worse source of enforcing mechanism.

2) Stocking should benefit from past abuses and should set the taxing structure to encourage private stockpiling at the point of use. This would tend to keep the stockpiling needs up to date and bring about automatic reaction to changes in need. The Swedish system is an example to be followed.

3) Federal agency allocation should be installed as a last resort and then administered directly with industry participation.

4) No comment.

5) Conservation and recycling eventually depend on the market which enforces it through the return to be realized. Attempts to plan and enforce either have not been too successful. Government procurement agencies can accelerate recycling by providing a market for these specific materials, and specifications which include conservation practices would be helpful.

6) R&D is a specific question and covers the basic principles involved throughout the Government. The Federal Government should encourage

the private sector to take the risks involved by recognizing it as a cost of doing business either for the Government or the private economy. Looking ahead for the markets such as the above mentioned titanium, zirconcum, and electrolytic manganese programs, the larger needs in such things as mining research require close cooperation between the extraction and manufacturing industries, the academic and research installations, and the Federal Government. They cannot be carried out except in active mines and as the results are needed by all members of industry, they must be a joint effort.

I regret that time did not permit me to edit the letter. If the effort is to continue under the new leadership, I would be happy to sit in.

Sincerely,

JAMES BOYD

JBOYD:lp:29Jan81

FREEPORT

Freeport Minerals Company
200 Park Avenue
New York, N.Y. 10017

Telephone
(212) 578-9200

January 30, 1981

Mr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Bldg. B-308
Washington, D.C. 20234

Dear Mr. Wachtman:

In response to the Department of Commerce request for comments on critical materials, as well as participation in a workshop on February 9-10, 1981, we would like to respectfully submit the following.

Freeport Queensland Nickel, Incorporated, a subsidiary of Freeport Minerals Company, currently operates a nickel/cobalt mine and treatment facility in Queensland, Australia as part of a joint venture with an Australian company, Metals Exploration Queensland Pty. Ltd. Freeport Minerals is, of course, vitally concerned with the dependence of the United States on the import of cobalt. Any adverse developments in Zambia and Zaire, which supply over 70% of the cobalt consumed in the U.S., could have a serious effect on our U.S.A. aerospace industry.

Given our role as an established cobalt producer and our general interest in strategic metals, we would appreciate the privilege of attending the February 9-10 workshop in Gaithersburg, Maryland sponsored by the Department of Commerce. We would hope to gain further insight into the critical need areas of the metal industry and communicate that information to our management.

Very truly yours,

WTJoyce

Walter T. Joyce

WTJ/jek

Allegheny Ludlum Industries, Inc.

TWO OLIVER PLAZA, PITTSBURGH, PENNSYLVANIA 15222

E. F. ANDREWS
VICE PRESIDENT-MATERIALS AND SERVICE
412-562-4250

January 30, 1981

EXECUTIVE AND GENERAL OFFICES
AREA CODE 412 PHONE: 562-4000

Mr. John B. Wachtman, Jr.
Vice Chairman
Department of Commerce Task
Force on PL 96-479
United States Department
of Commerce
National Bureau of Standards
Washington, D. C. 20234

Dear Mr. Wachtman:

Thank you for your letter of January 26 and invitation to participate in the Workshop. I look forward to the opportunity.

Enclosed is a copy of a paper that I had prepared in response to Jordan Baruch's letter of January 9.

Again, many thanks.

Sincerely yours,

E. F. Andrews

mjh

Enclosure

cc: Mr. Jordan J. Baruch

A NATIONAL MATERIALS POLICY FOR A DESTABILIZED WORLD

I have devoted most of the last 30 years working in and being concerned about the materials supply problems of my company and my country. For many years, I have been calling for a national materials policy and a higher profile on this general subject. I believe it is finally beginning to move to the top of the national agenda, and I am very pleased to have it do so. In the past decade, we have gone through the National Materials Policy Commission, National Commission on Supplies and Shortages, and the interagency study of the materials problem. But nothing much occurred to change the collision course of which the Paley Report gave timely warning. Nothing much, that is, until what can be milestone legislation cleared Congress last October.

Chromium presents a good example of why such a policy is needed. The United States has virtually no chromium indigenous to this country. But at the same time, we were in an accelerating, high level of consumption, we passed a group of environmental laws that virtually mandated an additional increase in the consumption of chrome to make the clean air and clean stream equipment and converters on our automobiles. After we had mandated this increase in the consumption of chrome, we then unilaterally, in another part of government, placed an embargo on the importation of chromium from what was then our largest supplier, Rhodesia. At the same time, we applied stricter environmental enforcement on the antiquated ferrochrome industry, reducing its productive capabilities. Also at the same time, we allowed unlimited export of stainless steel scrap, each ton of which contained 400 pounds of chrome. Truly, a good example of the need for a coordinated materials policy.

A brief look at history, and particularly at some events and developments that occurred in the lifetimes of most of us here, will help explain and in part define our present national predicament in this matter.

America had all the resources it needed from the outset of its nationhood and through its first 150 years or so. It was singularly blessed with timber, water, iron, coal, copper, petroleum, and much more---adequate for the American economy of those days.

That happy condition began to change markedly after the First World War. It was not that we exhausted our resources but that new materials were required by our industrial society: rubber, for instance, as we realized with a shock when, in the Second World War, the Japanese overran southeast Asia.

The explosion in technological development during and after that last global war has meant unprecedented advances in the quality of our national life and has wondrously transformed older industries and brought new industries unimagined only decades ago. But that explosion also put an end to our historic self-sufficiency.

We are import-dependent, in whole or in part, on a long list of minerals without whose assured and long-term supply we cannot function in the industrial sense. I am not speaking here of oil, for that is a topic which has not wanted for attention, but of non-fuel minerals: chrome, cobalt, manganese, platinum-group metals, nickel, tin, tungsten, and a score or so more.

Beyond technological development at a constantly accelerating rate of sophistication, the minerals predicament was enormously complicated by vast world-wide political changes. these included "decolonization" by the old Western imperial powers and the emergence of Third World nations. And it so happened that Providence chose to endow a number of the Third-World nations, particularly those in southern Africa, with minerals on which we are most dependent.

However salutary certain global political changes may be in the historical annals of self-determination, they have meant, to say the least, a destabilization of minerals access.

Now, as we venture further into the topic of non-fuel minerals, it would be well to avoid two extremes of mental attitude.

First, there's the attitude of blind faith in technological miracles. We solved the World War II rubber crisis in short order, didn't we? We put a man on the moon, didn't we? Surely we can make cobalt or chromium out of straw or who-knows-what when the crunch comes!

The fallacy of such gee-whizery lies not in any essential deficiency of technological research and development. Lord knows we've seen astonishing developments that have altered dependence on minerals. Consider what frozen foods have meant in respect to tin cans. Or the laser and satellite communications in respect to copper wire. Yes, there will surely be technological developments at some unforeseen time that will reduce or perhaps eliminate our present dependence on one or more strategic minerals.

But the point is precisely that the time is unforeseen. Time is at the heart of the problem. What presses for immediate attention and coordinated action is getting America from now to, say, 1990 or 1995. Wonderful indeed if we are mining the moon in the next century. But what can be done to mine the earth and have assured access to its mineral treasures in the next five, ten, fifteen years?

Secondly, I recognize that there some authorities who are concerned that we may be consuming basic resources of this world at a faster rate than we should. I do not wish to get into that argument.

however, I am one who believes that the world is not really running out of raw materials. It has been said that the first pound of copper ever discovered in this world is probably still here somewhere. Of course, all and everything are finite. If somehow or other, we consume or destroy until there is no place to stand on this planet, then I guess we could say the raw materials are gone. But I do not believe that is within our time frame of thinking. I do not anticipate that we are likely to encounter any serious natural constraints on the existence of raw material, at least in the next 25 to 50 years and possibly 25 decades. In the case of those raw materials that may run out, if there are any, we will merely let the system work as we reach deeper into the bowels of the earth for less yielding ores. Costs will rise. As the cost to extract these materials rises, the price to the consumer will rise. As the price rises, consumers will be forced to design away; and by the time the supply is exhausted, the need for the product will be gone also. It really is a self-correcting system, if we will just let it alone and let it happen.

Avoiding then either extreme -- the one of blind trust in instant technology, the other of resource-despair -- let's look at the situation in four just basic minerals.

First off, there's <u>chrome</u>, indispensable to the manufacture of stainless steel, ball bearings, and surgical equipment. This country has virtually no indigenous chrome. The world's reserves of it lie almost entirely in southern Africa -- in the Republic of South Africa and in Zimbabwe, the former Rhodesia.

Then there's <u>cobalt</u>, essential to jet-aircraft engines, machine-tool bits, and permanent magnets, to name some broad categories. We import 98 percent of our cobalt, the bulk of it from Zaire, the former Belgian Congo. Guess which nations account for a big share of the world's reserves, after one totals Zaire's and Zambia's? Our not-so-well-wishers, the Soviet Union and Cuba.

Next, there's <u>manganese</u>, without which you can't have steel, period; and for which we are almost wholly import-dependent. Of the world's present reserves of manganese, the U. S. Bureau of Mines estimates that southern Africa accounts for some 40 percent and the Soviet Union for 50 percent.

Finally, there's the <u>platinum</u> group of metals, on which we are more than 85 percent import-dependent for the manufacture of catalytic converters and a variety of electronic and chemical products. Roughly three-quarters of platinum-group reserves are in South Africa and about one-quarter in the Soviet Union.

This recital indicates why the four I have chosen out of a much longer list surely quality as "strategic" and why the reliability of their supply is less than reassuring. You also see why the Soviet Union already holds a powerful position from which to conduct a "resource war" and why southern Africa has been aptly called the "Persian Gulf of Metals."

The hallmark of such strategic minerals is their pervasive use throughout a modern industrial economy. Let us suppose, for a moment, that somebody in Detroit or any other American city were to say, well, in a pinch we could make do without chrome or cobalt.

Make do? Without these you couldn't build a jet engine or an automobile, run a train, build an oil refinery or a power plant. You couldn't process food, under present laws, or run a sanitary restaurant or a hospital operating room. You couldn't build a computer, clean up the air and water, and on and on.

The four minerals I've mentioned, plus others which we must import, impact intensely on our national defense -- for what defense could there be without planes and tanks and missiles? They impact intensely on our basic industry and on our quality of life, as shown by some of the specifics I've cited, and on the employment of our work force. With regard to jobs and national output, listen to what Helmut Schmidt, Chancellor of West Germany, has said about his country of some 60 million people. If you cut off West Germany's chrome for a year, according to Schmidt, there would be two-and-a-half million people unemployed and a drop in the GNP of 25 percent. Translate this in terms of the American economy and you have a "crises" by the most conservative definition of that term.

Such are the broad outlines of our mineral dependence. What can we do to alleviate it or at least render it less precarious?

One thing we can and must do is stop commissioning studies that come to nothing. What we need are studies upon which we are determined to act. Happily, a solid start in that constructive direction was made in the closing weeks of the last Congress. It was then that the lawmakers passed, and the outgoing President signed, what is formally known as the National Materials and Minerals Policy, Research and Development Act of 1980.

The Act declares, and I quote, "that it is the continuing policy of the United States to promote an adequate and stable supply of materials necessary to maintain national security, economic well-being and industrial production with appropriate attention to a long-term balance between resource production, energy use, a healthy environment, natural resources conservation, and social needs." It sets forth a comprehensive list of steps to be undertaken by Executive departments and agencies in line with the Act's objectives and calls on the President to submit to Congress within a year of the law's enactment a "program plan" -- including budget proposals and organizational structures.

Against the background of this promising start, some general comments and recommendations on certain aspects of a future program may be in order.

1. We need a coordinating mechanism, operating immediately under the President. Let us call it, for the sake of hypothesis, a National Non-Fuel Minerals Board. It should have full authority to cut across departmental jurisdictions in the interest of designing and carrying out a total and consistent minerals policy.

As part of the Executive Office of the President, the N.N.M.B. would coordinate and mitigate programs, tasks and analyses among the various agencies relating to the security of strategic minerals supplies. It would also recommend actions for the President, Congress and other Executive agencies.

It would add no new bureau or department but would combine the in-place functions of one each from State, Treasury, Defense, Commerce, Interior, Transportation, Labor and Energy.

2. To facilitate private sector advice, I would establish the President's Resource Advisory Board (PRAB) -- modeled after the structure of the former "President's Foreign Intelligence Advisory Board," i.e. limited term membership of distinguished experts from relevant fields, in this case from the mining, minerals production and end user industries; plus the fields of labor, environmental studies, regulation impact, investment banking and geopolitical/national security affairs.

3. We need a thorough inventory of our nation's reserves and resources in strategic and other minerals -- a reliable data base, in other words. Specifically, this need concerns what is or may be available as reserves in America's public lands.

The Federal Government owns about one-third of the U. S. land area, mostly in the West and Alaska. In 1968, the amount of this land withdrawn from mining and exploration -- and my own concern at this point is with exploration -- came to 17 percent. Eight years later, the figure was almost 70 percent!

As an Interior Department official noted at the time, the withdrawal for conservationist purposes "is being done too often without detailed knowledge of the existing mineral potential of these lands." At the very least, I would add, Americans have a right to know what resources of theirs have been locked away and are being locked away and why!

4. We need to internationalize the capabilities of the U. S. Bureau of Mines to assess supplies of minerals. The data base provided by the Bureau in this country -- with respect to those areas where it may freely operate -- is the best in the world. But the minerals problem is worldwide in scope, and so the data base should be as worldwide in scope as international political conditions allow.

The new public law recognizes this need by directing the Secretary of the Interior to promptly initiate actions aimed at improving the Bureau's capacity in an international sense. A decided improvement, it should be noted, could be effected by stationing a total of 20 to 30 Bureau experts in a few select countries.

5. We need a total reassessment of our present defense stockpile -- amounting, at today's inflated prices, to about $12 billion -- and we need new policies concerning it.

The reassessment should be made in the light of such considerations as quantity, quality, and mix. Are we too short on this and too long on that? What have time and weather done to the quality of, say, cobalt that was laid down 25 years ago? Should we not, for example, change the ratio of imported ferrochrome to chrome ore, now that a series of misguided actions in the past has virtually destroyed our former capacity to smelt chrome ore into ferrochrome?

Questions like these and remedial measures based on answers to them can help bring about a viable stockpile, appropriate to current realities.

A new program will then be required for, among other things, buying and selling relatively small quantities each year so as to maintain the quality of stockpile materials on the one hand and to make sure that markets are not dislocated on the other.

Further, Congress should establish parameters for certain limited economic uses of the stockpile. This statement must not be taken as implying there should be an economic stockpile, distinct from the established one for defense. Rather, it means that in the case of certain stockpile items which are essential to national well-being and on which we are import-dependent, Congress should allow for carefully circumscribed conditions under which they can be drawn on for economic purposes.

Economic use of the stockpile could have value in providing the time required for the United States to implement such long-term and more permanent solutions as substitution, conservation, and the development of alternate sources would provide. The United States must consider this alternative in its domestic and foreign supply policy.

The present policy of using the strategic stockpile as a de facto economic stockpile, subject only to the vaguest guidance and controls, we believe, is unwise and should be discouraged.

The legislators should explore to establish guidelines under which the stockpile could be so used. Among these should be:

(a) A certain percentage of import dependency before an item would be considered for stockpiling -- example, 75%.

(b) The geographic location of the supplying countries should be considered. In other words, the urgency would be quite different perhaps on an item from Canada, as opposed to an item from China or Africa.

(c) The number of supplying countries would be heavily considered. If only two or three countries supplied the item, it would be considered with a great deal more concern than if twenty or twenty-five countries could supply the item.

(d) The ease of substitutibility of the material would be an additional criterion and the essentiality to the domestic economy and to our security would also be weighed.

(e) We should take into account the economic or non-economic leverage that we might have on the supplying country. In other words, are they more dependent upon us than we are upon them?

(f) The political stability of the supplying country would be a major consideration as would be the cartelability of the item.

Congress should also provide in the enabling legislation the parameters under which items would be taken out of the stockpile. Stockpile disposal for price stabilization purposes I consider would be unwise and an inadvisable intrusion in the free market; however, certain other parameters for disposal should be made quite clear so that all concerned would know when a disposal time was near; for example:

(a) Never dispose of stockpile for export purposes.

(b) Never dispose at a higher rate than the difference between consumption and production in this country.

(c) Never sell from the stockpile when the material is available through normal channels.

(d) Replace materials in the stockpile only at times of low market activity.

(e) Insofar as possible, sell only to domestic consumers.

The most difficult problem is providing for the management of the stockpile within the parameters set forth by Congress. How can economic use of the stockpile be designed and operated so that it will not be misused for financial advantage of special interest groups? How can it be sufficiently insulated from the political process to prevent its misuse yet insure it will achieve the public benefit for which it was established? It must be sufficiently insulated from the political process that it may act in the public interest and yet remain responsive to Congressional scrutiny.

One final word on stockpiling. It is not and cannot be a long-term solution to our import-dependence on strategic minerals. It can only serve as a buffer in case of crisis, tide us over in case of war, give us options and maneuvering room in case of civil disruption at a source of overseas supply. In short it is a limited hedge against risk in a highly disturbed world.

6. We must, as the new law states, "promote a vigorous, comprehensive, and coordinated program of materials research and development." At the same time, we must overhaul tax policies towards the mining and metallurgical industries. Ironically enough, these policies have been a disincentive, not only to research, but to the capital formation needed to develop the fruits of research as well as the resources available to us.

7. But even as we press on with R&D, we must avoid fantasies of a quick technological fix. Substitution -- the use of a new or modified substance for another -- can readily become a voodoo incantation to exorcise the demons of mineral dependence. If one remembers in this context that a substitute -- for chrome say -- has to be of as good a performance quality as the material for which it substitutes and also that it has to be reasonably price-competitive, then fantasy will give way to reality. And reality is, for example, one considered estimate that it would take us 10 years to design away from chrome and might cost as much as a billion dollars; meanwhile, there is more than a thousand-year supply of chrome in southern Africa that might well be sold for something like 50 cents a pound.

These comments should not be taken as depreciating purposeful R&D across the spectrum of materials and minerals, but rather as putting the problem of dependence in focus. The one key element of that problem is diplomatic -- which leads to the next point.

8. We must reconsider the balance -- some would call it imbalance -- we have struck in recent years between the requirements of national security and the advancement of social justice throughout the world. The Washington Star put the issue well in an editorial some months ago, entitled "Bulletin from the Resource War."

> ". . .While the Kremlin (wrote the Star) has been trying to advance its interests via build-ups of well-positioned bases and client states in such areas as Africa, the United States has concentrated on human rights and hopes of coming out 'on the right side of history' by forbearing to press material or geopolitical interests against revolutionary regimes.
>
> "There is still time for us to protect ourselves in the area of strategic materials. But it will take a rethinking of priorities in the way we define allies and adversaries abroad as well as in domestic stockpiling policies."

Keep in mind that at the heart of our predicament is fair access to sources. Put another way, the problem is not sufficiency of the strategic minerals on which we depend, but rather the peculiar nature of their geographic distribution. Given that nature, disruption of some supply is a very real possibility. And the power to disrupt is, in this matter, the power to deny.

I would briefly note, however, with respect to what the Washington Star called "rethinking of priorities in the way we define allies and adversaries abroad," the phenomenon of selective indignation. This phenomenon has characterized much of our diplomacy towards mineral-rich areas of southern Africa. For instance, at one time we embargoed the importation of chrome from the then state of Rhodesia while at the same time we were buying chrome from that citadel of human liberty, the Soviet Union.

What is the answer to such inconsistency and, more specifically, to the need for looking after our security interests no less than our moral ones? At the least, it seems to me, we should tilt to the principle that our conducting trade with another nation carries no implication whatsoever that we either approve or disapprove of that nation's internal policies.

9. Further, in the diplomatic arena, we should try, in international forums and with individual Third-World countries, to shore up contract law and equity in financial and commercial transactions. The essence of such law and equity is common benefit to all parties concerned, as we have to make clear more forcibly than we have done. To accomplish that will take, among other things, persistence and a stockpile of patience.

It has been nearly 30 years since the Paley Report warned us of the predicament that lay ahead for us in strategic minerals. The warning was by and large ignored. The predicament is upon us. But it need not become a crisis if we rally ourselves now to act steadfastly and with purpose.

The materials and minerals law adopted last fall is a good start. But it is only a start. Nothing guarantees that we will proceed with appropriate speed to make the most of it -- nothing, that is, except the initiative and resolve of people like yourselves all across the nation.

Initiative and resolve are each a human resource. And fortunately, America has those qualities in abundance.

If we bring them to bear now on our minerals predicament, we will not and cannot fail.

1/29/81

E. F. Andrews

Cemented
Carbide
Producers
Association

A. P. Wherry & Associates, Inc.
COMMISSIONER

712 LAKEWOOD CENTER NORTH • CLEVELAND, OHIO 44107 • (216) 226-7700
TELEX 98-5559

February 2, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B308
Washington, DC 20234

Subject: Feb. 9 - 10 Workshop on Critical Materials Needs for the Aerospace Industry

Dear Dr. Wachtman:

Cobalt, particularly fine cobalt powder, is essential as the binder material for the tool carbides. The enclosures have been developed in our campaign as a trade associate to educate the Washington decision makers as to the importance of tool carbides to the defense and civilian production base and the importance of cobalt as the preferred binder for the carbides.

Summarizing the enclosures: 90% of the cubic inches of the tool cermets used are cobalt bonded. There are no substitutes having properties equal to cobalt for steel cutting compositions even rumored. There are two systems under development that may have merit in woodworking, mining, and similar low temperature applications-- but they are not yet out of the laboratory. The overall manufacturing efficiency of the nation as a whole and aerospace in particular would be significantly reduced if the next best substitute for cobalt-bonded tool carbides had to be used. For practical purposes, all our cobalt comes from overseas and most of it from Zaire, Zambia, Botswana, etc. The best solution to supply criticality is to guarantee under Title III of the Defense Production Act an assured market for cobalt domestically mined. There are deposits in Missouri, Idaho, and Oregon.

Cobalt powder in the Stockpile would be desireable. There has been no published information on shelf life so that people have been afraid to stockpile powder. Information is being developed, and extended shelf life seems probable when properly packaged.

We interpret the notice in the Federal Register to be an invitation to have someone attend the workshop. We hope to have someone there-- so if our interpretation is in error, please notify the undersigned.

For the Subcommittee on Cobalt Supply and Binder Research of the Cemented Carbide Producers Association,

Very truly yours,

J. D. Knox, Chairman
Multi-Metals Division
Vermont American Corporation
715 E. Gray St.
Louisville, KY 40202
Phone: (502)589-3781, ext. 266

JDK:ln

Enc.: Letter of December 22, 1980, to Representative Donald Bailey.
Letter of December 22, 1980, to Senator Henry Jackson.
Cobalt Powder: Its Importance to Cemented Carbide Tool Materials.
Some Cemented Carbide Tools and Their Applications. (photocopy)*
Close-ups, second edition.

cc: Allen Wherry, CCPA
Subcommittee members

*This is a copy of explanatory text and illustrations provided to Dr. John Morgan of the Bureau of Mines, with a series of samples.

Cemented Carbide Producers Association

A. P. Wherry & Associates, Inc.
COMMISSIONER

712 LAKEWOOD CENTER NORTH • CLEVELAND, OHIO 44107 • (216) 226-7700
TELEX 98-5559

December 22, 1980

Honorable Donald F. Bailey
206 N. Main Street
Greensburg, PA
15601

Dear Representative Bailey:

Premo Pappafava, President of General Carbide Corporation, Greensburg, has suggested we send you the enclosed copy of letters to Representative Santini and Senator Jackson relative our concern for the supply of cobalt powder for the cemented carbide tool industry. We will continue to keep you informed and would be pleased to have your suggestions for making our effort more effective.

For the Subcommittee on Cobalt Supply and Binder Research of the Cemented Carbide Producers Association,

Respectfully,

J D Knox

J. D. Knox, Subcommittee Chairman
Technical Advisor
Multi-Metals
P.O. Box 1475
Louisville, KY 40201

JDK:ln

Enc.

cc: Don Derthick
Premo Pappafava
Alex Fisher
A. P. Wherry

Cemented Carbide Producers Association

A. P. Wherry & Associates, Inc.
COMMISSIONER

712 LAKEWOOD CENTER NORTH • CLEVELAND, OHIO 44107 • (216) 226-7700
TELEX 98-5559

December 22, 1980

The Honorable Henry M. Jackson
United States Senate
137 Russell Building
Washington, DC 20510

Dear Senator Jackson:

Members of the Cemented Carbide Producers Association (identified by Enclosure 1) have been telling people in Washington of our concern that the supply of fine cobalt powder for making cemented carbide tools is very precarious and crucial to the industrial efficiency of the nation.

That you are as concerned about the broad materials availability problem as we are about our specific cobalt problem is evident from the news. This letter has a twofold purpose: To make you aware of our special problem, and second, to ask your advice as to the course our continuing efforts should take.

We made, on February 11, 1980, a presentation (Enclosure 2) before the DoD Interagency Materials Availability Steering Committee, chaired by Richard Donnelly. We prepared for Dr. John Morgan, Jr. of the Bureau of Mines a kit of carbide tool samples with application illustrations (Enclosure 3). He has prepared color slides from the illustrations and has used the material in several presentations on problems of materials availability. We had an hour and a half productive discussion this Spring with Dick Porter, Marilyn Viviano and Chip Heinz at FEMA. We have talked to other people by phone. The senior civil servants concerned with materials are as concerned as we are about cobalt and fine cobalt powder, and are in substantial agreement on a clear course of action which requires congressional action. The action would be to guarantee under Title III of the Defense Production Act an assured market for cobalt domestically mined.

The problem for us as producers of the cemented carbide tools is that we require fine cobalt powder, the supply of which is overseas and precarious, to make 90% of our product. The problem for the national productivity is that cemented carbide made with known substitutes for cobalt powder are 20% less efficient on the average. Since carbide tools are used very extensively in oil drilling, hard rock mining, coal mining, metalcutting, metal-forming, fastener making, wire drawing, woodworking, the adverse affect on national productivity would be drastic.

We would appreciate having your guidance for our activities in seeking a solution to our problem of cobalt and cobalt powder supply.

For the Subcommittee on Cobalt Supply and Binder Research of the Cemented Carbide Producers Association,

Respectfully,

Don Derthick, President
Tungsten Carbide Manufacturing
14451 Myford Road
Tustin, CA 92980

Premo Pappafava, President
General Carbide Corporation
Greensburg, PA 15601

Alex Fisher, Vice President
Valeron Corporation
P.O. Box 3950
Troy, MI 48084

J D Knox

J. D. Knox, Subcommittee Chairman
Technical Advisor
Multi-Metals
P.O. Box 1475
Louisville, KY 40201

JDK:ln

Enc.: 1) "Close-Ups" with up-to-date membership list inserted.
2) Copy of presentation at DoD by Derthick and Knox.
3) Xerox copy of pictorial material sent with samples to Dr. Morgan.

COBALT POWDER:

IT'S IMPORTANCE
TO
CEMENTED CARBIDE TOOL MATERIALS

11 February 1980

Report of a Study in Progress

for the

Cemented Carbide Producers Association

by

SII TUNGSTEN CARBIDE MFG.
Division of Smith International, Inc.

Donald J. Derthick
President

14451 Myford Road - Tustin, Ca. 92680
Phone (714) 832-3013

J. D. KNOX

Manager
Product and Process Development,
Industrial Divisions
VERMONT AMERICAN CORPORATION

715 E. Gray St.
Louisville, Ky. 40202
502/589-3781

Fine cobalt powder is critical to the production of cemented carbide tools. The source is overseas and politically unstable.

Mr. Derthick, President of Tungsten Carbide Manufacturing, and I are an ad hoc committee of the Cemented Carbide Producers Association charged with evaluating the status of this problem in the government and determining what we can do as a trade association to support effort toward a concrete solution to the problem. We have not made our final report and, therefore, the Association has not yet established a formal position.

The Association is made up of 24 producers. We make and sell cemented carbides for cutting metals, wood, plastics, masonry, rock, coal; for heading, extrusion, drawing, blanking, rolling, and general wear resistance; for critical structual parts requiring high compressive strengths and/or high elastic moduli.

The industry offers over 30 cobalt-bonded tungsten carbide base grades among which there are real practical differences. These represent in excess of 90% of the cubic inches of cermet tool materials produced. There are several grades of nickel-bonded tungsten carbide, primarily for combined corrosion/wear applications. Nickel-bonded titanium carbide and the ceramics have created niches for themselves, primarily in metal cutting. These two have had considerable publicity over the past 20 years as replacements for the tungsten carbide base materials. Yet, today, together they have between them no more than 2% of the total cubic inches of tool cermets. Coatings on tungsten carbide cobalt substrates have been the most important development of recent years. The synthetic diamond and boron nitride tool tips are formed on tungsten carbide cobalt supporting wafers.

I have phrased the foregoing to emphasize that cobalt has been the element of choice for 50 years, despite the fact that nickel has always been cheaper.

The basic U.S. problem with cobalt supply is 95% dependence on overseas sources, combined with concentration of the principle sources in one of the more politically unstable parts of the world. Zaire directly, Zaire through Belgium, Zambia, Botswana, and South Africa, together supplied 75% of our 1978 imports. A large proportion of the committed capacity increase is in the same area. Domestic sources are still in the talking stage. If they come on stream, crucial to whether they stay on stream will be the price the African producers are willing to accept in a buyer's market.

So much for background. Some of you have to consult your crystal ball, assign probabilities, and then recommend how much current effort is justified to minimize possible future problems. We assume that both the costs of defense preparation during peacetime and hot war requirements enter into consideration. Following are some factors that seem common to both.

There could be three relief programs for cobalt scarcity:

1) Substitutes for the cobalt as binder for the WC.

2) Substitutes for the tungsten carbide/cobalt system.

3) Domestic mining, refining, and powder making facilities on stream supplying industry and the Stockpile with cobalt powder.

Some substitutes for the cobalt as binder for WC are alloys containing various proportions of nickel, chromium, iron, molybdenum, etc. Grades of WC with nickel alloy binders have been on the market for years, primarily for combination wear/corrosion applications. As presently on the market they are neither as impact resistant nor as thermal shock resistant as the cobalt-bonded WC grades. One maker estimates the loss of performance in noncorro- applications to average 20%. Iron and steel bonded WC grades have been developed and tested over the years. There have been no field applications of any consequence.

The WC/Co system seems to be one of those naturals. Fe/C is another. Imagine what would happen if carbon was no longer available to the steel industry. The comparison is very much overdrawn but illustrates the point.

Cobalt is apparently the binder of choice for several reasons. It has zero wetting angle relative WC. It has the W/C/Co eutectic that makes sintering temperatures industrially practical. The solubility of W and C at sintering temperatures is relatively high but at room temperature, low. This has the effect of promoting densification at sintering temperatures but keeping a relatively ductile matrix at room temperature. It is not a carbide former. It has both the FCC and HCP structure with the transition from HCP to FCC at 427°C. The reverse transition is possible by cold work. This feature enhances the initial wet ballmilling together of the tungsten carbide-cobalt powders. To the best of my knowledge, no other element has this combination of favorable characteristics. Some of the developmental alloys may.

The second relief program would be substitute systems for the WC/Co system: Titanium carbide base systems, ceramics, coatings, diamond, boron nitride, lasers, electron beam, water jet. As previously remarked, the TiC base and ceramic systems have had plenty of time to establish their worth and yet have only a small fraction of the market. One company markets a series of steel bonded titanium carbide grades that have established themselves in die and wear applications--perhaps 1% of the market. Coatings have probably reduced the cost of cutting more than any development since the introduction of TiC/TaC additions to steel cutting grades in the late 1930's. They, however, are not total substitutes since they are coatings on WC/Co base substrates. In the very long term, the diamond and boron nitride tools may have the greatest affect of all. It, however, will be very long term. We do not yet have enough good machine tools to fully exploit the ceramics. Lasers, electron beam, water jets, etc., will all find a place. However, by analogy with high speed steel, 20 years from now WC/Co base grades will still be the most cost effective in enough applications to require substantially more cobalt than we use today.

I would conclude that there are no visible substitutes having potential to equal the WC/Co system for impact/wear or thermal shock/wear applications such as mining, oil well drilling, blanking, heading, steel wire drawing, steel mill rolls and guides, heavy interrupted metal cutting. In the last few days, I have spoken to two people who did quarrel with this conclusion for impact applications. One has field tested a nickel alloy bonded WC and found it equivalent to cobalt bonded WC, if hot isostatically pressed. If it is the HIPing that makes the binder system work, that could be an expensive solution. In order to HIP all products, the company that I represent would have to triple capital investment, and increase manufacturing cost 30%--with no performance gain. The other stated that an alloy binder looked very promising for mining applications--but nothing yet for metal cutting.

Making the substitutions in the remaining applications presents problems. The obvious problems of converting in a short period of time are the differences in processes and sources of supply. Some not so obvious center around the problems of cross contamination among the systems and criticality of process control. For example, contamination of WC/Co impact grade by 1 or 2% TiC reduces the impact properties so that it becomes a loser in a competitive situation. It is almost impossible now to get unmixed WC/Co salvage except from locations that use no other types of carbide. If substitutes become prevalent, the recycling process will be seriously compromised.

All of the substitutes apparently require closer process control to achieve their potential properties than does the WC/Co system. Both persons who think they have good substitute binders agreed that process control was much more critical than for the equivalent WC/Co grade. This sort of limitation is not a small matter. I heard recently of a significant product improvement that was not launched because production management would not accept responsibility for the people part of the process control.

So, my conclusion is still that substantial conversion to substitutes under non-emergency conditions is not on the horizon. The proven substitutes have been around long enough to establish their competitive position. They are, of course, subject to substantial improvement, but so is the WC/Co system. High strength grades of WC/Co have transverse rupture strengths in the 350-450,000 psi range. HIP'd specimens have had strengths over 700,000 and extrapolation of data suggests a potential of over 1 million for the ideal structure.

This is a good place to interject that none of the technical people I talked to would agree that there is no substitute for cobalt. It is just that very little good basic research on which to build has been done. This leaves most people cutting and trying. Even this effort will fade if the price of cobalt eases. It is not likely that the requisite basic research will be done by industry, and if it is, it certainly will not be published. I believe that we would advance faster and more efficeintly if there was more basic knowledge on which the product developers could build. National Science Foundation and similar federal programs are probably the only practical approach to obtaining the basic knowledge.

We do not intend to suggest that the various substitutions are impossible, but that the resulting inefficiencies in manufacture and loss of performance probably more than justify the third alternative; that is, assuring the supply of cobalt by providing for domestic mining and refining to metal, and converting a portion of the metal to fine and extra-fine powder. This will only fly with government subsidy. It could be two-fold; continued and strengthened research to reduce the cost from domestic sources, and a long term Stockpile buying program that would set a floor price. The precedent is there in the tungsten acquisition program of the early 1950's. The need is there in that the Stockpile is 45 million pounds short of target. Fine cobalt powders can be packaged for good shelf life* and a three-year supply at present levels would be 4,200,000 lb (\$130,000,000).

Mr. Derthick, whose expertise is greater than mine in the applications of carbide, will discuss some of the specifics of applications. When he is done, we think you will be convinced that the importance to the national defense is worth investment in binder research and cobalt supply.

*African Metals has verbally reported results of test conducted as follows. We are seeking the original report.

1.) Extra fine cobalt powder was loaded into 5 kg. hermetically sealed aluminum cans. Starting O_2 content of the powder was approximately 0.4%.

2.) Each year one or more cans were opened and the loss of weight by hydrogen reduction of the oxides determined.

3.) 1st year -- wt. loss increased over start 0.05%.
2nd year -- additional weight loss 0.05%.
3rd year thru 10th year -- nil.

4.) Conclusion would be that after the oxygen from the air trapped in the container has converted to cobalt oxide the remaining nitrogen is an inert atmosphere.

The U.S. carbide industry is comprised of approximately 50 manufacturers ranging from less than one million to several hundred million in annual sales. The great majority are closely held corporations, although most of the major producers are divisions of a parent company.

Although all producers use similar powdered metallurgy techniques, and at least 95 percent of products contain the basic refractory metal carbide-cobalt system, there are a broad variety of businesses specializing in different market segments.

The basic classification of products has six categories: <u>Cutting tool inserts</u>, <u>blanks</u>, <u>brazed tools</u>, <u>wire bar and tube drawing dies</u>, <u>mining tools and mining blanks</u>, and a category called <u>all other</u>. However, each of these categories can be further divided into sub-groups.

A few carbide manufacturers attempt sales of all or most products. The majority specialize in market segments that match management philosophies, strengths and available capital with market requirements.

Carbide cutting tools for metalworking have the largest market, and therefore have attracted the greatest number of producers.

This concentration of efforts results in a somewhat distorted view of the carbide industry by outsiders. Frequently, the press and reports from government agencies, or other interested parties, tend to concentrate only on machining applications. However, according to figures issued by the C.C.P.A. in 1978, less than 60 percent of all sales could be directly identified as cutting tools.

Also greater than 50 percent of the weight of cobalt is used for other than cutting tools. This is due to the higher percentage of cobalt in other products. The majority of the remaining sales portion is used for wear, oil field and mining applications.

Let's examine each area for material requirements, and potential for technology change.

As Mr. Knox has stated, there are a number of recent developments that have improved or replaced indexable cutting tools, such as chemical vapor deposited coatings, cermets, nickel bonded titanium carbide, sintered diamond, and others. When these developments occur, much publicity is released. The uninvolved observer is of the opinion that a rapid change is occurring, which will soon obsolete existing systems.

However, change occurs very slowly. With the exception of coatings, each of the above-mentioned developments have succeeded in finding applications in a market segment. Coatings have become accepted for most applications, but user acceptance is gradual. In the next several years, coated inserts are forecasted to reach 50 percent of cutting tool marketshare. Coatings were introduced ten years ago.

In spite of these significant advances over the past decade, the basic system is still metal carbide-cobalt for greater than 90 percent of all non-ferrous cutting tool sales. Cost, machine capabilities, user reluctance, undesirable properties, and application have been the limitations which have prevented these innovative materials from gaining greater marketshare.

Consequently, most carbide producers involved in cutting tool sales have manufacturing positioned to produce only tungsten carbide-cobalt based products, which are offered either coated or uncoated.

The category listed as blanks includes many end uses. Included in this are blanks to manufacture brazed tools and wear parts. Almost all blanks used to manufacture brazed tools are from the tungsten carbide-cobalt system. Brazability and thermal shock must be considered on use of materials.

Wear parts have good potential for other known binder systems, due to the generally lower physical property requirements in most applications. However, many products in the wear category are fabricated from recycled materials, due to cost considerations.

Draw dies are subject to materials substitutions, but are of insignificant volume.

Mining tools and mining tool blanks present the greatest dilemma on use of substitute materials.

Disposable coal mining tools and rock drilling tools use the greatest portion of material in this category.

Coal tools have brazed carbide blanks supported by steel shanks. The assembled tools are used for underground mining of coal. Also, similar products are used for various construction applications, such as road scarifying and trenching.

Rock drilling tools include rotary rock bits for oil and gas exploration, open pit mining, water well development and tunneling, as well as various other percussion types used for many applications, including construction.

All of the above require the tungsten carbide-cobalt system. This is particularly true for rotary rock bits used in the oil field. These bits encounter tremendous forces at up to six-mile depths.

A fine balance between toughness and wear resistance is required for the carbide parts which form the teeth of the rock bit. This requirement of hardness with toughness has eliminated all other materials as potential substitutes. The bond strength between carbide grains and binder must be maximized to prevent crack propigation, which leads to breakage. Premature failure can cost many thousands of dollars while hundreds of sections of drill pipe are pulled from the hole. Many substitutes have been tried but all have drawbacks. More than 20 percent of the total U.S. output of carbide is used in this application.

Coal tools also have similar requirements in physical properties of carbides to materials used for rock bits. However, the cost of premature failure is not nearly as great.

The "all other" category includes hundreds of specialized applications that are too numerous to mention. However, again most applications require the superior properties of the tungsten carbide-cobalt system.

We have attempted to demonstrate the total dependence the carbide industry has on cobalt. Substitutes for the majority of applications are not in sight.

Unfortunately, our industry is limited to one major source of supply. Cobalt mined and refined in Zaire is processed to a pure, micron-sized powder at Metallurgie Hoboken-Overpelt, S.A. in Belguim, which is distributed in the U.S. by African Metals Corporation. Other sources are available for smaller quantities.

The requirements for manufacturing satisfactory carbide powders are such that, for most applications, only one type of powder is acceptable. This extra-fine powder has a morphology that lends itself to good distribution by ball milling or attrition milling. This property is necessary to surround each carbide grain with cobalt to produce the desired strengths.

Other types of cobalt powders are used for specific applications.

The purity also is of great importance. Many elements cause undesirable effects on sintered carbide, which limits performance. Some oxidation can be tolerated, but excessive oxides cause quality problems.

Now perhaps you can see our dilemma. Cobalt must be used for most carbide applications. This material is supplied by one unstable nation, to be processed by one European company, distributed in the United States by a single source. The powder must be of an exact nature and of good purity.

Currently our industry is on allocation. There is sufficient powder available now, but any disruption in that chain could spell disaster. That very nearly happened during the invasion of Zaire in 1978.

There are other cobalt sources available to us for a portion of our requirements.

Other European companies supply small quantities of satisfactory powder. Sylvania has a plant in the U.S. that will distribute cobalt in some form from material gained through reclamation of scrap. Other hard scrap reclamation methods provide cobalt by returning cobalt-contained parts to powder.

Reclaiming is a very important source, with estimates running as high as 25 percent of all carbide sold being produced from recycled scrap. However, the greater portion of carbide is lost forever through attrition, as in the case of rock drilling.

Hoboken has a plant under construction in North Carolina which will produce extra-fine powders. Although, this will replace materials now produced in Europe the cobalt will continue to come from Zaire, still leaving us one major source.

Our industry has had a difficult time in gaining attention to our problem. We use less than 5 percent of the U.S. requirement for cobalt, and, therefore, are not considered in crisis planning. However, we are a substantial factor in U.S. productivity. Almost all consumer goods use carbide somewhere in the manufacturing process. Interruption in carbide production would substantially reduce the output of many products, including military hardware. It would take unbearably long for our industry to make a substantial change in the present carbide system.

In addition, energy output would be seriously impaired by use of a non-cobalt system, due to a major reduction in performance. Oil field rock bit plants are operating at full capacity, and would be unable to supply the additional demand caused by poorer performance. The fact that this could occur is in direct opposition to our current policy of less dependence on foreign oil.

Alternate binders have been investigated for 50 years. Many companies have spent considerable sums on research for alternate binders with little success. Other systems are in use for specific applications, but cobalt is used in greater than 95 percent of all products.

Therefore, Mr. Knox and I propose the following:

1. That plans are formulated as soon as possible to place a minimum of two years usage of extra fine cobalt powder in the G.S.A. stockpile;
2. That the government assist our industry to research satisfactory alternate binders to cobalt through the National Science Foundation, Bureau of Mines, the Department of Defense or other government agency research grants; and
3. That the government assist in the development of a domestic source for cobalt, including a process plant.

This project would provide the 45 million pounds required to replenish G.S.A. stockpiles.

Mr. Knox and I are proposing what we feel are the needs of our important industry, and that our position is generally supported by all other member companies.

We ask for your assistance and guidance to help us alleviate this serious situation.

Some Cemented Carbide Tools and Their Applications

The samples and illustrations of this collection are representative of some major application areas for carbide tools, but are by no means exhaustive. Not included are steel strip rolls and guides, blanking dies, powder compacting dies, snowplow edges, tire studs, extrusion dies, wear parts for valves, slitter knives for steel strip, paper knives, and any number of wear applications from lining power plant fan housings to tips for surgical forceps.

The message intended is the pervasiveness of this material throughout our national production base and the importance of maintaining its availability and quality to the efficiency of that production. Ninety percent (90%) of these tool materials are the tungsten carbide/COBALT base composition. For substantially all of the applications of this 90%, there are now no substitutes for the COBALT in the composition, and where substitutes can be used there is a loss of efficiency.

1) Tungsten carbide/COBALT "compacts."

   --Oil and gas well drilling as shown.
   --Blast hole drilling.
   --Tunneling, airways, etc., in mine preparation.

2) Tungsten carbide/COBALT inserts for "point attack" bits which are the cutting elements on continuous miners.

3) Tungsten carbide/COBALT inserts for "roof drill bits" which are used to drill the holes for the bolts which hang the roof from sound rock strata above.

4) Tip of tungsten carbide/COBALT base composition with tantalum and titanium carbide additions. Tip has been used. "Craters" are result of chip erosion. In the picture, tool is behind jury rigged chip deflector.

5) Indexable inserts of tungsten carbide/COBALT base composition. Some with tantalum carbide and titanium carbide additions. Some with titanium nitride (gold) coating. Several have been used. By indexing, each corner can be used.

6) Wire drawing dies. The illustration is actually of a diamond die. Diamond dies are used on smaller sizes. Tungsten carbide/COBALT dies are used for medium and large dies, bars, and tubes. The sample is a used carbide die.

7) Tungsten carbide/COBALT punch used to cold form the cavity in the sample sparkplug body. Would normally be mounted in position shown (7).

8) Tungsten carbide/COBALT insert for heading die which would normally be mounted in position shown (8). The machine is a five blow parts former which would have a cutoff position and four die/punch pairs. (Sample die insert is not for sparkplug.)

9) Tungsten carbide/COBALT tips for circular saws, molding cutters, routers, and planers for woodworking.

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   - --Blast hole drilling.
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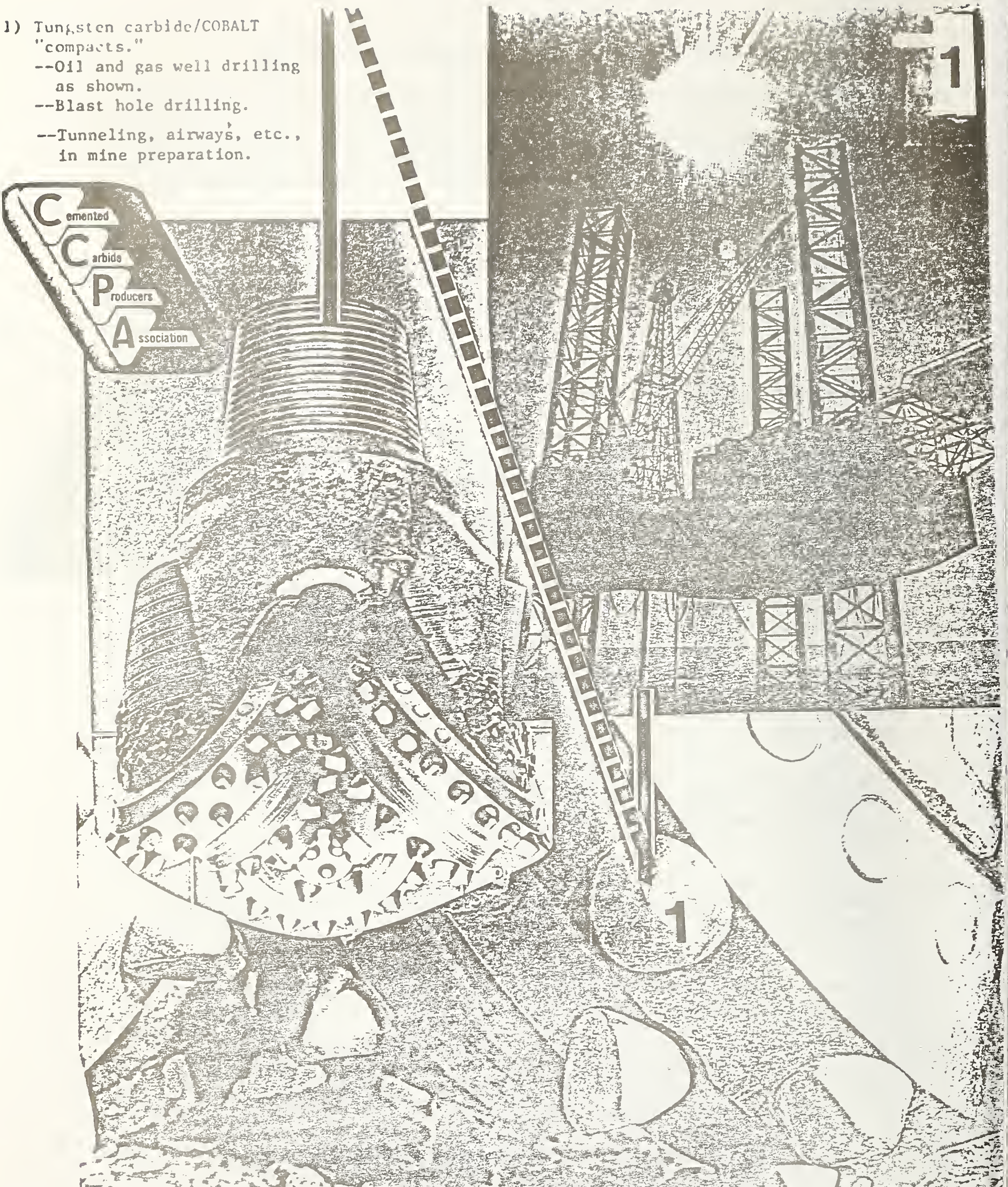
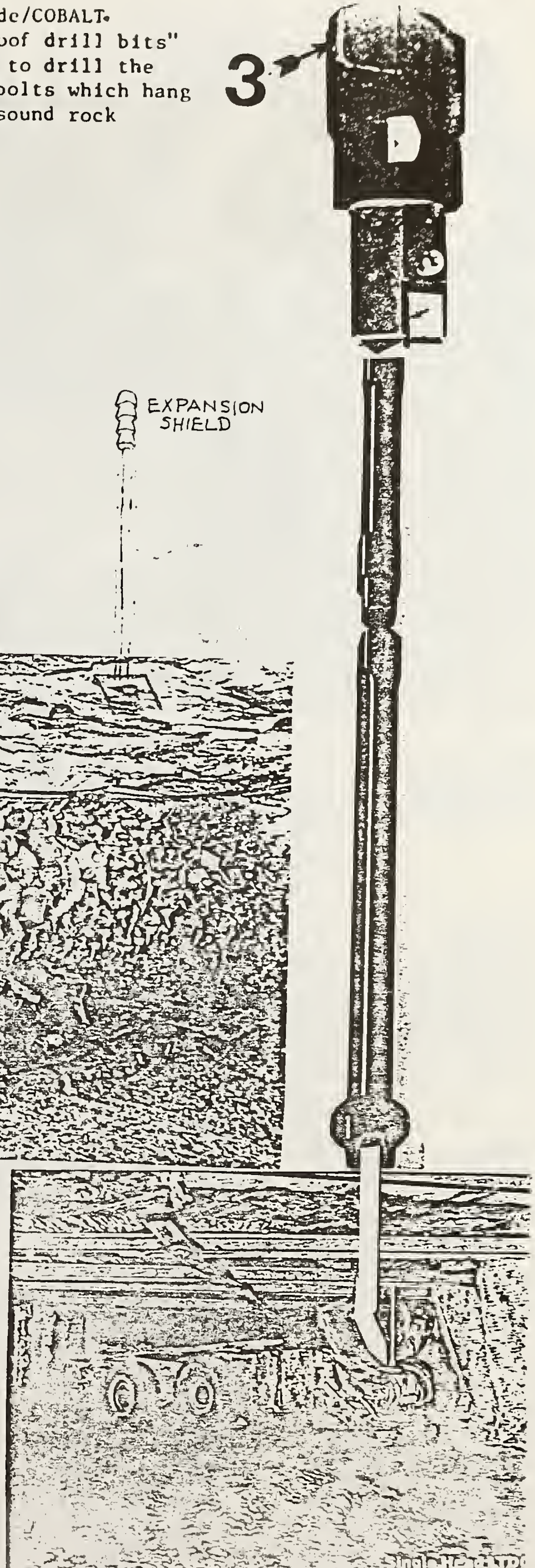


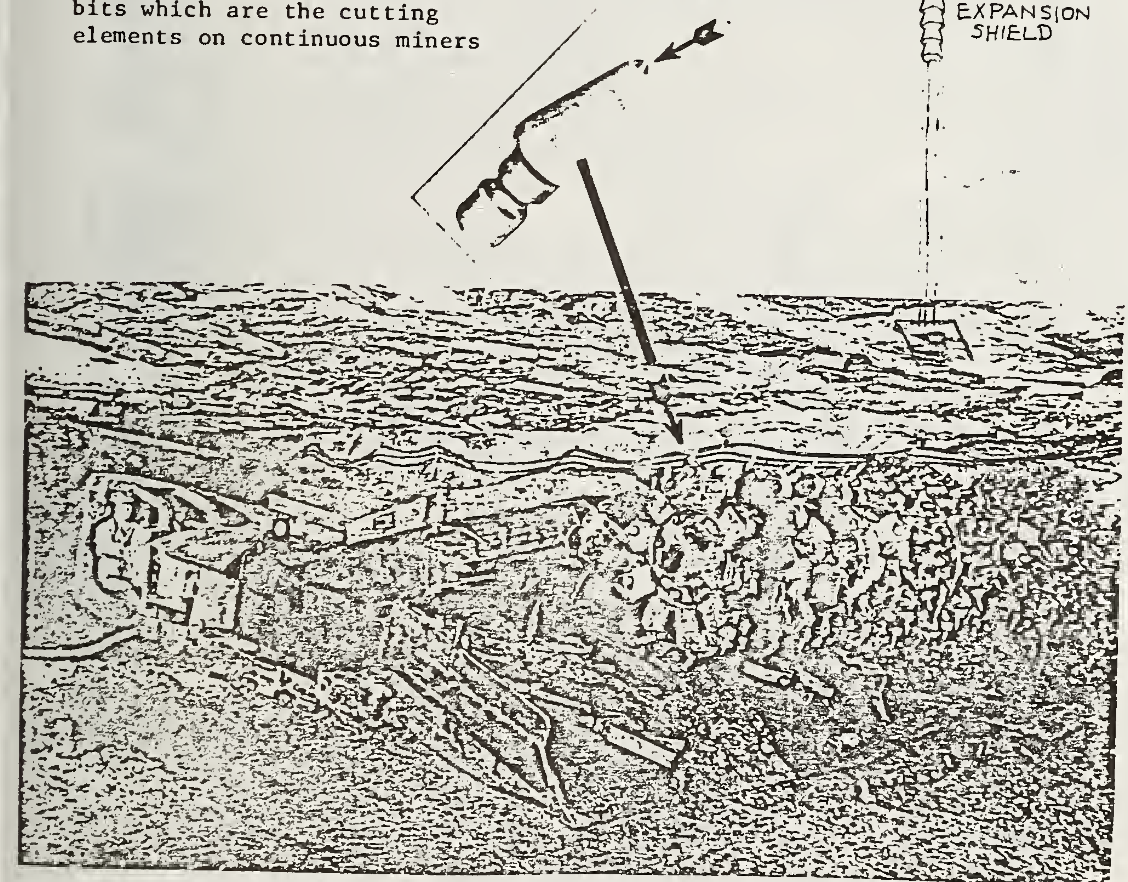
3) Tungsten carbide/COBALT inserts for "roof drill bits" which are used to drill the holes for the bolts which hang the roof from sound rock strata above.

3



2) Tungsten carbide/COBALT inserts for "point attack" bits which are the cutting elements on continuous miners

2



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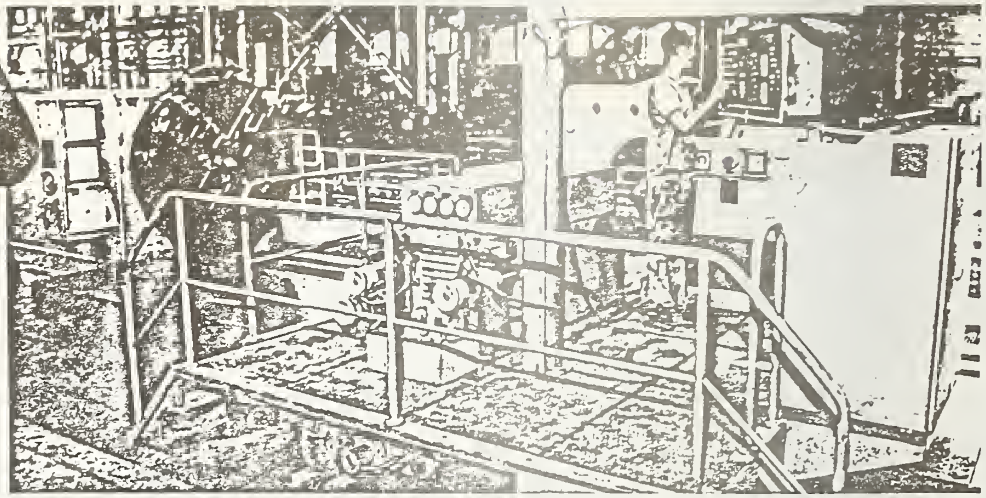
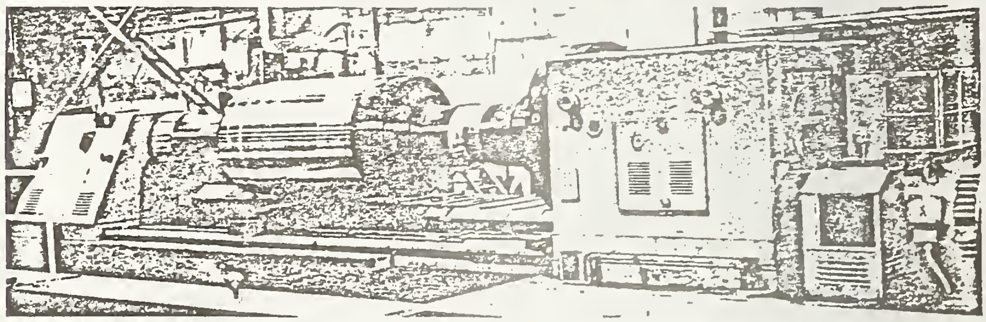


98" x 50' cc WALDRICH SIEGEN Heavy Duty N/C Turning Lathe; D-7992 (1973)



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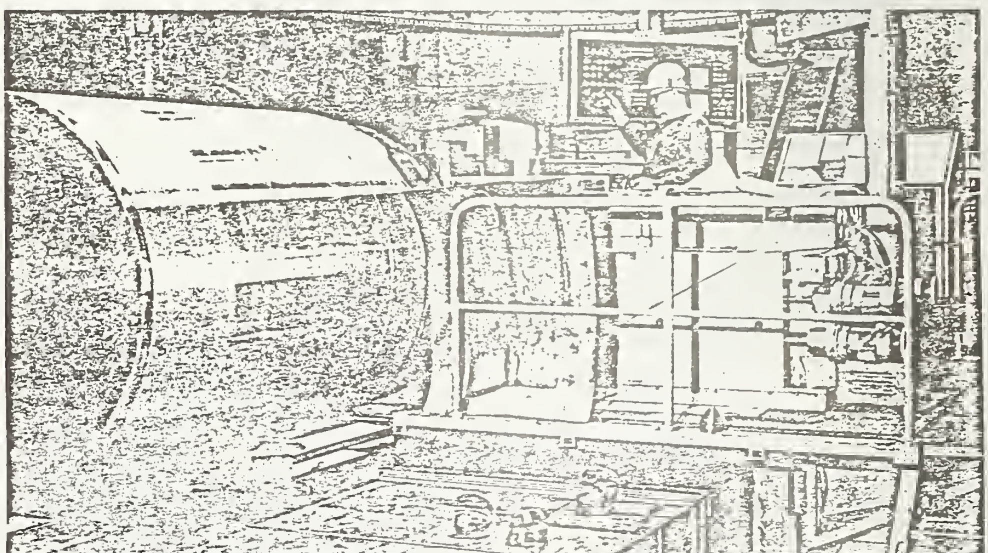

98" x 50' cc WALDRICH SIEGEN Heavy Duty N/C Turning Lathe; D-7992 (1973)

Tip of tungsten carbide/CO-BALT base composition with tantalum and titanium carbide additions. Tip has been used. "Craters" are result of chip erosion. In the picture, tool is behind jury rigged chip deflector.

4

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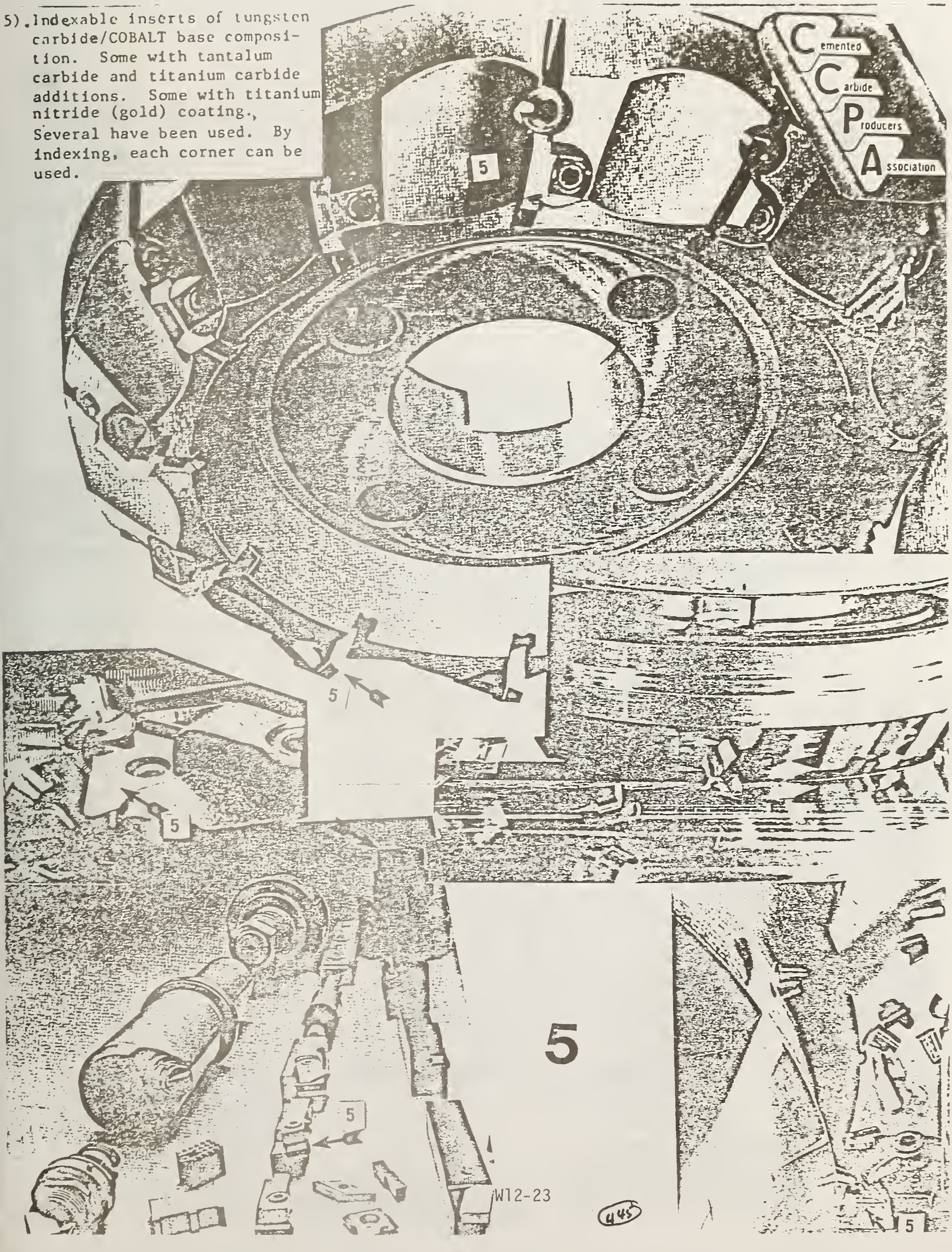
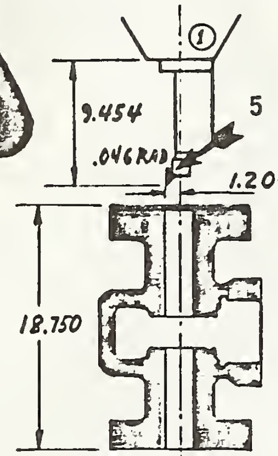
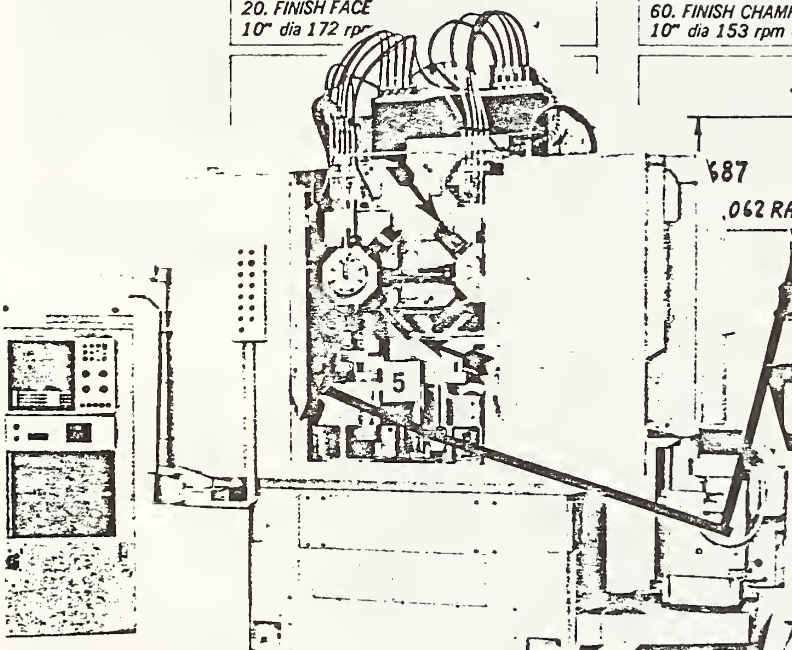


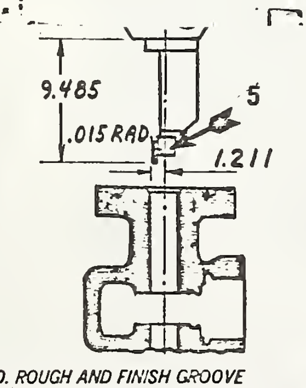
W12-23

10. UNLOAD & LOAD—INDEX CHUCK



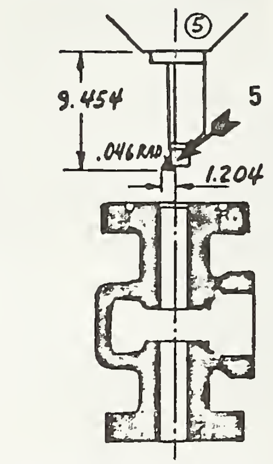
20. FINISH FACE
10" dia 172 rp



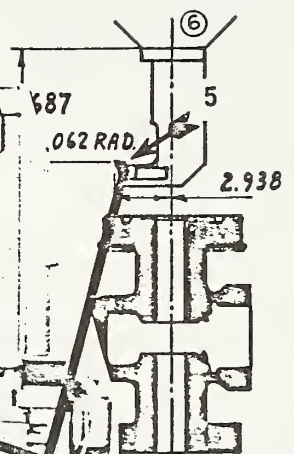


40. ROUGH AND FINISH GROOVE
Rgh 4.5" dia 297 rpm 350 sfm .006 feed
Rgh 4.7" dia 284 rpm 350 sfm .010 feed
Rgh 3.8" dia 352 rpm 350 sfm .010 feed
Fin 3.8" dia 402 rpm 400 sfm .005 feed
Fin 4.7" dia 325 rpm 400 sfm .005 feed

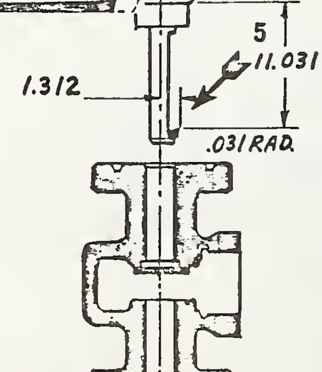
50. SKIP INDEX (PASS STATION 4)



60. FINISH CHAMFER AND TURN
10" dia 153 rpm 400 sfm .015 feed

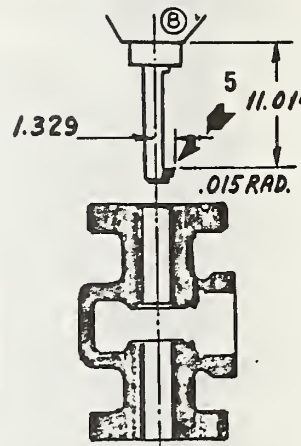


ER AND BACKFACE
450 sfm .015 feed



80. FINISH BACKFACE AND RGH C'BORE
Face 4.1" dia 280 rpm 300 sfm .009 feed
Rgh 3.46" dia 331 rpm 300 sfm .009 feed

85. STOP CYCLE—REMOVE CHIPS

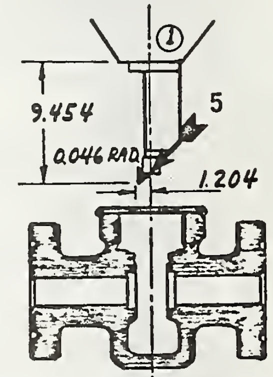


90. FINISH C'BORE
3.49" dia 383 rpm 350 sfm .005 feed

100. STOP CYCLE—INDEX CHUCK 180°

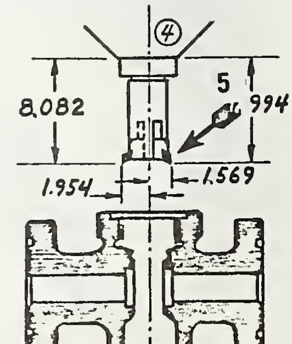
110. REPEAT ABOVE SEQUENCE

120. STOP CYCLE—INDEX CHUCK 90°



130. FINISH FACE AND CHAMFER
7.8" dia 220 rpm 450 sfm .015 feed

140. SKIP INDEX—(PASS STATIONS 2 & 3)



150. FINISH BORE AND C'BORE
TI X 4.4" dia 260 rpm 300 sfm .010 feed
TI Y 4.6" dia 243 rpm 300 sfm .005 feed

6) Wire drawing dies. The illustration is actually of a diamond die. Diamond dies are used on smaller sizes. Tungsten carbide/COBALT dies are used for medium and large dies, bars, and tubes. The sample is a used carbide die.

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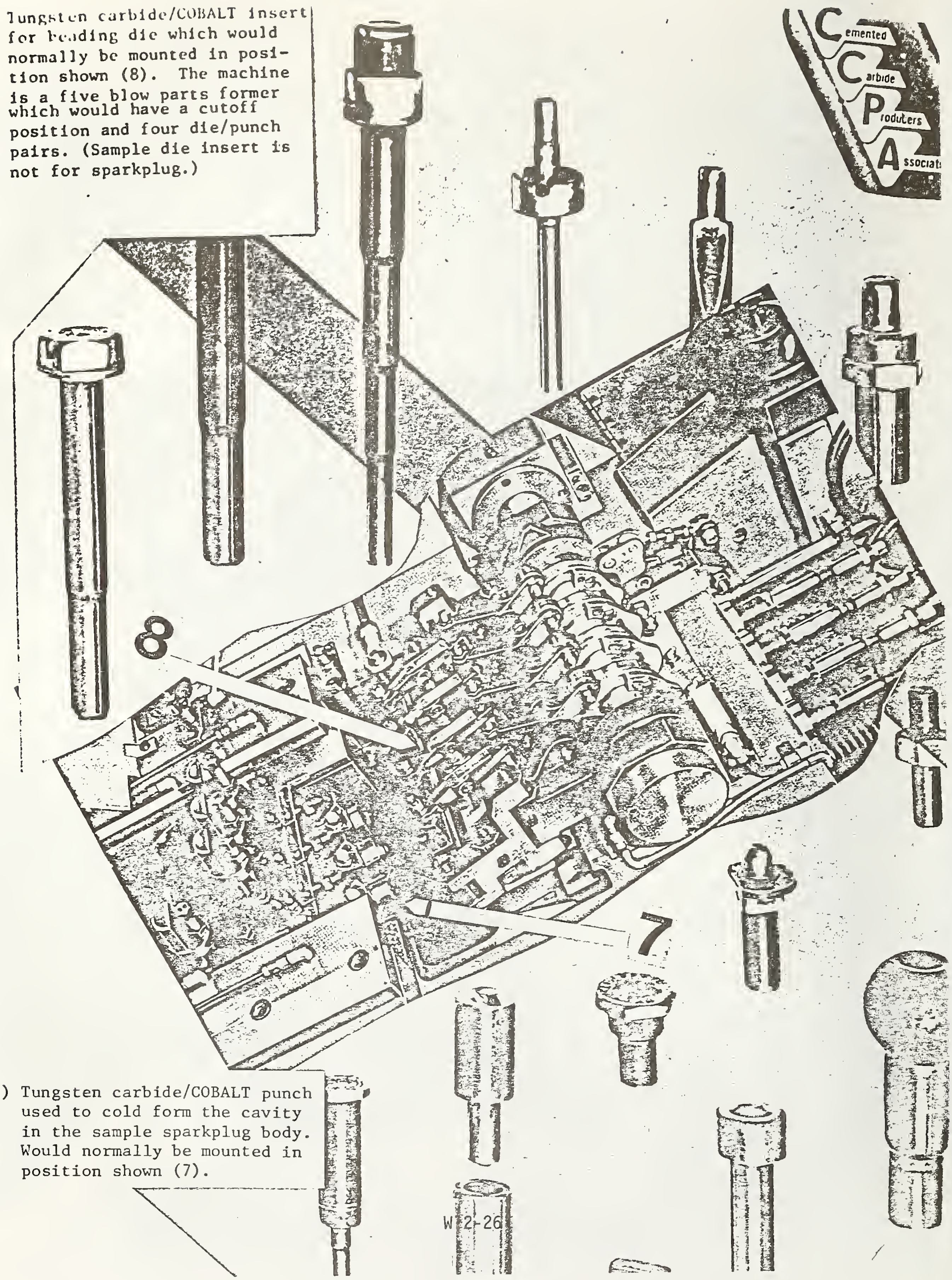
8) Tungsten carbide/COBALT insert for heading die which would normally be mounted in position shown (8). The machine is a five blow parts former which would have a cutoff position and four die/punch pairs. (Sample die insert is not for sparkplug.)



7) Tungsten carbide/COBALT punch used to cold form the cavity in the sample sparkplug body. Would normally be mounted in position shown (7).

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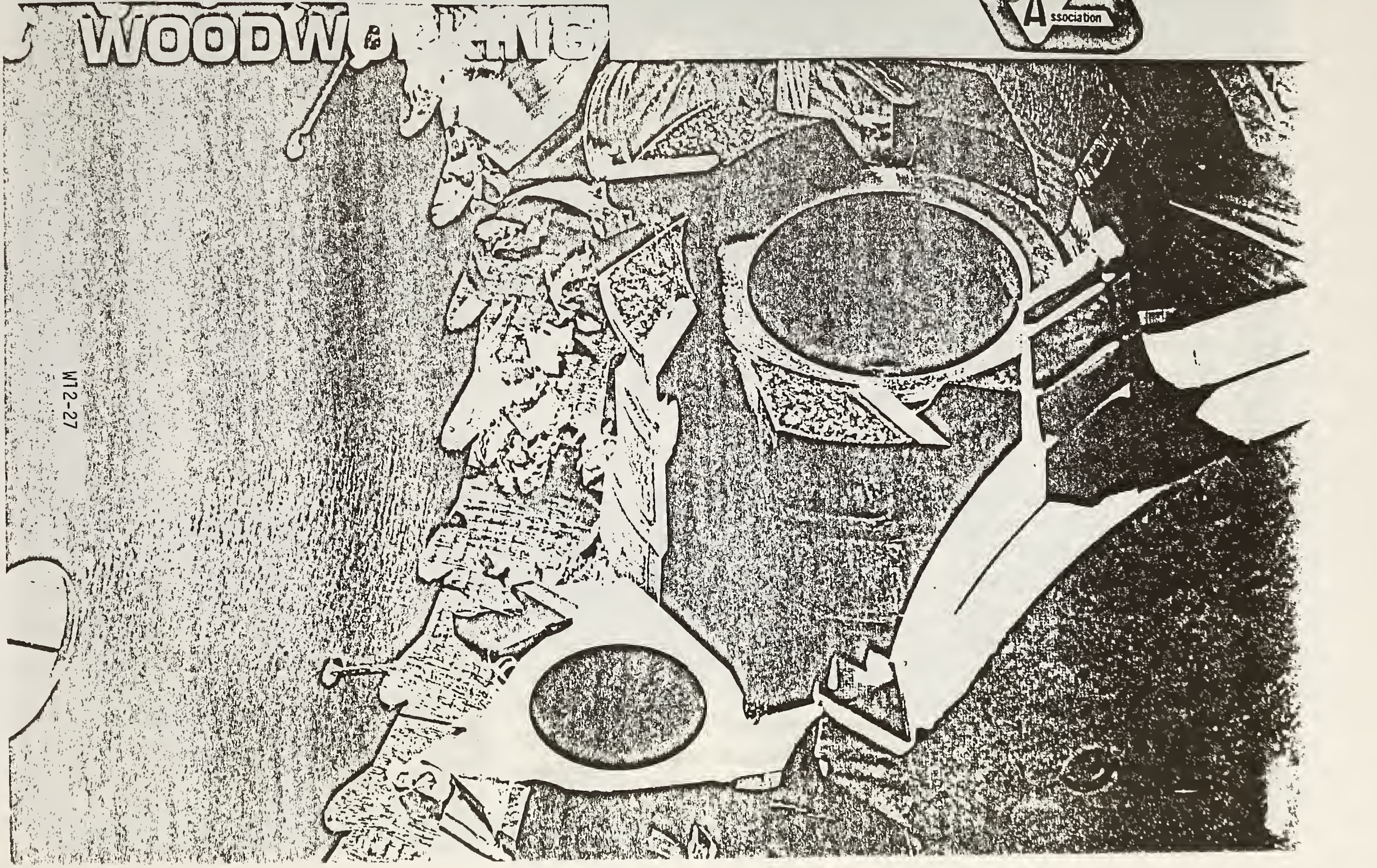
9

9) Tungsten carbide/COBALT tips for circular saws, molding cutters, routers, and planers for woodworking.




close-ups
CEMENTED
CARBIDES
in your
world of people

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CLOSE-UPS
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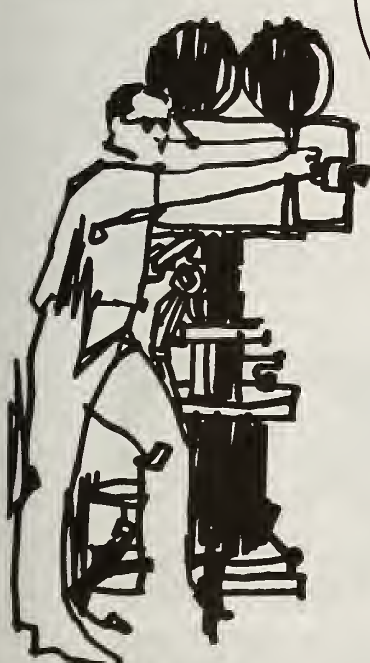
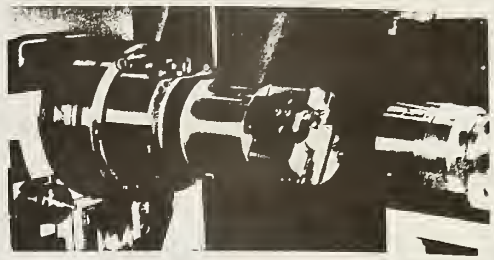
SECOND EDITION





This work updates the book of the same name authored in 1968 by a special industry committee, George T. Brennan, Roger L. Brogan, Frank W. Hogan and Allen P. Wherry. The author committee of this edition is A. G. Weiland, E. S. Hilty, G. T. Brennan and A. P. Wherry. They were privileged to draw upon the informational resources of the Cemented Carbide Producers Association members and referred extensively to *Cemented Carbides*, The Macmillan Company, New York, 1960, by Dr. Paul Schwarzkopf and Dr. Richard Kieffer; and *Treatise on Powder Metallurgy*, Vol. II, by Claus G. Goetzel, Interscience Publishers, Inc., New York.

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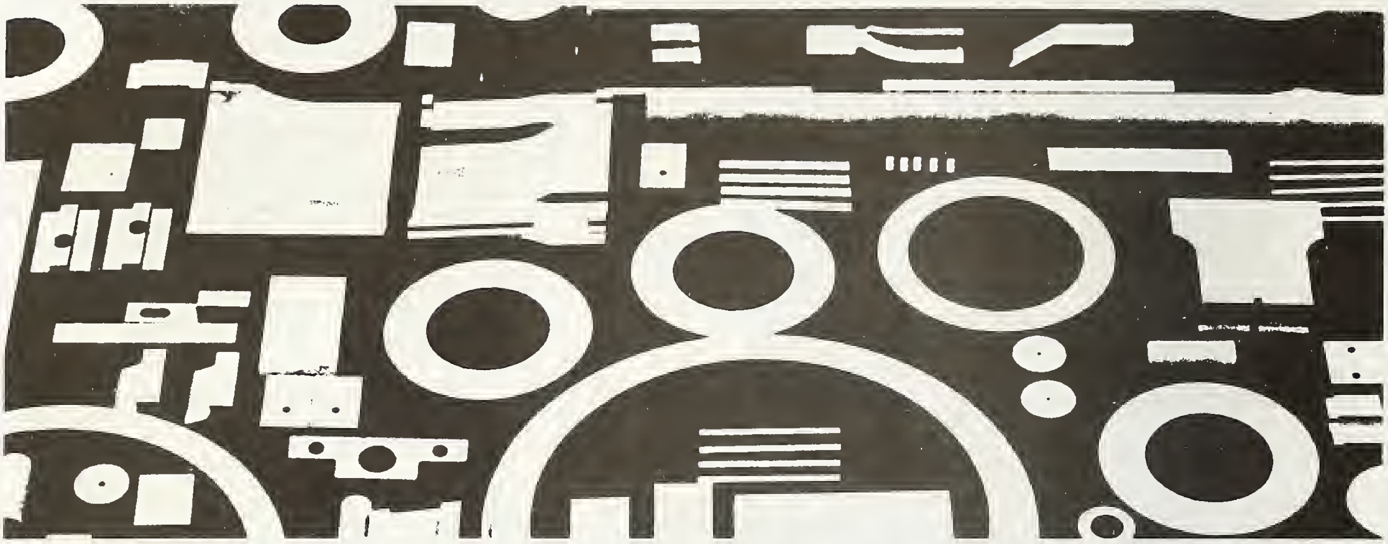
The work is published by Cemented Carbide Producers Association.

William D. Ellis
and Pauline G. Fanslow,
Editors



Chapter One—Would You Repeat the Name?

Yes — Cemented Carbides . . . The Essential Industry.

The Quietest Revolution in History

To the average citizen, cemented carbides are the best kept secret in industry. If he has seen any, he doesn't know it.

Comparatively speaking, the quantity producted is miniscule; and most of it functions in key places he seldom sees.

Yet cemented carbides make possible the ongoing industrial production revolution. No substitute for them has appeared and none is forecast by metallurgical science.

What are they?

The Hardest Metal Made By Man

The layman *can* see cemented carbides, but usually in their least crucial uses (ballpoint pen balls, knife sharpeners, cement drills, wear surfaces on certain home tools).

In industry, however, cemented carbides bear the brunt of nearly every severe industrial action . . . pounding, stamping, punching, rolling, abrasion, corrosion. Their two major missions are cutting and wear resistance which makes them the basic shock troops of all industry.

Cemented carbides are fine particles of hard carbides (most common being tungsten, tantalum, titanium, niobium) held in a matrix such as cobalt or nickel.

They have revolutionized productivity, making possible huge production runs of other products at tremendous speeds. You find cemented carbides on the cutting edges of tools, or on the heavy wear surfaces of high speed machines: the rolls; punches; dies; bearing surfaces.

Gram for gram, cemented carbides are comparatively expensive; but in terms of what they make possible, they are a bargain.

In mining and petroleum drilling, it is the carbide cutting edge that lets us cut through hard rock at high speeds. In metalworking, it is the carbide edges which let us cut or stamp or work production metals at tremendous speeds. A single example easily envisioned by the layman is the common beverage can. This is a deep drawn product made from a flat metal blank. Steel tooling won't endure this operation at the new fantastically high volume, high speed production rates. Beverage cans today are made in the billions.

Another example which speaks eloquently of the super hardness and toughness of tungsten carbide is that this material is often used to manufacture armor-piercing, anti-tank projectiles.

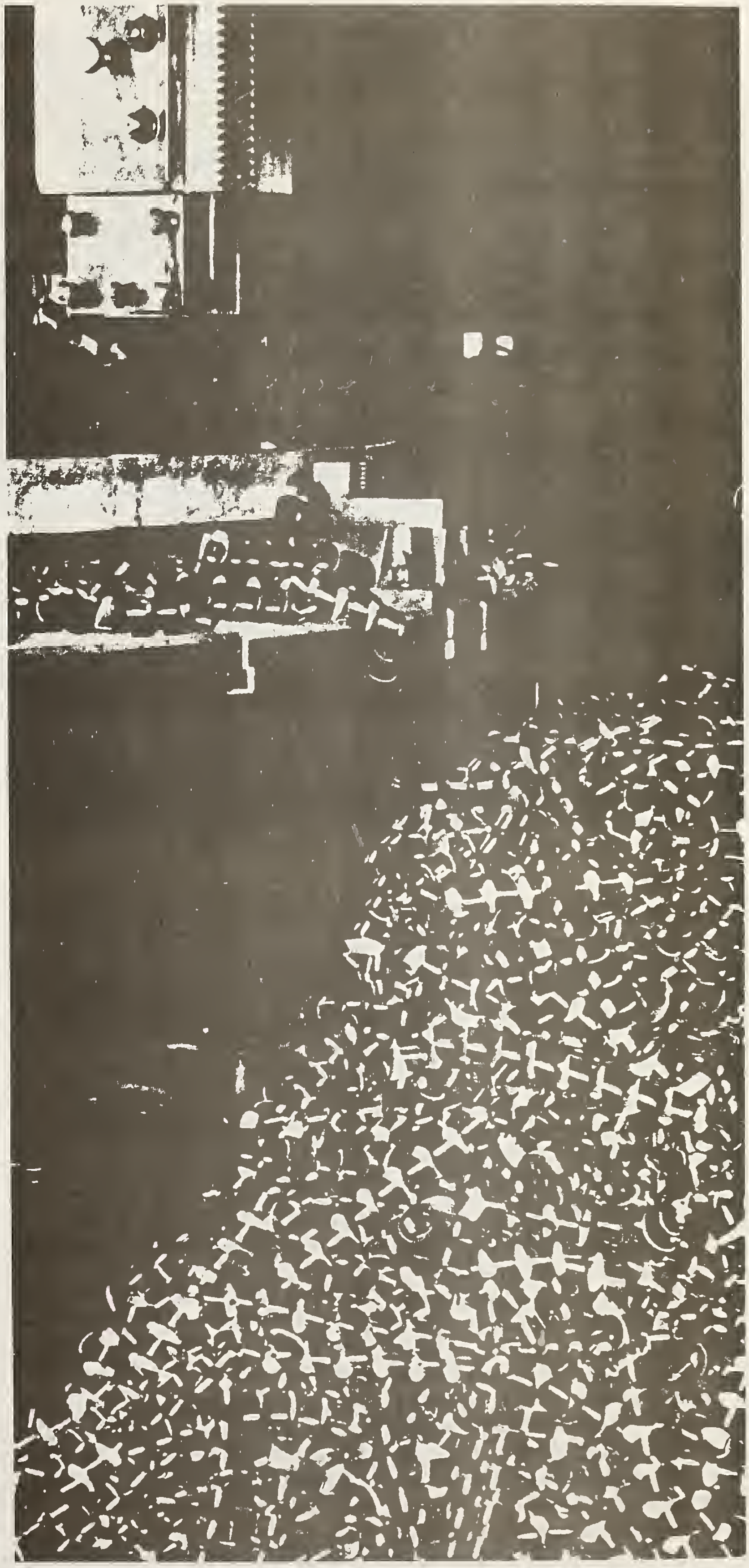
W12-30

The Great Leapfrog Race

Find harder, tougher metals, then find a metal hard enough and tough enough to cut them. Design hotter and higher compression ratio turbo-jet engines, then find metals which can survive the heat and stress. This is the eternal leapfrog in human progress.

Cemented carbide technology is a key leap in the development of almost every industry, and could now assist some companies who have not used or been exposed to its full-range capability. In addition, the industry represents exciting vocational prospects for many who are not aware of its total reach. And for the engineering designer who has filed away the drawings for "the impossible dream" . . . cemented carbides may now make it feasible.

This book is published by the Cemented Carbide Producers Association for people with a need to know. The Association, or any member of it, will be pleased to provide additional information if desired.



Chapter Two — Properties

"Tailorability" . . . to deliver almost any desired combination of wear resistance, shock resistance, or temperature resistance is perhaps the most exciting feature of cemented carbides, possible because their composition can be closely controlled.

The carbides of tungsten, titanium, tantalum, and niobium, for example, approach the diamond in hardness.

Various properties to perform various end uses are achieved by varying the combinations of the metal carbides and the binders.

An important development is the use of titanium carbide (without any tungsten carbide content) bonded with nickel and molybdenum carbide.

In addition, properties can be greatly varied by changing particle size; and the industry can supply these various particle sizes to achieve these specific properties. Some specifications call for uniform micron particle size, others for multiple grain sizes.

Basic research into the properties of cemented carbides has reached the point where available data make it possible to predict their performance in most applications. Their major roles are in:

— resisting wear
— cutting materials

Wear

Chiefly needed to resist any high-wear action are hardness, mechanical strength, compressive strength, and resistance to corrosion and oxidation at various temperatures.

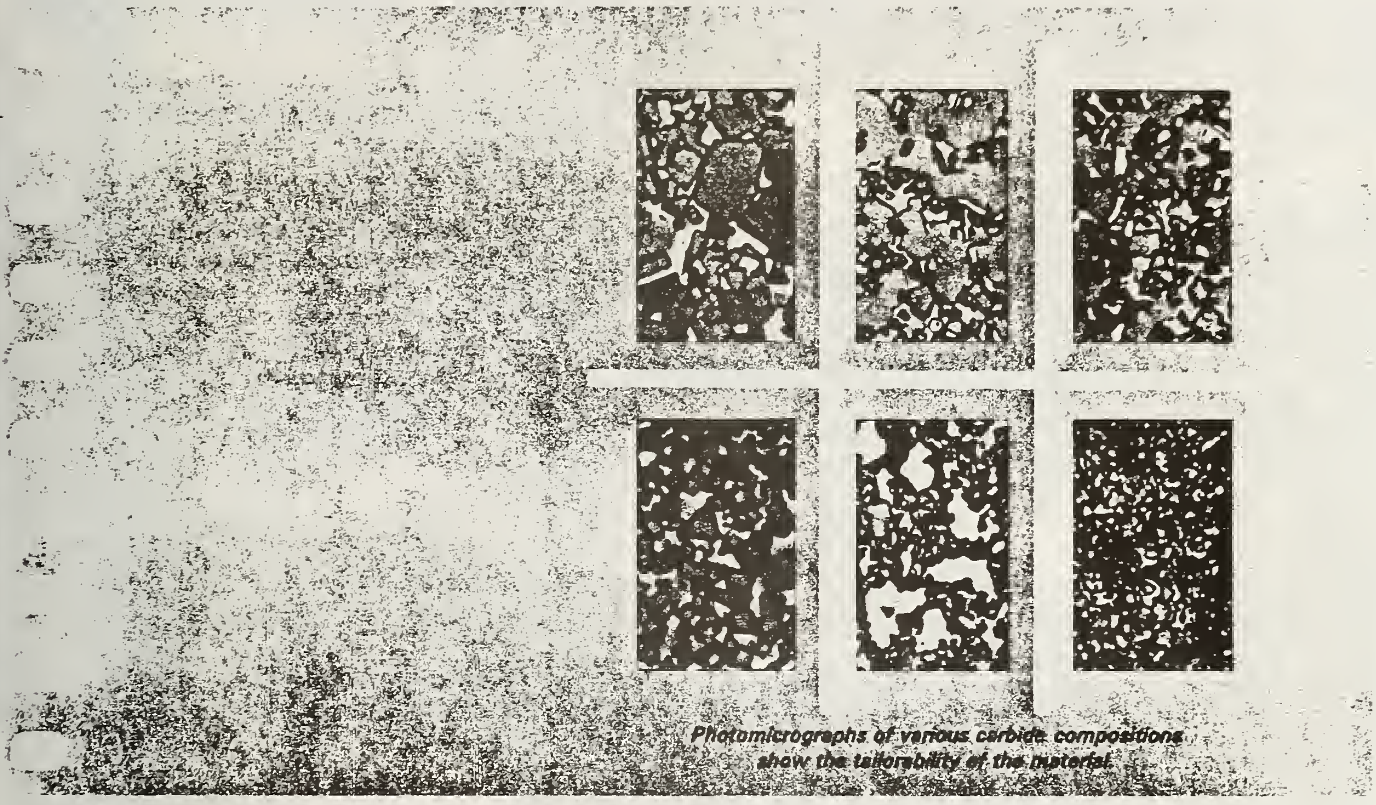
What is an example of dramatic wear resistance which might be envisioned easily by the layman? On the easy-open or snap-top opening tab of beverage cans, have you noticed the hairline scoring on top? That scoreline is produced by carbide tooling which must have a perfectly finished triangular ridge with only a .005 flat top. This makes it sharper than most kitchen knives. Tungsten carbide is used because of its wear resistance. Millions of lids can be produced before the tool is worn enough to require replacement.

The binder or matrix which holds the carbide particles together is generally cobalt. The less cobalt used, the harder the cemented carbide. Increasing the cobalt binder decreases the hardness while increasing the toughness. However, even with as much as 25 percent cobalt content, cemented carbides are harder than most steels and a match to the hardest steels. The cemented carbides used for cutting tools generally have cobalt binder up to about 8 percent. Ten percent or more cobalt binder creates a cemented carbide which is very good for wear and abrasion resistance in combination with high toughness, as in rock drilling. Carbides with binder above 12 percent are generally the die and stamping grades.

A general-purpose cemented carbide used in machine tool cutting will have a Rockwell A hardness of approximately 92.0, while a wear grade having 10 percent cobalt binder may have a Rockwell A hardness of approximately 89.5. As the cobalt binder increases, the transverse rupture strength increases . . . to a maximum at 15 to 16 percent cobalt, then decreases slightly as cobalt content is increased.

Other physical properties vary according to composition, but the hardness, wear resistance and transverse rupture strength are the most critical attributes for judging how good a tungsten carbide grade is for a given application. The transverse rupture strength approximately doubles between a general-purpose cutting grade and an impact-resistance wear grade.

Generally wear resistant and die grade cemented carbides are basically tungsten carbide-cobalt grades as opposed to steel-cutting grades which may need, in addition, tantalum carbide or titanium carbide. For most cast iron and nonferrous metal cutting, the straight tungsten carbide-cobalt grades are used.



Photomicrographs of various carbide compositions show the tailorability of the material.

Cutting Characteristics

The controllable properties of cemented carbides make it possible to provide extremely hard cutting tools with high abrasion resistance, high transverse rupture strength and low coefficients of friction. Cemented carbides also provide great rigidity, exceptional antiweld properties, and retention of high hardness at elevated cutting temperatures. They suffer minimal deformation at high working temperatures because of the cemented carbide characteristic of high hot hardness.

The extremely hard metal carbides have great wear resistance, making possible closer tolerances at high volume production than can be obtained with other cutting tool materials.

General-purpose 6 percent cobalt cast iron cutting grade has transverse rupture strength in excess of 225,000 pounds per square inch. Increasing cobalt content to 10 percent increases the transverse rupture strength in a wear grade to at least 300,000 pounds per square inch. A 13 percent cobalt wear grade has a cross break strength of nearly 400,000 pounds per square inch.

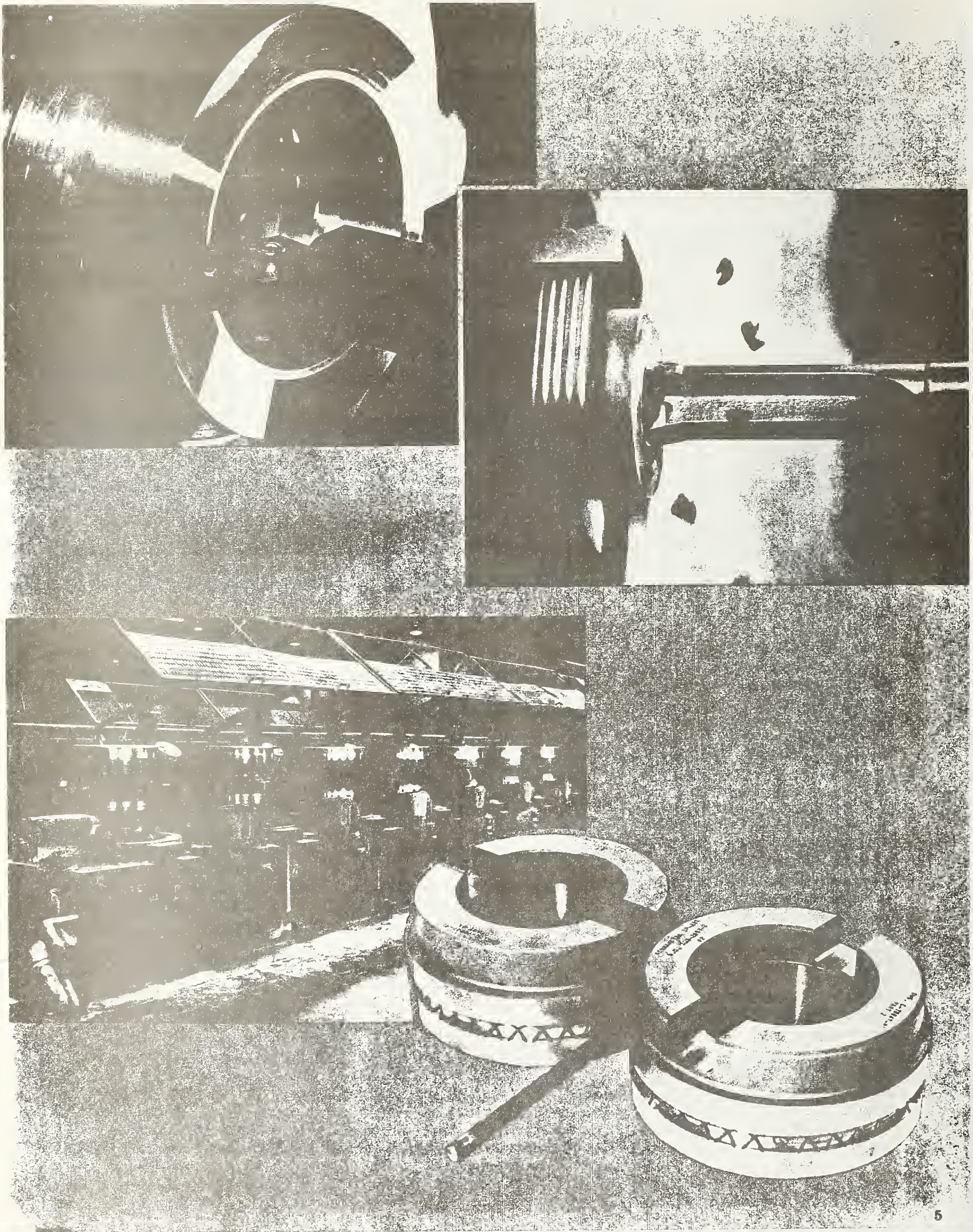
Fighting edgewear and cratering (page 9) or a combination of both in machining different grades of steel, the cemented carbide producer varies the composition of the material.

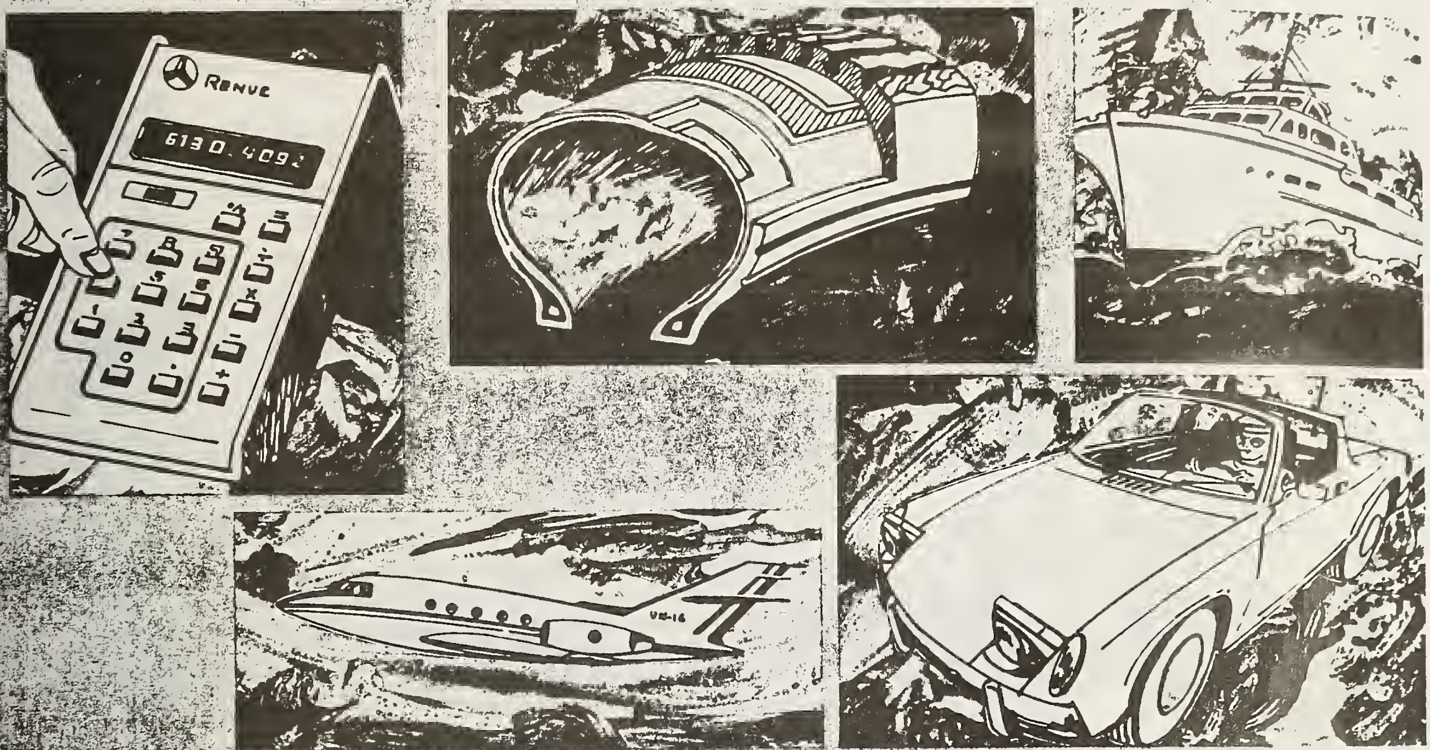
In combating cratering, tantalum carbide and titanium carbide are added in large proportions. The tantalum carbide works against deformation at extremely high temperatures.

While there is much more to this than indicated here, the real point of the example is to show perhaps the principal advantage of cemented carbides, namely that their composition can be quite precisely tailored to the user's application . . . to the type of material being worked, to the type of cutting, the cutting speeds and/or feeds, and the working temperatures involved.

The purpose of this book is not to provide detailed working data, readily available by querying carbide producers, but to give some idea of the flexibility and range of this tailorability.

Opposite —
Above: Cutting
Below: Wear resistance





Chapter Three—Time Exposure ...at the wear point

In 1913 in Germany, two men bent over a wire drawing die containing an insert they had made by sintering compacts pressed from powders of tungsten carbide and molybdenum carbide. They were H. Voightlander and H. Lohmann, and they had just solved the Kaiser's diamond problem.

German patent 289,066 was issued, covering the first practical cemented carbide use, a substitute for diamond wire drawing dies.

Since then resistance to severe wear has been at the heart of all cemented carbide applications, including machining. But since machining is a world of its own, it is separately covered in Chapter Four.

Wear parts, exclusive of cutting tools, represent a considerable percentage of cemented carbide use.

Composition for Wear

In wear resistance we want the correct combination of hardness and mechanical strength combined with the required compressive strength and corrosion and oxidation resistance.

The majority of cemented carbides used for wear parts are made from straight tungsten carbide and cobalt. Some exceptions to this basic composition are found in applications like heading or hot extrusion dies where high temperatures suggest adding tantalum carbide. Light shock wear applications are usually handled with the use of a tungsten carbide plus 3 to 8 percent cobalt; medium shock applications with the use of tungsten carbide plus 9 to 15 percent cobalt; and heavy shock situations with the use of tungsten carbide plus 17 to 30 percent cobalt.

Dies

Cemented carbide dies currently in use have inside diameters from as small as the thickness of a human hair to as large as a bushel basket. Cemented carbide assures lasting high precision tolerance in the die cavity under tremendous volume production.

For example, the very wire drawing application which sparked the industry and solved the Kaiser's wire drawing problem has now mushroomed anew with the tremendous demand for steel-belted radial tires. But steel rolls on mills which produce the rod for the wire can't endure under the heat generated by the very high-speed, close tolerance production needed for such high volume work. Cemented carbide takes over from steel in this and other applications because carbide will maintain size under higher speed, higher volume production, and permit greater size reductions in one step.

The dramatic integrated circuit industry requires production of literally billions of die-stamped terminals held to close tolerances. Only carbide stamping dies can deliver this. One company which produces 10,000,000 . . . (repeat ten million!) . . . terminals per day stamps 45 per second on a triple die at 900 strokes per minute. The units spray out the delivery end into the tote tray like water out of a hose.

Rolls

Cemented carbide rolls have been produced in sizes from a few inches in length to several feet, for rolling products as diverse as stainless steel strip for razor blades, exotic-metal sheets for aerospace applications, sound recording tape and aluminum foil. Harder than the hardest steel rolls, tungsten carbide rolls have more than double the modulus of elasticity of steel, hence more than twice the resistance to flattening and deflecting under pressure. They take a mirror finish which they transfer to the product, and their working life exceeds steel rolls many times.

General

Wherever wear is the major bottleneck to production progress, cemented carbide advances may give us new capabiltities.

For centuries, cables sliding around capstans wore grooves in any material until we learned to face the capstan with cemented carbide, which outlasts steel 100 to one.

Cemented carbide balls and seats in some types of valves were enabled to retain their size and shape as process industries started to transport more abrasive and corrosive materials.

In today's fuel hunger, improved cemented carbides endure under higher pressures in cylinders and liners needed to reach deeper resources both in exploration and production in oil and gas.

In sand and grit blasting under increasing pressures where the very purpose of the blasting particles is to cut, how do you protect the nozzles and chambers? Cemented carbide.

While these applications are now common, environmental pressures, energy conservation, short work hours and other societal forces will demand quantum jumps in productivity and hence greater wear resistance. A National Material Advisory Board report forecasts a hugh growth by 1987 in cemented carbides usage: "The greatest growth is predicted in wear parts."

The advent of new environmental emphasis, for example, coupled with energy shortages, force industry to a number of sweeping product and process changes unattainable without a sharp step-up in wear resistance. The already mentioned beverage container exemplifies both. Needed was a container using less energy-consuming metal, and with fewer litterbug hazards.

The industry moved from a three-piece to a two-piece, thin-walled, drawn-and-ironed can requiring a deep draw in billions of copies. Only cemented carbide tool surfaces make it work.

In the environmental drive to eliminate the throw-away tab previously mentioned, a scoring edge was required which could maintain precision in the face of the wear from huge high-speed runs.

As the cashless society breaks upon us, business machines triggered by telephone will proliferate and will operate around the clock. Small, but crucial, wear parts will log 24-hour friction. In those solid-state electronic business machines without moving parts, the machines which build them suffer high volume wear. Already Madame Consumer goes to the supermarket in large numbers using her pocket calculator which required production by cemented carbide tooling.

This presages a home computer age which will require billions of miniaturized parts stamped with carbide dies.

However, while new applications will multiply, the familiar applications will step up their cemented carbide requirements dramatically.

In satisfying the nation's energy hunger by deeper drilling, improved cemented carbides endure under higher pressures to reach deeper fossil resources. Coal gasification processing will use cemented carbide wear parts. The working surfaces of coal pulverizers are armored with cemented carbide brazed into place.

The work rest blades in centerless grinders are faced with cemented carbide for longer life.

Cemented carbide strips on the blades and guides of paper cutters will remain sharp despite the anticipated surge in book production in the future.

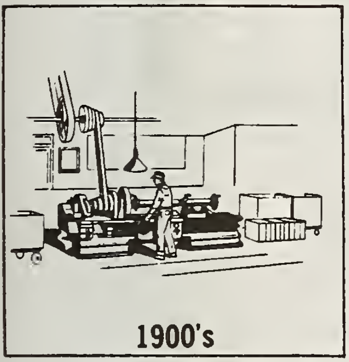
Hammers and blades for stirring, mixing, crushing, pulverizing and blending materialssuch as paint pigments, tobacco, grain and coal now enjoy tremendously increased life spans with cemented carbide wear surfaces.

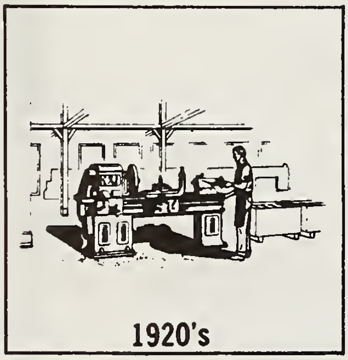
In wear parts . . . bushings, mandrels, die nibs, cams, gears, arbors, sleeve rings, rollers, slitters . . . cemented carbides will outlast and outperform other materials up to 200 to one. The life of a cemented carbide die can be 20 to one or better over a similar steel die.

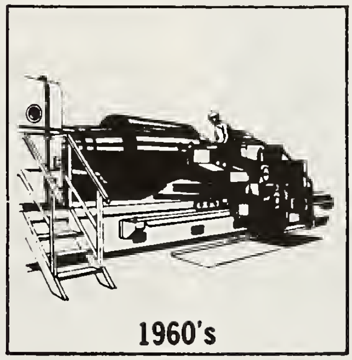
Increasingly we will find carbide inserts in swaging dies to hammer down refractories in high heat where alloy steels wear considerably, and in steel dies for cold heading rivets, for cold swaging wire, needles, profiles . . . with a 30 to 60 percent longer life than tool steels.

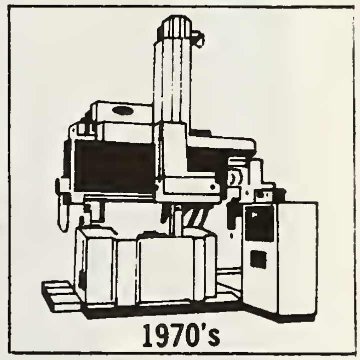
In many cases, where wear has been blocking revolutionary new production volume requirements, the gate has been opened by cemented carbides.

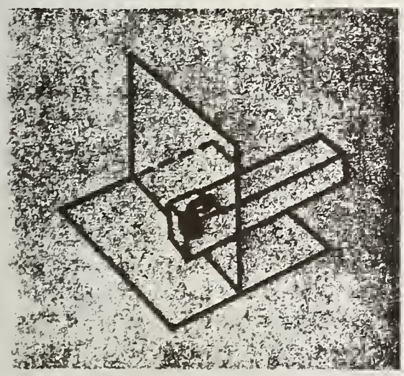
Chapter Four
The Cutting Edge

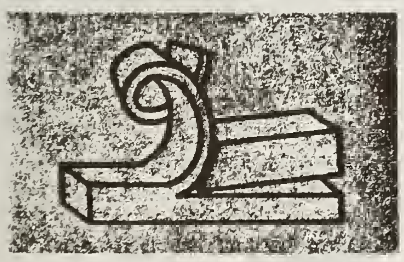


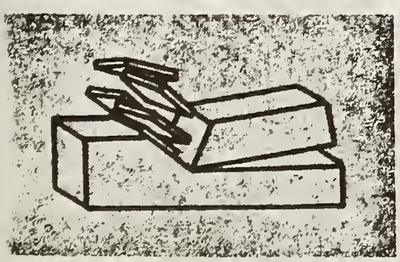












With diminishing patience, we tune out voices telling us man's progress is utterly contingent upon everything from aspirin to xerography. Yet, truly, man's increasing ability to work metal does seem to pace our advance.

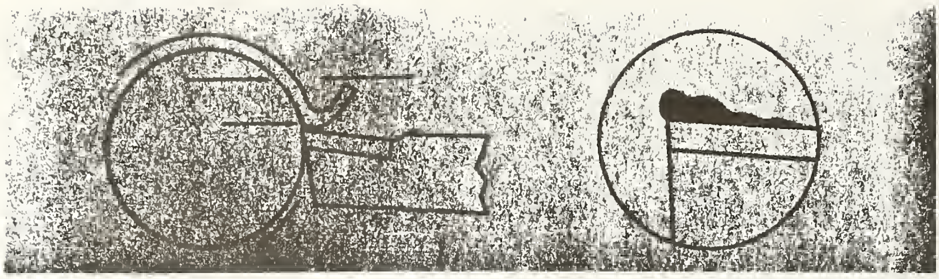
The chief factors in production metalworking success are precision, speed and output. Tremendous advances in machine tool design and in measuring and sensing devices have achieved marvelous precision. But speed and output have been limited by cutting tool materials.

Cemented carbides are pivotal in that part of the metalworking story.

A cutting tool exerts force along its cutting edge to overcome the cohesion of the metal in the workpiece. The resulting shear plane reaches maximum stress when perpendicular to the tool face. The metal will rupture with continued application of force, becoming a continuous chip or segmental chips. Cutting tools removing metal must be able to withstand tremendous forces.

Machinability is influenced by the type of metal being cut, the type and geometry of the cutting tool, the cutting process, the type of machine tool, the size and shape of the cut, the cutting fluid, the cutting conditions . . *but most importantly by the material and geometry of the cutting tool.* The user wants to remove metal at a rapid rate at low cost to produce a specified surface finish.

In direct response to these conditions, we select the best cemented carbide compound for the specific job. It will have a specific composition and grain size, and will have been manufactured in a controlled way. Both the amount of metal carbide and the amount of metal binder, for example, affect tool hardness. Edgewear and cratering, the two basic types of wear in machining operations, can be limited by carefully selecting the cemented carbide grade for the application.



Edgewear/Crater Wear

Edgewear, which occurs along the cutting edge of a tool as a result of friction or abrasion, is most critical when machining materials which produce a brittle, flaky chip. This occurs mostly when machining nonferrous metals, nonmetallics and most cast irons. Strong wear-resistant cemented carbides are used, usually combinations of tungsten carbide and cobalt.

Cratering which occurs on the rake face of the tool at the point of impingement of the chip results from high temperatures and pressures which tend to cause the chip to weld to microscopic particles of carbide in the tool face. These weld points build up, creating pressures between them and the chip which increase until they tear out and wash away. Most steels, and some highly alloyed cast irons, when machined, are prone to cause a combination of both edgewear and cratering on the cemented carbide cutting tool. To overcome this tendency, titanium carbide is added to the tungsten carbide-cobalt mix. The titanium carbide decreases the tendency of welding and subsequent cratering, because the diffusion temperature between steel and titanium carbide is higher than that between steel and tungsten carbide. It also lowers weld strength if welding does occur.

Crater resistance as well as resistance to deformation is improved by the use of tantalum carbide and titanium carbide. Reduction of the amount of cobalt also improves resistance to cratering.

Although cobalt predominates as a binder in cemented carbides for cutting tools made with tungsten carbides, nickel and molybdenum are used as binders in titanium carbide tools operating at high speeds to produce fine finishes. The titanium carbide-nickel-molybdenum carbide compositions also serve in some tools for interrupted cutting.

While we have discussed here the classic cutting edge, the degree of advantage accrues to other metalworking — stamping, impact applications, wire drawing, extrusion punching, drawing and ironing.

Coated Carbide Development

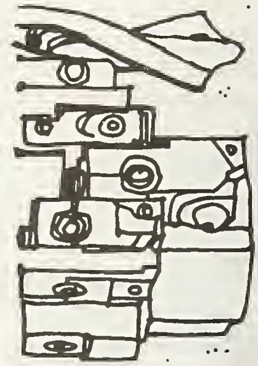
Coated carbides are a relatively new development which enhances those properties previously described, minimizing wear and increasing length of production runs while allowing utilization of high speeds.

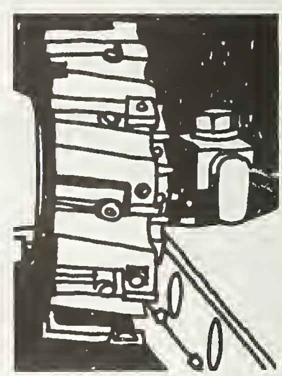
Carbides really caught on as cutting tools rather late, the early 1940's. With high usage it became apparent that if carbide had a weakness in cutting it was largely caused by the friction heat of the chip sliding across the tool face. Major research went into developing tool materials that would reduce chip friction, including many types of treatment of the carbide and also a multitude of compositions. None was really successful until the development of the types of coatings now commonplace. These first gained acceptance in the late 1960's.

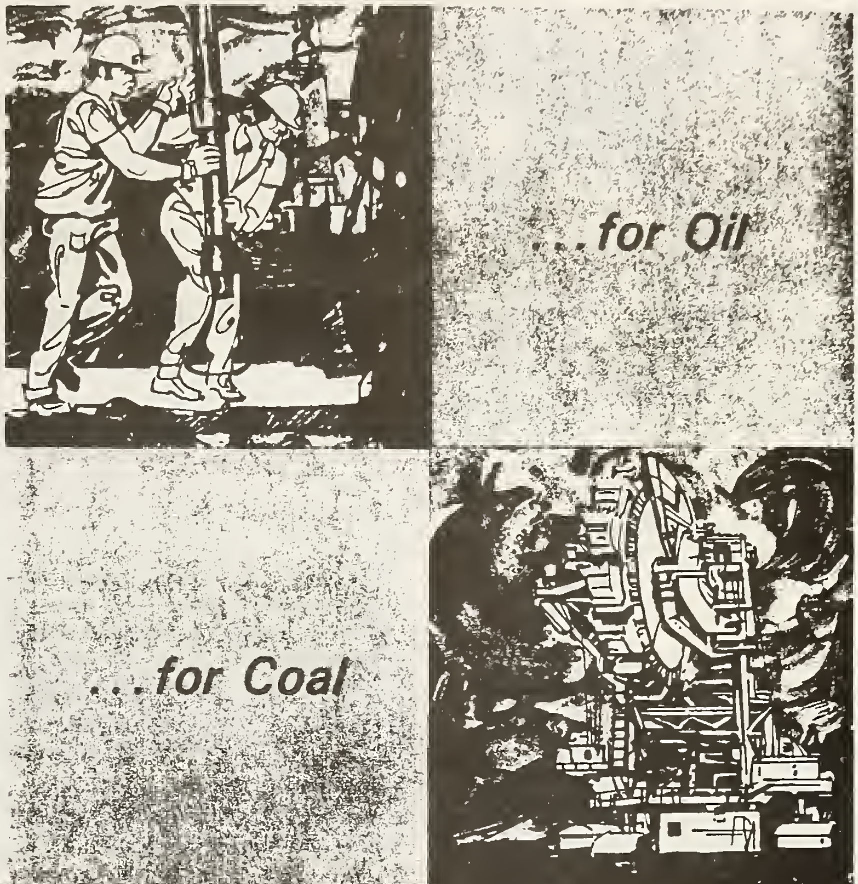
Today's coatings are single or multilayer coatings of metallic carbides or nitrides which at least in part reduce chip friction.

Coated carbides are available in a variety of types including titanium carbides and nitrides in single phase, combination of both in double and triple phase, hafnium carbide and nitrides and ceramic coatings. Coatings are usually used for cutting materials but other applications are being found daily.

With the achievable properties shown in Chapter Two, tailorable as will be shown in Chapter Seven, cemented carbides have revolutionized metalworking.







Carbides In Energy

Cemented carbides spectacularly revolutionized mining and drilling for resources. For example, while steel tipped cutters became blunt in drilling a few inches through rock, carbide edges regularly drilled several hundred feet or more without reconditioning.

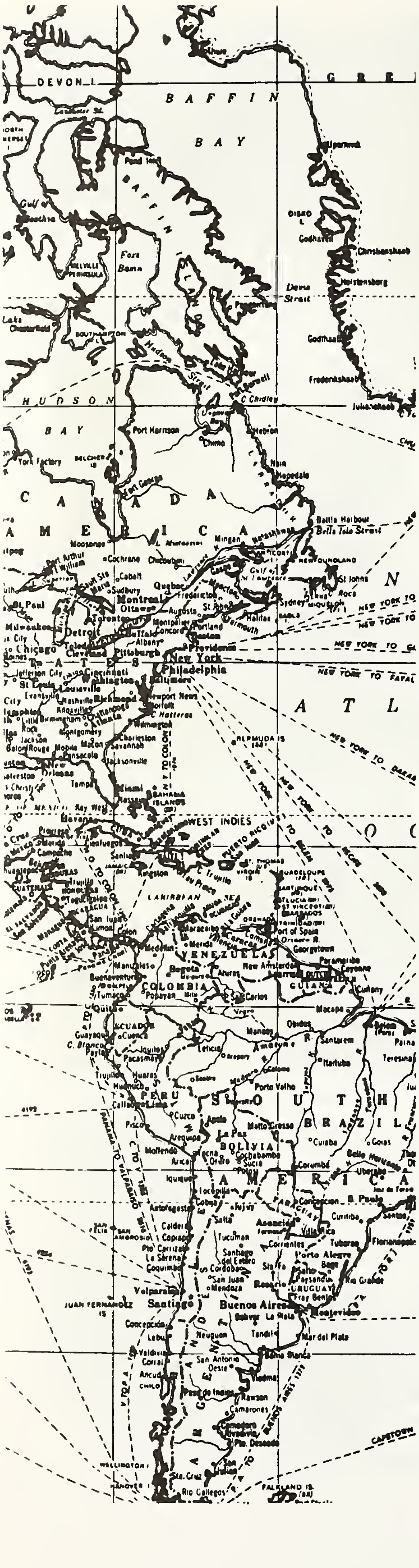
With the later arrival of energy shortages, such dramatic gains become routine necessity. Without carbides, coal mining costs would be mind boggling. Carbide cutters

become the point of attack for going deeper into reopened coal mines and for stepped-up production and for deeper exploration for oil and gas.

In the energy picture, cemented carbides are the teeth for increasing recovery of every type of fuel. You will find carbide inserts in the cutting edges of all cutting tools used in recovering fossil fuels of all kinds.

But over and above energy fuel *recovery*, carbides make probably an even greater contribution in energy conservation. The drive is on to consume less electric power by using thinner materials in products, thus conserving the energy expended in producing those metals. Tremendous amounts of energy are required in smelting, quenching, and rolling. The use of thinner metals often requires new processes. These new processes in turn often depend upon harder, tougher cutting tools or wear surfaces.

You have noticed how beverage cans, for example, have become increasingly thinner-walled, to the point where you can now squeeze them with two fingers. These are made by the draw and iron process which could not operate without carbide dies.



Chapter Five — Strategic Value to the Nation

One of the most accurate measures of the strength of a nation is the capability of its metalworking industry, which is in turn dependent on its cemented carbides.

By this criterion, the United States is emphatically world leader.

Although the pioneering research took place in Germany, France and England, the United States assumed the lead in cemented carbide technology . . . by necessity . . . during World War II.

A nation's cemented carbide resources continue to be so pivotal, not only in its defense but also in world economic competition, that America's industry is moving to recycling carbides, reclaiming materials not normally a natural resource of the U.S.

The U.S. cemented carbide industry is now a major supplier of both cutting tools and wear parts to other nations in all parts of the world. For example, cemented carbide rolls from the United States are now being shipped to the German Ruhr . . . where cemented carbides began.

By increasing tool feeds and speeds, and by making possible other improvements in metal processing such as better surface finishes, cemented carbides are the fastest-growing tool material in the world.

The reason is uncomplicated: *Cemented carbide tools last longer and do a more precise job . . . faster and better and cheaper.* This effects major cost savings. Second, cemented carbides make practical the manufacture of products not previously feasible, for example the billions of tiny stamped parts required for a surging electronics industry and the billions of paper thin drawn and ironed metal products.

How Big Is The Industry?

The drama of it is smallness.

Though doubling every five years lately, the industry is still measured in less than a billion dollars. But it is the classic horseshoe nail of the industrial kingdom, making possible all else. And future growth is only limited by raw material supply.

Regarding size, a second amazing aspect is that the industry's approximately 11,000,000-pound output is made up of tiny pieces of carbide averaging under an inch long and weighing less than 3-1/2 ounces.

Third, and more amazing, while the material is not inexpensive, it will lead any anti-inflation breakthrough. Although the cost has plunged from $1.00 per gram in 1935 to about 12¢ per gram at this writing, that doesn't begin to be the point. Cemented carbides make possible production economies of scale in every other industry they touch, thereby battling inflation, one of the overriding challenges of the last third of this century, worldwide.

So how big is the industry? As a major hope against energy shortage and inflation, it looms gigantic.

"Global responsibility"

Look Ahead Lens

The cemented carbide industry expands by surges, usually when production engineers in other industries run into wholly new conditions requiring quantum jumps in productivity or precision or cost reduction or drastic design change.

Since those events will occur on accelerating cycles under accelerating pressure of energy and resource shortages, cemented carbide cutting and wear applications will proliferate even faster in the future.

Some idea of how much room for growth lies ahead comes clear when we realize that cemented carbides are only now beginning to be appreciated and exploited by such giant industries as electronics, chemical processing, business machines, and the food industry.

The Surprise of Discovery

As industry discovers cemented carbide rolls, tremendous production advances become possible. The carbide rolls dramatically reduce the cost per pound of material rolled. For example, one producer of zirconium sheet who only reluctantly tried cemented carbide rolls on a trial basis found that they were able to reduce the cost per pound of rolled zirconium 38.6 percent, and output was increased 65 percent.

With these kinds of gains, manufacturers are finding many startling new advances are possible.

Cemented carbide thinking is only now reaching many manufacturing operations. And it is also just reaching many original equipment designers.

Meanwhile, application engineering within the cemented carbide supplier companies has matured into new applications — semiconductors, integrated circuits, new space applications, just to mention a few. These in turn become proving grounds for still newer applications.

If you're interested, contact any of the companies listed on the back cover.

Compounded by Carbide Research Advances

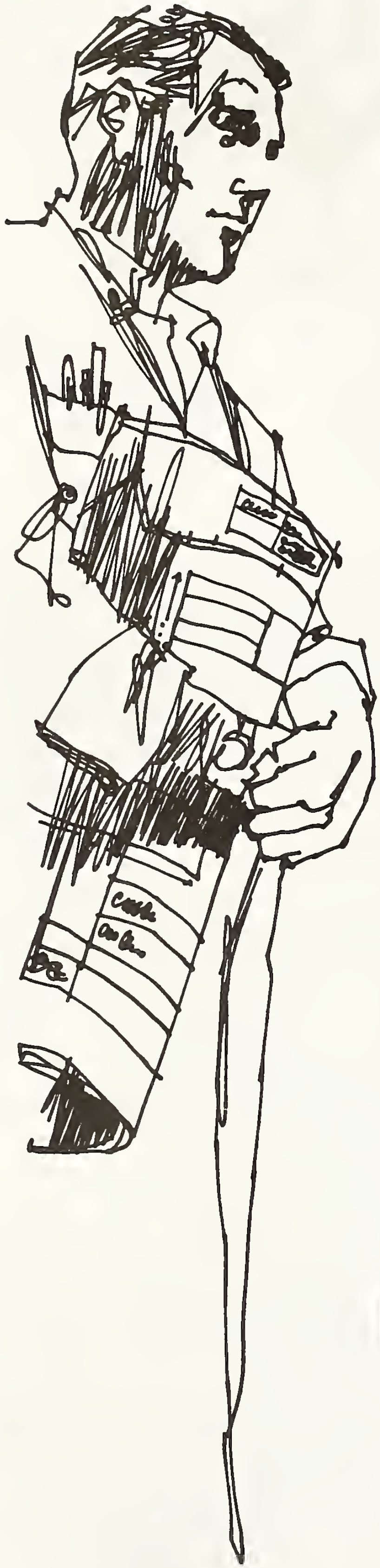
In addition, the industry itself enlists entire new user industries as it develops carbide technology. For example, the application of tungsten carbide into and onto the surface of cutting tools, punches, dies and even the electric carving knife, gives metals a hard wear-resistant surface not otherwise obtainable. This new development opens up an entire new potential.

The overlay principle will permit the use of tungsten carbide wear metal on any metallic surface regardless of shape, size of configuration.

Coating carbides, meaning articles coated with a layer of refractory carbide or nitride or metallic oxide, open up new applications.

The excitement in the future of cemented carbides lies in the accelerating daily discovery by more potential users who encounter the wide range of money-saving applications. Complete performance data are now available for literally thousands of combinations of the basic materials and processing methods used to create cemented carbides. And material is available to help users determine which cemented carbides can best meet their particular requirements.

Design engineers find that shelved plans are now possible and horizons widen with cemented carbides.



Chapter Six — Wide Angle Lens

From Heavy Stone to Cemented Carbides

"I cut steel with the first carbide in these parts," you can still hear a machinist say.

Like electronics, oceanography and aerospace, cemented carbides do not yet have an ancient history. But in the accelerating pace of multiplying applications, the young industry is maturing fast.

Yet of course there were steppingstones in the past to build upon. In the buildup to cemented carbides, the first stones were "heavy stones," that is . . . "tung sten" . . . as the Swedish pronounced it.

It takes a wide-angle lens to picture the origins, because the contributors to cemented carbides were far-flung, working separately in Germany, France, England; and the raw materials came from Peru, China, Bolivia, Mexico.

These are two separate currents which flow along in parallel before they converge to become cemented carbides. The two currents are:

— the story of the carbides and the matrix

— the story of man's need.

The Carbides and Matrix

Those who spoke of tungsten back in 1574, when we first find it mentioned in scientific literature, knew it was hard, but considered it a nuisance.

Tin miners in Cornwall, England, called it mock lead and "the wolf" . . . "because it eats up tin as a wolf eats sheep." The name stuck and became official, wolferam (wolf and ram). Later it shortened to wolfram, and still later to the symbol, "W".

The Need

By approximately 1800, man's best cutting tool was high carbon steel. We could cut at about 25 surface feet per minute. We could not sustain this cutting action long; the heat softened the tool, which lost its cutting edge.

Mr. Walleston

In the early 1800's, in England, W. H. Walleston was exploring in metals. We owe him much for his pioneering in modern powder metallurgy which is the essential process in cemented carbides. Walleston made platinum products by reducing chloroplatinate to powder. He then cold pressed and sintered it.

Walleston also invented a brass die and punch and a hand-operated toggle press. His molded parts were ejected much as we eject today, and then sintered.

Needed: Tungsten's Toughness

In 1868 in Terre Noire, France, men needed tougher rail road rails for a mountain stretch. They found that tungsten alloyed in steel gave them greater toughness.

In Need Of A Diamond

In 1896, Henri Moissan, a French chemist, and a giant in the carbide story, needed a method for making diamonds. He designed and built an electric arc furnace which produced the hottest heat to that date. He heated chunks of iron and lumps of sugar burnt to charcoal. Then he withdrew the burning mass and plunged it into a quench. He made diamonds. But they were too small.

Monsieur Moissan's Giant Step

Next Moissan tried heating carbon with other elements including *tungsten*. Tungsten had the highest melting point of any pure metal. The result was a dull pebble. It was not a diamond; it was a new chemical compound, tungsten carbide. He reported the compound to be 16 times heavier than water and harder than any known material *except* the diamond. He told us some other properties, including the melt point (6150°F). Though he won the Nobel Prize in chemistry in 1906, he died the following year not knowing what he had done for the world by inventing tungsten carbide.

Need For More Than 90 sfpm in 1900

By 1900, we had developed high speed steels and could successfully machine at about 90 surface feet per minute (sfpm). Tools would hold their hardness at around 1100°F, a low-red heat. But 20th century mass production was ready to be born.

". . . How To Use The Blooming Stuff"

In 1913, the year before the Kaiser's armies invaded Belgium, the Cornish mines in Britain received orders for all the Wolframite they would sell. Glad to get rid of the nuisance material which made tin extraction difficult, one British scientist said, "The Germans somehow know how to make use of the blooming stuff."

For Want Of a Diamond Source

In World War I the allied blockade cut Germany off from its source of wire drawing diamonds. Looking for a substitute, their engineers produced inserts for wire drawing dies. The inserts were tungsten carbide grains cemented with iron. While this matrix was not ideal, it is believed that the Germans used it to machine Big Bertha . . . the world's biggest gun.

Enter Cobalt

Heinrich Baumhauer and Karl Schroeter, working at the Osram Lamp Works in Berlin, soaked the porous, spongy, melted tungsten carbide in liquid iron. Later, in the Osram-Studiengesellschaft laboratories, Schroeter crushed tungsten carbide particles into a powder with which he mixed a strong, malleable auxiliary metal . . . cobalt. With Schroeter's patent, Krupp began producing die inserts and tool tips, called Widia ("like a diamond"). They exhibited these in the Leipzig Spring Trade Fair, 1927. Some of these were imported into the United States in 1928 for test.

Dr S. L. Hoyt, an American research scientist, addressed the 1928 American Steel Treaters' Convention on the properties of tungsten carbide, on which several companies were experimenting.

A major electronics manufacturer acquired American rights to manufacture under the Krupp process; and, in 1929, in turn licensed others to produce tungsten carbide.

Leapfrogging The Tools

Initially users had difficulty harnessing the hard brittle material. They had to invent new tool geometry and brazing techniques to bond the carbide cutting tool to the steel tool shank because of the difference in expansion and contraction between carbide and steel. To make advantage of the carbides, machine tool builders had to boost horsepower. And because of the carbides, parts could be machined from tougher metals.

We will see a continuing leapfrog of tools, metals and cutters.

150 sfpm

So in the late 1920's cutting speeds leaped to 150 sfpm. Now several companies got into the business, pressing the art forward.

Enter Titanium Carbide

In the 1920's the first major change came, a tungsten-titanium carbide mixture. These carbides machined steel at much higher speeds because of their ability to withstand cratering of the top face by the chip. In boring mills, planers, lathes and other single point machine tools, the rates were as much as 150 percent faster.

Enter Tantalum

Even superior to titanium carbide came the combination of tungsten, titanium and tantalum carbides with small amounts of columbium carbide. These materials were dramatic in machining higher strength alloy steels where high heat was generated. This combination gained hardness from the tungsten, crater resistance from the titanium and heat resistance from the tantalum.

Enter Hitler

During the 1930's as Hitler's shadow blackened Europe, the world woke up to find that Germany had bought up virtually all of the world's off-grade tungsten ore. He knew that to control the world, you had to control the cemented carbides.

The New Carbides

For certain roles in the continuing drama, metallurgists tried out an exciting cast of other carbides: molybdenum, manganese, chromium, vanadium, silicon and zirconium. The stars of the show, however, remain tungsten, tantalum, titanium and niobium.

Needed: "Arsenal For Democracy"

In World War II, the United States needed to become the arsenal for the allies. That unmatched tour de force of high-speed production was made possible only by the extensive use of cemented carbides.

WW II Ends

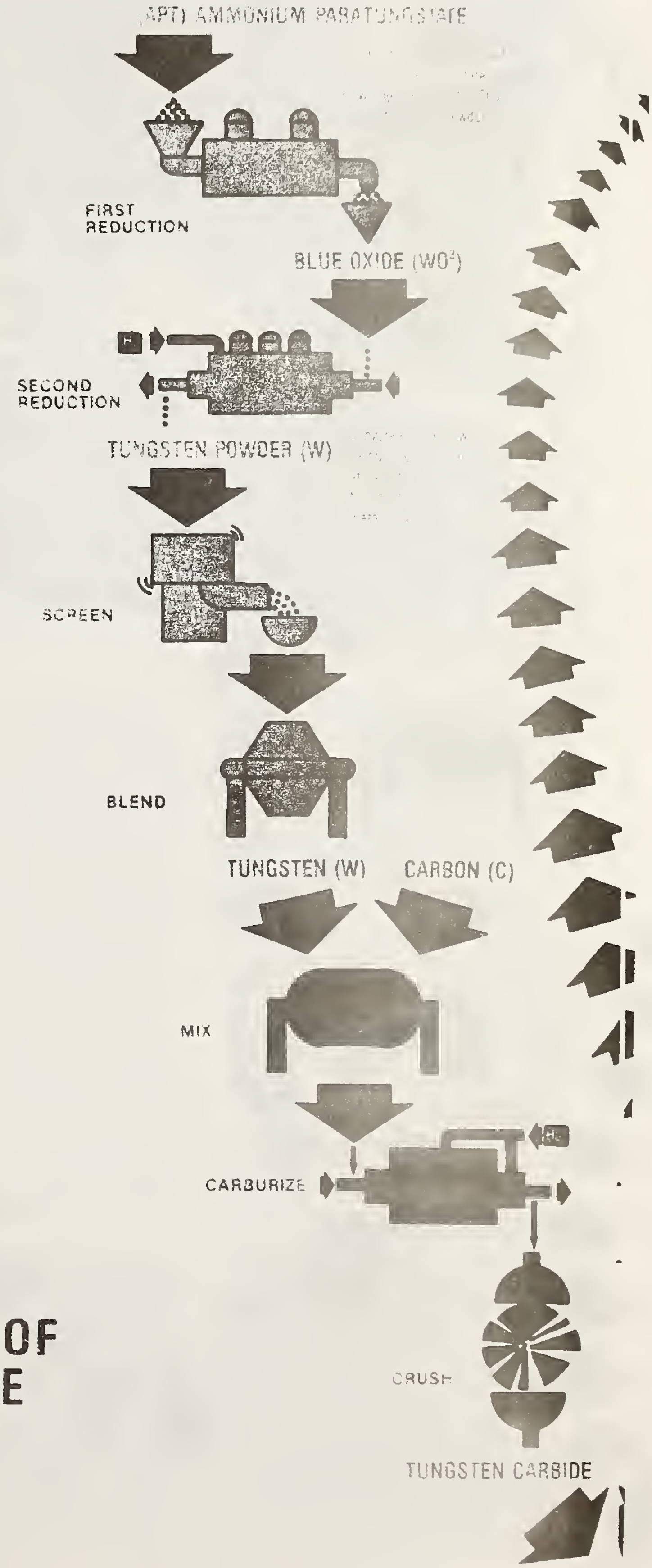
The rebuilding of the post-war world and supplying pent-up consumer demand kept the pressure on American industry which again stepped up the use of cemented carbides which were then fully recognized as essential to productivity.

The relatively small number of young cemented carbide producer companies born to fill the crucial need had to keep running full out without taking time out for establishing routines. In those early days, each new and different application was a special case.

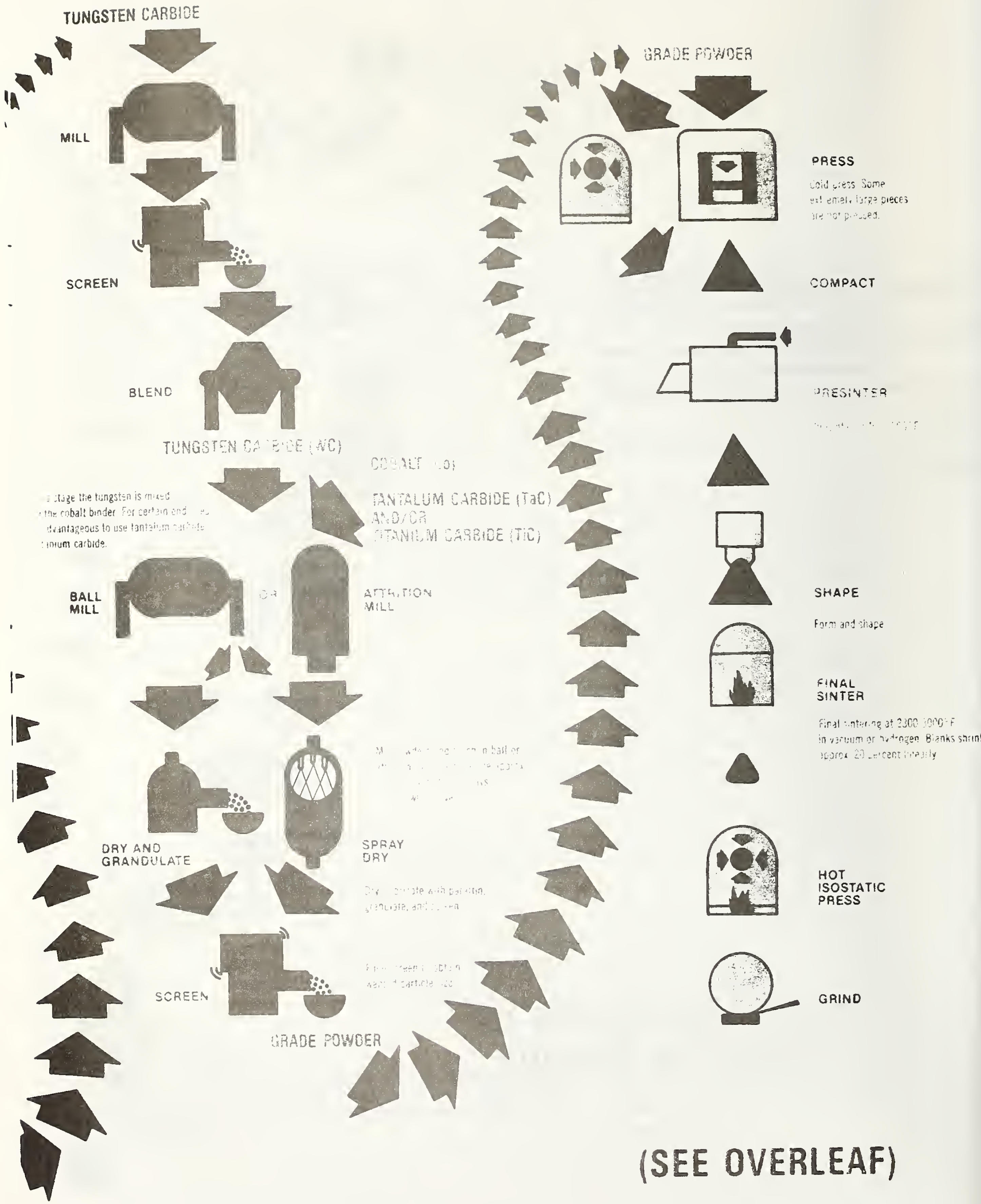
While this vigor was healthy, industry leaders yet recognized that the fast growth gave rise to some of the wasteful Topsy-ism and often gave customers confusion of sizes, numbers, standards and lack of uniform and organized information. Therefore three of the companies in the industry met to discuss formation of an association to work on standards, grade numbering, and the focussing of certain research priorities for the good of the nation (Chapter Seven). That was the beginning of Cemented Carbide Producers Association and a new level of service to carbide users.

Chapter Seven — Instant Replay

How Do They Make It?



THE MANUFACTURE OF TUNGSTEN CARBIDE



(SEE OVERLEAF)

Carbides for use in cemented carbides are usually produced from oxides of tungsten, titanium or tantalum, or reductions of these oxides, with carbon in an induction furnace. This creates carbide powder.

Next, the carbide powder is mixed with cobalt or nickel powder, which has been produced by reducing oxides of these metals in a controlled atmosphere at high temperatures. This mixed powder is then crushed and pulverized, usually by wet ball milling, to a very small size. Drying and lubricating follows (generally with paraffin), after which the powder is processed by screening, blending, and granulating to prepare it for hot or cold pressing. For cold pressing the powder is pelletized and granulated. Some producers make the granules by spray drying.

Both hot and cold pressing create cemented carbides by the powder metallurgy process. Compacted or pressed powder is heated to the point at which the cobalt or nickel powder in the mix melts. This melting point is below that of the tungsten, titanium, tantalum or niobium carbide powder. This creates a "cement" which holds the hard fine carbide particles — hence, the term "cemented carbide."

The cold press and sintering process is used primarily to make cutting tool blanks, wire drawing die nibs, wear-resistant parts of relatively small size and mining tool blanks. It also is employed in manufacturing blanks in intricate shapes. For cold pressing, a tungsten carbide lined mold presses the blank at pressures in the range of 15 tons per square inch. The pressed blank or briquette is then given a preliminary heat treatment to remove the paraffin, after which it has a chalk-like consistency. This preliminary sintering also gives the part enough strength to make it possible to form angles, steps, holes and other shapes. Finally, the completely formed blank is sintered in a controlled atmosphere, generally vacuum or hydrogen. This final process shrinks blanks 20 to 30 percent linearly, requiring strict control.

The hot press method is used to make large cemented carbide products such as work rolls and bar stock with diameters to 25 inches and length to 40 inches, and weighing as much as 1,000 pounds per piece. It also is used to make large carbide drawing dies. In hot pressing, a graphite or carbon mold is filled with unwaxed blended powder. The mold is placed in an induction furnace where heat and pressure are applied simultaneously to form and sinter cemented carbide. Here, the mold must be made accurately to assure absolute adherence to the dimensions desired in the finished cemented carbide product.

Recently some carbide manufacturers in seeking more dense material have adopted hot isostatic pressing. The process involves applying high temperature and high pressure in a controlled atmosphere and virtually eliminates porosity.

Regardless of which method is used the most difficult part of the process is this: *Laboratory standards of quality control must be applied to the mass-production methods.* Even slight impurities in carbon, oxides, carbide powders, metal powder, blended powder or foreign material cannot be tolerated. Heat, pressure and atmosphere must be held within extreme limits to assure a finished product to exact specifications.

But . . . the payoff for this effort is the remarkable savings in time and money that cemented carbides have made possible for industry.

Chapter Eight— Portrait Shots

Who's Involved?

From whatever motive one approaches cemented carbide, he finds himself in the company of discoverers.

An industrial designer finds that he can now employ certain exotic alloys which could not previously be machined economically. A rolling-mill production superintendent, fighting the costs and the clock, finds that with cemented carbide rolls he can now make fewer passes and larger step-downs. A petroleum driller, stopped at a rock ledge at the thousand-foot level, finds that with cemented carbide cutters he can cut through. A coal producer who has crossed an area off his mining plan as "mined out" finds that it can now be reworked because of the sharper bite of carbide-tipped cutters.

A manufacturer faced with the need for an enormous productivity jump to 10,000,000 tiny parts per day finds that with carbide stamping dies unprecedented new volume is possible.

Young people are discovering unexploited career opportunity in carbide. In marketing, for example, there is room for talent in bringing the advantages to the users and in assisting customer engineering in problem solving. Graduates in metallurgy, chemistry, and mechanical and electrical engineering discover in cemented carbides a whole new career area. The material is still young enough in application that elbow room is enormous for people with ideas . . . as in the early growth days of aluminum and plastic.

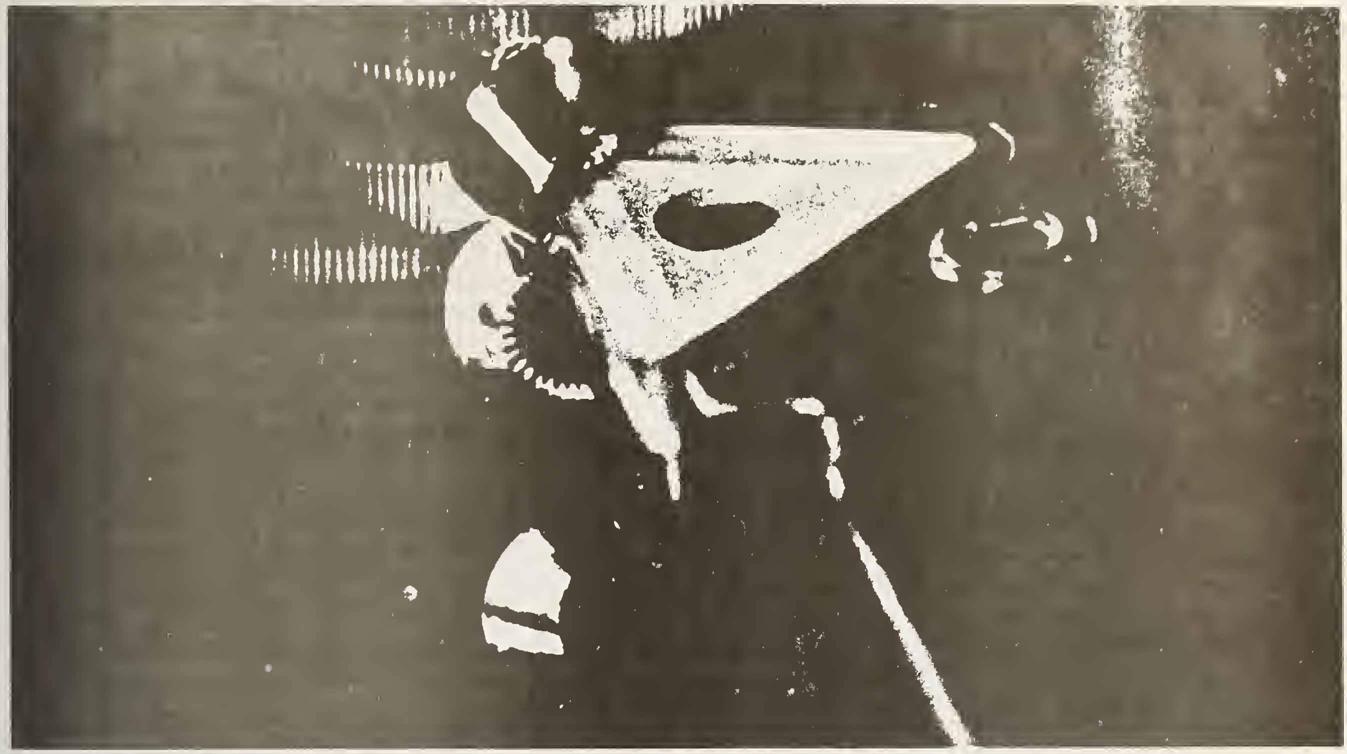
The university research director finds new and exciting demands upon his department for exploitation of cemented carbides.

These are opportunities for metallurgists in research and development as well as careers in production.

On the production floor the industry still needs more people trained as tool and die makers, machine operators, and production superintendents to produce carbide.

There are opportunities for tool engineers to instruct users in the proper application of carbide. The development of application data is accelerating, but many are unaware of the substantial body of material already available.

In addition to carbide specialists, the industry offers in increasing numbers those careers found in most production industries.



Sources for Detailed Information

The Cemented Carbide Producers Association (CCPA) has concentrated since 1955 on developing recommended procedures for making chemical, metallographic, and physical determinations on the products of the industry and disseminating these procedures broadly through independent recognized agencies such as American Society for Testing and Materials (ASTM), American National Standards Institute (ANSI), The American Society of Mechanical Engineers and The International Standards Organization.

To foster completeness and consistency of information, CCPA coordinates with all established arms of the tool industry, such as the Society of Carbide and Tool Engineers (SCTE), the Society of Manufacturing Engineers (SME), the American Society of Mechanical Engineers (ASME), and the Metal Cutting Tool Institute (MCTI). Internationally the CCPA coordinates information through the International Standards Organization (ISO).

The searchers can now find specific cemented carbide information in public and private technical libraries because of the cumulative publishing activity of CCPA.

Cemented carbide grade classification charts for users were published early by individual member companies, followed by a series of bulletins by the Association on standard industry test procedures for determining basic properties, a recommended numbering system for many carbide products, plus a multiplicity of dimensional standards for various classes of products. In addition to its own developed information, the Association bulletins chronicle the availability of other technical reports, thus becoming cumulatively a bibliography on cemented carbides.

Since cemented carbide applications have compounded rapidly during the short publishing life of the Association, the user would do well to note the dates on the publications.

Search

To keep the research action focussed on the priority areas and to avoid redundancy, the Association technical committees maintain an alert information network. Important projects not being undertaken privately are encouraged, supported and sometimes sponsored by the Association at universities and other qualified institutions.

Momentum

Like a chain reaction, each new cemented-carbide application releases two or three more neutrons of ideas which in turn each spark two or three more. This multiplication brings more and more professions, skills and students into the cemented carbide *discoverer's club* which compounds the momentum.

Welcome aboard.

Cemented Carbide Producers Association Members

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Delta Carbide, Inc.
4141 S. Oak Street
Metamora, MI 48455

Duramet Corporation
24343 Gibson Drive
Warren, MI 48089

Fansteel VR/Wesson
800 Market Street
Waukegan, IL 60085

General Carbide Corporation
Greensburg-Hempfield
Industrial Park
P.O. Box C
Greensburg, PA 15601

Hydro Carbide Corporation
Division of Vulcan, Inc.
P. O. Box 363
Latrobe, PA 15650

Leech, Inc.
P. O. Box 593
Meadville, PA 16335

Mac Donald Carbide Company
16300 E. Arrow Highway
Irwindale, CA 91706

Metal Carbides Corporation
6001 Southern Blvd.
Youngstown, OH 44512

Multi Metals Division
Vermont American Corp.
P. O. Box 1475
715 E. Gray Street
Louisville, KY 40201

Newcomer Products, Inc.
P. O. Box 272
Latrobe, PA 15650

Sandvik, Inc.
1702 Nevins Road
Fair Lawn, NJ 07410

Teledyne Firth Sterling
Parkway Center
Pittsburgh, PA 15220

TRW Wendt-Sonis Division
205 N. Thirteenth St.
Rogers, AR 72756

Tungsten Alloy Mfg. Co., Inc.
306 Sussex Street
Harrison, NJ 07029

Tungsten Carbide Manufacturing
14451 Myford Road
Tustin, CA 92680

Valenite Division
The Valeron Corporation
31100 Stephenson Highway
Madison Heights, MI 48071

Vista Metals, Inc.
1024 E. Smithfield Street
McKeesport, PA 15135

Walmet Cemented Carbides
P. O. Box 10
Royal Oak, MI 48068

XLO Tool & Abrasive Products
P. O. Box 274A
Detroit, MI 48232

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THE BOEING COMPANY

P. O. Box 3707
Seattle, Washington 98124

January 26, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards, Materials
Building B308
Washington, D. C. 20234

Dear Dr. Wachtman:

The Boeing Company welcomes the opportunity to comment on critical material needs in response to the Commerce Department notice in the January 8, 1981 Federal Register. The problem of critical materials is real - and it is growing. We believe that supply risks, in both availability and price, will be a major challenge facing U.S. industry in general, and the aerospace industry in particular, during the 1980s.

Boeing wishes to address its comments to two key items: (1) identification of the most critical materials to be examined in detail; and (2) the current or anticipated problems with these materials. At the conclusion of these comments are some suggestions for corrective action.

The following materials, listed in alphabetical order, are considered critical and are recommended to be included to the government's study:

1. Cobalt
2. Chromium
3. Graphite Fiber
4. Titanium
5. Titanium Forgings

With one exception (titanium forgings), the problems faced today, or foreseen in the future, are related to the U.S. dependency on foreign countries as a source of supply. For titanium forgings, the problem is a limited production capacity. A shortage of any of these materials will either impact Boeing directly or through suppliers of engines.

With the current downturn in production by Boeing and other commercial airplane manufacturers, the supplies of nearly all critical materials are adequate and, in some cases, supply exceeds demand.

However, potential increases in demand loom because of programs such as the C-X transport, B-1 bomber, and contemplated increases in other military production, coupled with any attempt to rebuild the nation's strategic material stockpile.

BOEING

Titanium remains our number one material problem. Boeing uses 72,000 pounds of titanium in each 747; 32,000 pounds in each airframe, plus 40,000 pounds in the engines. The crisis shortage condition of 1979 and early 1980 has subsided. However, tight market conditions prevail. The titanium industry is typified by its limited ability to refine the imported ore (rutile) into titanium sponge metal and the required mill products. Although the industry's capacity is growing, it could be easily outpaced by increases in military demand.

Until domestic production capacity increases to the level of domestic demand, we will continue to be partially dependent on foreign sources for sponge. Additionally, the capacity to produce certain titanium mill products is also questionable. Items such as large press titanium forgings are quoted by suppliers on special inquiry basis only and are now receding from leadtimes in excess of two years.

Supplies of cobalt and chromium are critical to the support of the aerospace industry and some of the most important supply sources are vulnerable, either because of uncertainty about the stability of their countries', or, in some cases, hostility toward the U.S. which could mean supply interruptions for political reasons. Most are developing countries possessing an ability to increase their mining and refining capacity. Civil strife has disrupted and will continue to disrupt these supplies. Increased military consumption under these conditions threaten the support of commercial needs.

Emphasis on weight reduction to improve performance and fuel economy has resulted in increased use of graphite fiber reinforcements on existing and new military and commercial programs. Adequate domestic weaving and impregnation capacity exists; however, fiber availability could become a problem because of the limited domestic source base for graphite fiber.

Among the possible strategies for dealing with these and other critical material problems are:

"Insurance policy" investments such as stockpiles.
Substitution of critical materials through products or process redesign.
Expansion of R&D on substitute materials.

The key though is better and more consistent planning for military needs. We need to examine alternative ways of military planning and of getting funding consistent with lead times. This, combined with different management of national stockpiles, would relieve many of the foreseeable critical material problems. The current use of the stockpile is only for military purchases. The stockpile needs to be turned over on a regular basis and be used for commercial as well as military needs.

If we take these actions, it is our feeling that requirements for allocation procedures can be extremely limited. Allocation would only be required in times of national emergency.

The Boeing Company will be represented at the February 9-10 workshop through the Aerospace Industries Association by our representative to the AIA Materiel Management Committee, Mr. F. E. (Gene) Akin. It is not intended that he make a presentation on behalf of The Boeing Company. Should you have any questions regarding this letter, feel free to contact Mr. Akin on (206) 931-2280.

We hope these comments will be of use to you. There will be no gas lines to drive home the reality of a titanium, cobalt or chromium shortage, but the effects of such supply shortfalls on our industry could be severe. We will fully cooperate with you in any future studies by providing all available data on usage of the critical materials you select.

Very truly yours,

W. M. Maulden
Senior Vice President

WYMAN GORDON

Wyman-Gordon Company
Eastern Division
Worcester Street
North Grafton, Massachusetts 01536
(617) 839-4441

January 30, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards, Materials
Building B308
Washington, D.C. 20234

Reference: Mr. Jordan Baruch's (Assistant Secretary for Productivity, Technology and Innovation, DOC) Letter to Mr. John Matson (Manager Government Relations, Wyman-Gordon Co.) dated Jan. 9, 1981

SUBJECT: Private Sector View (Wyman-Gordon Co.) Materials and Mineral Policy, Research and Development Act of 1980 (PL96-479)

The following brief commentary is in response to a request of Mr. Baruch for private sector views on specific material needs in the Aerospace Industry as they relate to national security, economic well being and industrial production.

We would also be most willing to participate in your workshop of February 9-10, 1981, to expand on our views more fully.

Materials

We have spoken out many times concerning our nation's mineral vulnerability which in many aspects is similar to the OPEC oil catastrophe which has impacted us. Our tremendous degree of reliance on imports and the distinct possibility of supply interruptions and embargoes for political or ideological purposes pose real concern for material security and the well being of many industries.

Future supplies of chromium, manganese, cobalt and the platinum group metals appear to be less secure now than ever and they are the metals we view of greatest near term concern.

WYMAN GORDON

Titanium Forgings

It is noted that in the Federal Register of Friday, January 9th, citing the Aerospace Industry as a special case for study, the subject of titanium forgings was listed.

The problems that arose in 1979 and 1980 were not the result of a lack of forging capacity for titanium, but the lack of titanium material availability. We believe that the whole subject of titanium availability should be evaluated. This subject, we believe, should cover not only the basic supply characteristics of the industry, but should reflect on our national stockpile policies, the substitution of ilmenite for rutile in case of a constriction in the sea lanes, and domestic incentives for increasing U.S. sponge production capability.

We are prepared to comment also at your workshop on improvements in capacity for airframe and engine components and other materials production base considerations.

In attendance from Wyman-Gordon will be Mr. Marwood Rand, Manager Raw Materials Purchasing and Mr. John Odell, Manager of Marketing from our Aerospace Division.

Very truly yours,

William J. Barlow
Vice President & General Manager

cb

February 3, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B308
Washington, DC 20234

Dear Dr. Wachtman:

I would like to make a written statement in regards to the upcoming Workshop on Aerospace Industry Needs which you will conduct.

I am an exploration geologist working for a major company conducting base and precious metals exploration activities in the western United States and Alaska.

I know that this country imports tremendous quantities of metals that are vital to the aerospace industry. At the present time we import approximately 93% of our cobalt, 91% of our chromium, 97% of our manganese, and 94% of our alumina. The list goes on and on.

I, as an exploration geologist, am concerned because governmental policies are removing more and more of the public domain from mineral entry. The public domain (mostly in the western United States) provides the bulk of our minerals. In 1964, when the Wilderness Act was passed, about 14% of the public domain was withdrawn from mineral entry; today the figure is 65%. In order to promote mineral self sufficiency the United States must not "lock up" those areas that have mineral potential. An <u>intensive</u> mineral survey <u>must</u> be made before any additional public domain is withdrawn from mineral entry.

The length of time from a conceptual geologic idea to a producing mine is great (10 to possibly 15 or 20 years). There is no such thing as an instantaneous mine. If exploration activities are restricted either by "lock up" or stringent regulations, then the time table for metals self sufficiency or at least reducing dependency is increased.

Yours very truly,

Gordon L. Pine

Gordon L. Pine

850 Pennsylvania Dr.
Reno, NV 89503

FORGING INDUSTRY ASSOCIATION

55 PUBLIC SQUARE • CLEVELAND, OHIO 44113 • DIAL 216/781-6260

February 2, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building - B308
Washington, D.C. 20234

Dear Dr. Wachtman:

This letter is in response to the January 9, 1981 written request from Jordan J. Baruch for Forging Industry Association comment on the definition of aerospace industry materials needs. The Association and a number of its member companies are in full support of this effort. We will have representation at the February 9-10 Workshop.

Preliminary observations:

I. 1) Anticipated requirements in the foreseeable future
2) current or anticipated difficulties in obtaining materials in any form
3) prospects for, and implication of, fluctuations in demand, supply, and prices
4) timely availability of processed materials and parts
5) other materials issues of prime concern to the aerospace industry.

These are concerns that can best be examined and commented on by airframe and engine manufacturers whom the forging industry serves and also by the prime material suppliers.

II. 1) Cobalt, as a raw material on which the U.S. is import dependent
2) titanium forgings, as a special processing capacity need
3) rapidly-solidified alloys, as a promising route to both conservation of materials or increased performance.

These concerns warrant priority attention from all sectors of the military/industrial community. The recent article in FORTUNE addressed a number of questions in this area of interest in a clear and concise manner. We are also aware that individual forging companies are devoting considerable time, effort and investment to #3).

Continued. . .

III. 1) Improvement in materials production base
2) stockpiling, both public and private
3) federal emergency allocation procedures
4) improvement of capacity for airframes, engines and components
5) expanded conservation and recycling of materials
6) improved research and development of new materials both for substitution and for higher performance.

We strongly support an improvement in the materials production base. Private stockpiling as we interpret the written concern is probably not possible from a capital investment consideration -- on the other hand, government financed stockpiling at forging facilities is an opportunity that deserves further study. Concerning #3), DMS and DPS procedures are in place. While these procedures did not serve well during the 1978-80 supply problems, they could serve well if properly administered. Airframe and engine contractors should speak to #4). Isothermal forging of titanium and other proprietary processes are a step in the right direction concerning #5). An intense effort on the part of the entire military/industrial community is required.

You will be interested to know that FIA's Board of Directors has appointed a special committee to examine many of DOC's expressed concerns. The committee has functioned for almost a year now. Distilled to the fewest words possible, the committee has tentatively concluded:

1) Material shortages severely hampered the forging industry's ability to meet aerospace requirements 1978-80.
2) The forging industry is capable of meeting known or anticipated aerospace needs with equipment that is in place at this writing. Private investment is constantly increasing this capacity.
3) Multi-year purchasing for military aerospace programs is sorely needed to properly manage military spending and to increase productivity.

We appreciate this opportunity to contribute to and be a part of this investigation.

Yours very truly,

C. G. Scofield

C. G. Scofield
Director of Marketing
and Conferences

CGS:tlw
cc: Jordon J. Baruch

Allied Chemical

Metglas® Products Department
P.O. Box 1021R
Morristown, New Jersey 07960

February 4, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B308
Washington, DC 20234

Dear John:

Before joining Allied Chemical, I was privileged to write an overview about the status of tantalum and other aerospace metals. A copy of that report is submitted as an attachment to this letter per the requirements of your recent announcement (Federal Register, Vol. 46, No. 6, 9 Jan 81).

Mr. R. L. Kennard (USAF/WPAFB/AFML/LTM) has approved the release of this report and both Lee and I hope that this information might be of some value to you with your workshop activities on critical materials.

I look forward to meeting you again during the week of 9 February 1981.

Sincerely,

Charles Hays

Dr. Charles Hays

CH:mh

Attachment: (1)

Summer Research Assignment:

TECHNOLOGY ASSESSMENT
ON THE CRITICAL AND STRATEGIC
STATUS OF TANTALUM METAL

Dr. Charles Hays
Summer Faculty Research Associate
AFML/LTM
WPAFB, OH 45433

Summer Research Assignment:

Technology Assessment
on the Critical and Strategic
Status of Tantalum Metal

ABSTRACT

Because of a deep concern about the limited supply of tantalum resources for the Aerospace industry, the possible formation of tantalum cartels and overt political activities by some tantalum-rich nations, this study on the tantalum situation was initiated and thereby justified. Although of short duration and limited scope, this study attempts to focus on the tantalum problems that face primarily the Aerospace industry of today and in the future. Specific recommendations are given with the intention that these suggestions might lead to some definite undertakings for meeting the projected needs for tantalum metal.

August 1979

Dr. Charles Hays
Summer Faculty Research Associate
AFML/LTM
WPAFB, Ohio 45433

Approved:

H. A. Johnson, Chief
AFML/LTM
WPAFB, Ohio 45433

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INTRODUCTION

The combination of market cartels and political instabilities within certain nations have highlighted the fact that the price-supply relationship for any imported material can be strongly influenced by the unpredictable vagaries of world events and local politics. In recent months, much concern has been expressed with regard to one vital area of nonrenewable mineral resources; i.e., petroleum deposits. Yet, petroleum is not the only foreign-supplied commodity upon which the United States is highly dependent, see Figure 1. Here it is to be seen that the United States imports more than fifty per cent of all mineral supplies for needs which involve chromium, platinum, osmium ruthenium, iridium, tantalum, aluminum, cobalt, manganese, tin, nickel and columbium. More important is the fact that the United States is almost totally dependent on other nations for its supply of certain important aerospace minerals; viz., chromium, tantalum, aluminum, cobalt and manganese.

Because of a deep concern about the limited supply of tantalum resources for the Aerospace industry, the possible formation of tantalum cartels and overt political activities by some tantalum-rich nations, this study on the tantalum situation was initiated and thereby justified.

Historical Information[2]

Tantalum (Ta) is a metallic element in the fifth group of the periodic system, which includes the metal vanadium. It derives its name from the Greek mythological King Tantalus, because of its ability to 'absorb' acids. It is not very richly distributed in nature, but is found with columbium and many other rare minerals. It was first discovered in a curious way. In 1801 C. Hatchett found a new element in a mineral from Massachusetts, to which he gave the name 'columbium'. In the following year A.G. Ekberg found a new element in yttrium minerals from Sweden, and called it tantalum. Then followed the failure of an attempt to prove these two new elements identical. Other new elements discovered during later years confused the issue considerably, but eventually tantalum was established as a metal in its own right and is no longer confused with columbium (niobium).

In a pure form it was obtained by Berzelius in 1820 by the heating of potassium tantalofluoride with potassium. The pure metal was not obtained until 1905, when Werner von Bolton fused compressed metal of the type obtained by Berzelius in the electric furnace from which air was excluded.

Ore Deposits[(2)]

The principal sources of tantalite, the ore, are Nigeria, Zaire, Portugal, Rhodesia, Uganda, South Africa, South-west Africa, Australia, Mozambique, French Guinea, Brazil, Spain, Canada, Sweden and the United States. Of columbite, the principal sources are Nigeria, Rhodesia, Uganda, South-west Africa, Malaya, Australia, Zaire, Madagascar, Mozambique, Bolivia, French Guinea, Argentina, Brazil Portugal, Spain, Norway, Sweden and the United States. The production of columbite is forty times as great as that of tantalite. By far the largest importer is the United States.

Extraction Techniques[(2)]

In modern production, the ore tantalite $Fe(TaO_3)_2$ obtained from columbite $Fe(NbO_3)_2$, is comminuted to a powder and then fused with caustic soda, from which product the silica is eliminated by extraction with water. Other materials soluble in acid, such as manganese, are eliminated by means of hydrochloric acid, leaving the insoluble hydroxides of tantalum and niobium as residues. After dissolution in hot hydrofluoric acid in the presence of potassium ions, the solution is allowed to cool, after which tantalum double fluoride (K_2TaF_7) is crystallized out by repeated fractional crystallization, leaving behind niobium double fluoride (K_2NbOF_5) which is much more easily dissolved.

This process, however, is only suitable when tantalum is obtained from tantalite ore. If the ore contains a high niobium content, liquid-liquid extraction is employed instead, and this is the process most commonly used, because niobium is also required from the ore, and Nb is not as easy to recover.

There are, however, other means of obtaining the metal, such as the thermit process already mentioned, in which caustic soda and the double fluorides are used. Electrolysis is another method, using molten salts of the double fluoride. A mixture of the oxide and carbide can be thermit-reduced as follows:

$$Ta_2O_5 + 5TaC = 7Ta + 5CO$$

Important Characteristics[2]

Tantalum is a heavy metal with a steel-blue color, which, when the metal is polished, becomes platinum-white. It has a high melting point, and when exposed to the atmosphere forms a tough and impermeable oxide film serving to protect it from corrosion. In consequence, it is the most resistant of all the metals to acid attack. Ta withstands many chemicals, including organic acids, fatty acids, and, indeed any one acid other than hydrofluoric acid. Caustic alkalis attack Ta with difficulty only. It is thus superior even to platinum in resistance to corrosion, and being less expensive, can be substituted for Pt in many applications.

Ta is tough, ductile, malleable and capable of being readily welded. It has no effect on water even at temperatures up to 600 deg. C. (1112 deg. F.), but at this same temperature it will burn in oxygen. Its machinability is similar to that of cold-rolled steel, and either tungsten carbide or high-speed steel tools can be used. Carbon tetrachloride or light oil will serve as a cutting fluid, and machine oil is sometimes recommended as a lubricant. Ta automatically rectifies an alternating current, and is capable of being pressed, sintered, hammered or swaged. The impurities that are usually found in processed tantalum include carbon, oxygen, nitrogen, hydrogen, niobium, iron, titanium, tungsten, silicon and nickel. Carbon and oxygen are the most abundant, but rarely exceed 0.05 per cent (by weight).

The metal is produced in powder form from tantalite. Only one process produces the metal in massive form as 'hairpins', but this is merely for experimental laboratory work. In the difficult recovery of the metal, the powder is obtained, washed to eliminate impurities, heated in a vacuum and by hydraulic pressure formed into bars, which are resistant in themselves to an electric current, so that the heat generated in the passage of such a current serves to sinter them. Bars can then be formed into sheet or wire, and because Ta bars do not readily work-harden, it is not often necessary to give intermediate annealings during powder forming processes. If such an annealing is required, however, it is carried out in a high vacuum.

The compactibility of tantalum is good. In general a small amount of extremely fine-ground titanium is added to the normal powder to make molding easier. The ingot sizes are, typically, 30-in. long by 2-1/2-in. wide by 1/4-in. thick, and weigh mostly from 8 to 12-lb. each. The pressure required for forming into bars without pre-sintering is about 50-tons/sq. in.

Important Applications(2)

Tantalum has a higher melting point than molybdenum and is much more ductile. When recrystallized, Ta is much more ductile than either molybdenum or tungsten. Its properties make Ta particularly suitable for grids in electronic power tubes, because it has high gas absorption and retention at lower pressure and temperatures than most other metals. In resistance to corrosion Ta is equal to glass, but has a much higher rate of heat transfer. Ta also has the special property of forming anodic oxide films which are self-healing.

When heated in nitrogen at 600 to 900 deg. C, Ta absorbs the gas to form nitrides, and this means that the metal becomes embrittled and may raise its hardness to 600 Brinell.

The production of tantalum has greatly increased in recent years. It is being extensively used for stills, agitators, containers, pipes, etc., in the chemical industry because of its strength, ductility, workability and corrosion resistance. Ta is also applied to equipment used in combination with plastics and ceramics, the principal uses being for heat exchangers, and for the absorption, evaporation and condensation of hydrochloric acid. Its oxide film stability makes Ta valuable for wet rectifiers. Ta is also applied to self-healing electrolytic condensers and lightning arresters. Centrifugal pumps are another application for Ta.

Tantalum is also used for capacitors because of the wide range of temperature over which Ta works effectively (-60 to 200 deg. C or -75 to 400 deg. F). Ta is valuable, too, in 'getters' and grids for electronic tubes, particularly in ultra-high-frequency transmission. Additional uses include steam turbine blades, valves, nozzles,diaphragms, spinnerets for the production of rayon, and the tips of fountain pen nibs. There are applications of tantalum also in the field of high vacuum. Tantalum anodes for electric power tubes are used, especially in service at ultra-high-frequency.

Surgical uses are numerous, including the use of cover wires for uniting fractured bones and implanted plates for replacing lost skull sections. Nerves and tendons have been sewn together with fine tantalum wire and protected by foil of the same metal. Dental instruments also make use of tantalum. Ta metal does not irritate living tissues, and this compatibility makes it most serviceable in surgery and medicine.

Ta is being studied at the present time as a possible alloy base for future thermospheric structures and 'hot' aerospace engine environs: e.g., directionally-solidified eutectic alloys in military applications. As an alloying element in the manufacturing of steel alloys, Ta has not gained widespread popularity. This situation exists because, for most applications, Ta is inferior to niobium in the important characteristic of specific gravity. Ta has, however, been added to austenitic stainless steels to form carbide, thereby preventing intergranular corrosion, and to nitriding steels as a means of speeding up the formation of the nitride case, but in both instances niobium is better. Ta has, however, been used on an increasing scale as a 'hard metal' for cutting and other tools, by reason of the extra toughness obtained when the tools contain Ta and/or tantalum carbide.

Because of its hardness, toughness and ductility Ta is used for the manufacture of linings of pipes and tanks for the transport and storage of dangerous fluids.

The metal is usually supplied as ferro-tantalum, in which form Ta is alloyed to steel, but Ta is also sold as sheet or wire, of 99.95 percent purity, at prices either per pound or per kilogram. An alloy of tantalum with tungsten has been successfully used for special springs working at high temperature and high vacuum. Use is made of tantalum in electronic tubes for radar, and potassium tantalum fluoride has a catalytic application in making synthetic rubber. At one time, tantalum was used for electric lamp filaments.

Limitations[2]

Tantalum is not resistant to corrosion in galvanic couple action. Excessive impurities in its composition lead to lower elongation percent, and high yield and tensile strengths, but has little effect on corrosion resistance. If the metal is to be used as an alloy, from 7.5 to 10.0 percent tungsten should be added to give superior yield and tensile strengths combined with a higher temperature of recrystallization. If electronic properties are primarily required, thorium should be added.

In melting the metal, oxygen, hydrogen, nitrogen and carbon should be carefully excluded, and melting should be done in a vacuum. If this is not possible, an inert gaseous atmosphere should be used. Annealing can be done at above 1050 deg. C (1920 deg. F), in high vacuum. The maximum reduction between annealing operations is more than 95 per cent. All the normal forming processes can be employed. The compacting pressure ranges from 10 to 60 tons/sq. in., being governed by the physical characteristics of the powder. Sintering should be done within the range 2300 to 2600 deg. C (4175 to 4700 deg. F) in high vacuum, which will eliminate harmful contaminants. The normal finishes of the metal are dull or bright for rolled sheet, and smooth dull for wire. Brazing with copper can be carried out in vacuum. Welding by the customary processes is possible, but it is essential to exclude air by use of inert techniques for tungsten arc, electron beam, resistance spot, or other suitable processes of welding.

DISCUSSION OF RESULTS

Recently, many important publications have been given to the concept that the world's resources shall not last indefinitely.[3-56] These articles of the open literature have been excellent surveys about the general condition that exists but none have been dedicated solely to the problem of tantalum metal and very few are concerned with the needs and priorities of the Aerospace industry. This study, although of short duration and limited scope, attempts to focus on the tantalum problems that face primarily the Aerospace industry of today and in the future. The intent of this study is to form certain specific recommendations that might lead to some definite undertakings to meet the projected need for tantalum metal.

The Problem of Reserves

Before any metal may be considered strategic or critical for the needs and priorities of the Aerospace industry, some clear definition is always required. Typically, the known U.S. reserves are taken to be the primary indicator for any such classification.[1] For the purposes of classification, reserves are defined as known and identified deposits from which minerals can be extracted profitably with existing technology and under current economic conditions.

Table I summarizes the present status for the U.S. reserves of aerospace mineral deposits, listing them as being either "abundant" or "scarce". Mineral reserves are taken to be "abundant" if the U.S. currently imports less than 50 percent of our Nation's needs and can maintain that position to the year 2000. Metals used in amounts that are at least 1 percent of the total projected aerospace requirements in the year 2000 are arbitrarily considered of "major" importance while metals making up less than 1 percent of the metals used in aerospace are considered of "minor" importance. Of the seven metals that are listed as of "major" importance to the Aerospace industry, it should be noted that current U.S. reserves for three of these metals are considered "scarce" (Al,Cr, and Ni).

One problem with such a classification is that surveys of this type consider the needs and priorities of *all* aerospace applications. If military engines are to be evaluated and classified separately, then the problem of U.S. reserves becomes a much greater issue. This is to say that military engines run hotter than commercial engines and that military engines are designed to more rigid requirements, especially with regard to tantalum, cobalt, columbium and manganese contents thereof. Accordingly, the problem of tantalum reserves is a problem of immense importance to the defense of our Nation. If this be true, what else can be stated about the problem of tantalum reserves?

The problem of tantalum reserves reaches new proportions of relevancy if one considers the fact that, at a time when this Nation's tantalum needs are greatest, almost nothing is being done to solve these urgent problems of demand and supply - Note Table II for a summary of the tantalum situation. From the data of Table II, it can be shown that, in recent years, imported tantalum ores are stable, exports of tantalum ore are increasing, consumption of tantalum is steady, the government stockpiles are depleting and industrial stockpiles have not changed in like manner - see Figure 2.

Prices for tantalum products continue to reflect a growing concern over the possibility of future shortages - in 1978, prices increased by about 30% for tantalum concentrates and by nearly 50% for tantalum metal as compared to the prices of 1977! Domestic demand for tantalum products is expected to exhibit a minimum increase of about 40% per year through 1985 and the supply needs for such demand can now come only from foreign production and industrial stocks. Although the United States has about 3.4 million pounds of identified tantalum ore deposits, no attempt is being made to utilize these resources - these ore deposits are classified (by industry) as being uneconomical based on 1978 price levels. As in the case for petroleum, it would seem that it is more expeditious for industry to exploit imported tantalum than it is to explore new tantalum recovery processes. New domestic tantalum deposits must be sought and new, or improved, methods for extracting tantalum from sub-marginal mineral materials and low-grade tin slags must be developed so that future requirements can be satisfied more economically to reduce our net reliance on imports - see Figure 3 for a summary of this critical import reliance.

According to information from the Bureau of Mines[57], tantalum metal is currently being utilized primarily by the electronics and chemical processing industries - note Figure 4. Of the amounts used in 1978, less than 2% were given to aerospace applications. Although the aerospace needs for tantalum may be great, it cannot be assumed that military applications of tantalum metal are any real threat to the scarcity of tantalum. The chief culprits for this problem of tantalum reserves involve those industries which require more tantalum... electronics and chemical processing. These firms continue to utilize tantalum in great quantities even though it is common knowledge that...

- Columbium *can be substituted for tantalum* in high-strength steels and superalloys.
- Aluminum *can be substituted for tantalum* in electronic capacitors.
- Silicon, germanium and selenium *can be substituted for tantalum* in electrical rectifiers.
- Glass, titanium, zirconium, columbium and platinum *can be substituted for tantalum* in corrosion-resistant equipment.
- Tungsten, rhenium, molybdenum, iridium, hafnium and columbium *can be stubstituted for tantalum* in high-temperature applications.

Although these substitutions are known to be economically feasible and attractive to the National needs or priorities, there is no apparent mechanism to force tantalum substitutions. The obvious thought is this... if excessive tantalum consumption is allowed to continue in such wild and uncontrolled fashion... how will we someday substitute for the dead engines of our imperiled military aircraft?

This problem of reserves and its relevance to the Aerospace industry is not a problem of numerical magnitudes. If numerical magnitudes alone are argued, the military needs of the future will always be badly considered. For example, Stephens *et al*[1] have shown that, by the year 2000, Aerospace industries will require only about 1.3% of the total U.S. demand for *all* the aerospace metals. More important, Stephens has shown that, by the year 2000, this Country will no longer have the capability to meet the total U.S. requirements for *any* aerospace element other than molybdenum - see Figure 5. It is clear that something needs to be done... and it must be done *now* !

The Producer Problem

According to References 3 and 57-61, domestic production of tantalum products (metal, alloys and compounds) is a producer problem of essentially four sources; imported concentrates, imported tin slags, tantalum-rich scrap and industrial stocks - see Figure 6. This very typical source distribution is, by itself, not a producer problem... the producer problem that exists is simply this... in 1978, six companies with seven plants processed imported concentrates and tin slags to account for 100% of the 1978 production totals [60]. This apparently innocuous statement is graphically displayed by Figure 7. Here it is to be seen that, in 1978, domestic producers apparently met all market demands without using any tantalum scrap or stocks. This is to say that all production needs were ostensibly satisfied through the selective use of imports. In this way, producers have conserved their scrap and stockpiles through the use of *stockpile substitutes* called imports. Again it would seem that it is more expeditious for industry to exploit imports that it is to explore new tantalum recovery processes.

The producer problem is even more insidious if the variable of tantalum ore usage is evaluated in some detail. Figure 8 represents the current situation on how tantalum ores *are* processed.... inputs to the system of tantalum production include ore shipments from stockpiles and foreign ore imports while outputs to the system of tantalum production include ore consumption and the export of tantalum ores. What we need so desperately (quantities of tantalum ores) is bought from foreign nations and resold to other foreign nations! There are no apparent mechanisms to restrain these windfall profits by tantalum producers even when such profits are against the National needs, priorities and long-range interests.

If tantalum ore exports were somehow regulated, the efficiency of tantalum ore consumptions would be greatly enhanced. Figure 9 shows how efficiencies might increase if tantalum ore exports were not permitted... the process of tantalum usage, which is now out of control, could be brought into control. This is one method by which the producer problem can be greatly alleviated - see Figure 10 on how tantalum ores *should* be processed.

Earlier it was reported by Stephens, *et al*[1] who projected that, by the year 2000, Aerospace industries will require only about 1.3% of the total U.S. demand for all Aerospace metals and that, by the year 2000, this Nation will no longer have the wherewithal to meet the total U.S. requirement for *any* aerospace metal, except molybdenum. Figure 11 reveals the Bureau of Mines predictive data for the future needs of tantalum products according to their end use. Of interest here is the obvious question that, at these demand rates, how long can the producers survive... or, in other terms, how long will the world supply of tantalum continue to exist?

According to recent estimates by the Tantalum Producers Study Center (Brussels)[62], the average supply which existed at the 1977 level will continue for only twelve more years at the current rate of utilization. Note Table III... 1989 represents the terminal point for the existing world's supply of tantalum ore. New domestic tantalum deposits must be sought and new or improved methods for extracting tantalum from the now "uneconomic" mineral materials and low-grade tin slags must be developed... something needs to be done and it needs to be done *now!* Figure 12 represents one solution to the problem of tantalum production. If research and development investment monies are spent in massive amounts and in timely fashion, the threat of 1989 might be effectively managed. Through diligent development of new sources and new techniques, the World might be assured of a continuing supply of tantalum metal adequate to meet World demand at projected levels for many years to come. If, on the other hand, this problem is approached through the mechanism of typical R&D long-term management investment trends (Note Figure 12), it is quite likely that some scientist may someday find an appropriate solution for an inappropriate problem; e.g., what good could be served by new tantalum extraction techniques if tantalum sources were, at that time, non-existant? Clearly, the needs of today need to be served today, *not* tomorrow!

The Availability Problem

It has been shown that the U.S. has limited reserves of both "major" and "minor" aerospace metals [1]. In addition, because of either limited resources or lack of technological developments or favorable metal prices, domestic resources are not being mined. Because of these conditions the U.S. must turn to foreign sources to meet the aerospace needs as well as total U.S. metal requirements. Figure 1 illustrates the current percentage of various aerospace metals that are being imported and the major countries from which we obtain the metals. Figure 5 indicated that of the seven "major" aerospace metals, the U.S. in the year 2000 would not be able to produce any Cr and only 8 percent of the required Ni and 10 percent of the required Al. Figure 1 shows that the U.S. is currently importing 100 percent of its required Cr ore, 96 percent of the required Al ore, and 74 percent of the required Ni ore. Also, imports of the Pt group metals and of Co, Ta, and Mn are all in excess of 90 percent. In the case of Sn, approximately 80 percent is imported. The remaining Sn supply currently comes primarily from scrap and from selling of stockpiled Sn. The U.S. imports about 65 percent of the required supply of Cb. The remaining metals fall into the "abundant" category

(Table I), and imports range from approximately 40 percent for W to about 10 percent for Mg. Of the nineteen metals considered important to aerospace, it should be noted in Figure 5 that Mo is the only metal in which the U.S. maintains a net export position.

There are certain indirect factors which also affect the availability of important aerospace materials. For example, several existing or potential cartels are being considered by the countries that supply the Nation's minerals. The nature and content of recent news releases suggest that 'closed-door' meetings between mineral-producing countries may soon cause mineral-producer cartels to exist in the world market for aluminum, copper, chromium, platinum, tantalum and cobalt. Ostensibly, the 'official' purpose for these 'closed-door' meetings was to discuss mechanisms by which higher prices might be achieved for these important aerospace minerals on the World market. Although political differences and geographical separation make it more difficult for the mineral-exporting countries to form cartels similar to that formed by the oil-exporting Arab countries, several elements seem ripe for stronger control through cartels. Of particular concern is the potential cartel for Cr involving the countries of Rhodesia and the Republic of South Africa. Another possibility is that cartel which has been proposed to exist between Zaire and Nigeria for tantalum. In the latter case, collective cartel bargaining has been virtually suspended by the Civil War that now rages in Zaire. The combinations of market cartels, political unrest and even civil war pose great threats to the World price-supply relationships for all aerospace metals and, especially, for tantalum.

Another indirect factor that influences the use of domestic reserves is the effect that processing ores has on the environment. For example, the Cu industry has failed to start building new smelters to keep up with mining production because of new environmental restrictions being placed on the smelting operation. As a result, a potential Cu shortage can develop similar to the current oil shortage largely due to lack of required refining capacity. Insofar as tantalum is concerned, there has been no domestic mining-extraction industry since 1959 but this may have been caused by choice, not chance... it appears more expeditious for tantalum companies to exploit imports than to explore new extractive methods.

A third indirect factor that contributes to the problem of tantalum availability is the role that is played by ore allocations.... if tantalum ore imports were not resold to other producing nations, this Country could operate its tantalum resources at peak efficiencies (Refer to Figs. 8-10). In this way, tantalum shortages may develop similar to the problem of gasoline allocation difficulties that stem from supplying two-dollar-per-gallon markets (Europe) instead of supplying 95-cents-per-gallon markets (domestic).

The final factors that contribute to the problem of tantalum availability are the interactive roles exerted by apathy and/or a total lack of traceability. In the case of the former, no explanation is really necessary - it should suffice to say that *too many people care too little* about the tantalum situation and the threat that it represents. With respect to the latter, however, some discussion is, indeed, required. Although tantalum consumption can be monitored, tantalum production cannot be evaluated [57]. In 1978, two key suppliers of tantalum metal (Fansteel Metals and Kawecki Berylco) refused to divulge any figures on the amounts of tantalum that they produced... this they were able to do under the cover of "confidential proprietary information."[60] It is now a truism that, where tantalum availability is concerned, we must be *more* concerned. The tantalum-rich scrap of military engine components that are retired-for-cause should represent an important source for badly-needed tantalum resources if good traceability did, in fact, exist. Here, traceability does not exist... some of this vital tantalum that once served important Air Force needs may be released to the tantalum producers so that it may one day become transistors in electronic toys... it is a pity that we are not *more* concerned. Since World War II, Japan has steadily invested tremendous sums of money into the purchase of mineral rights and ownership ... certain other nations (particularly the OPEC countries of the Middle East) have followed the example set by Japan. This trend of purchase power has continued without control or traceability to the point that important domestic mineral reserves are no longer controlled by the Nation in which the reserves occur! Conservative estimates predict that, by the year 1989, consortiums shall control what Congress cannot control. Concern about active traceability and real action is no longer enough... *more* concern and *more* action is now mandatory.

Methods to Improve The Situation

The inadequate status of our critical reserves and the finite character of our mineral resources and our dependence on other countries to supply the Nation with several strategic metals makes it imperative that efforts be increased to conserve the use of all such materials through immediate, positive-action programs.

One method to improve the tantalum situation is the business of more recycling activity by our Nation's primary metal producers. In recent years, producers have resisted recycling through the argument that tantalum scrap contains too much "old material" and not enough "new material" and, of course, "new" is more economical than "old"! Here, an explanation is in order; viz., "old material" is defined as scrap metal which has been exposed to a full service life in its own service environment (e.g., retired-for-cause jet turbine blades) while "new material" is scrap metal which has not seen any service applications (e.g., sections or cuttings from blooms or ingots during primary metal production and fabrication operations). In other words, the metal producer, if given a choice, will always choose to process scrap in terms of its purity... more pure is better than less pure. In this matter of recycling scrap metal, an important point exists and some explanation is necessary... the point of discussion is simply this: Are primary metals producers really recycling enough?

The current role of "old material" in the U.S. consumption arena is demonstrated by Figure 13[9]. This illustration reveals, for example, that about 12% of the U.S. needs for chromium metal are being met by the recycling of "old material" or "old scrap". Now it is to be understood that stainless steel scrap is the main source for reusable chromium and primarily as "new material" or new scrap". Isn't it ironic that any piece of stainless steel, "new" or "old", contains, as a minimum, 12 weight percent chromium metal? This bit of irony would suggest that producers are recycling "new" stainless steel but not "old" stainless steel... it is more economical to process "new" than "old". In fact, the truth of the matter is this... for every hundred pieces of scrap metal that contain chromium, less than 15 pieces are being reprocessed[1]. Unfortunately documented evidence reveals that, for the material which is available for recycling, only certain amounts are even reprocessed; e.g., copper - 61%, aluminum - 48%, nickel - 40%, titanium - 30%, iron - 26%, chromium - 15% and tantalum - 2%. Why does this situation exist... what needs to be done to improve the situation? In order to increase the use of strategic metals contained in "old material", new manufacturing technology must be developed, existing standards need revision and recycling requires stimulation.

It is easy for primary metal producers to process "new material" for this amounts to very little more than a remelting process. Such technology exists and has existed for many years since the time that metallurgists first learned to correct their mistakes in metal manufacturing. But, it is technically incorrect to say that 'reprocessing' is identical to 'recycling' and this was demonstrated by the previous example of stainless steel and the chromium problem. The truth is simply this.... manufacturing technology does not now exist for the recycling of all "old material". Industry needs to develop new extraction methods for the removal of all service contaminants from all "old material" (see Figure 14). It is imperative that new technology be supported so that economical recovery of strategically - vital metals may soon be a reality.

Before these new technologies for recovery of "old material" can ever become widely - accepted by consumers, it is also necessary that *this Nation must raise their Standards down.* For years now, the developing nations of the World have been amused by the restrictions of the American metal standards on composition, properties and structure. These nations are amused by the fact that all American standards (e.g., AISI, ASTM, ASM, ASME, SAE, SME, API, AMS and etc.) are based on one central theme... the use of virgin material by primary metal producers - a luxury which American metal manufacturers may one day be forced to classify as improper, wasteful or dangerous to our Nation's wealth! Perhaps, a true story will serve to demonstrate this point better.

The author of this report has a good friend in India who owns and operates a factory that uses only recycled stainless steel products. Each time this friend visits the U.S., he brings with him a different metallurgical sample from one of his many stainless steel products. These samples are brought to America to demonstrate a very important point... to this date, no American metallurgist has been able to look at his samples under a metallurgical microscope to correctly state the alloy type! I have played his game many times and I have always lost even though I am an expert on the microstructures of domestic stainless steels... but that's unimportant. The important thing is simply this... American metallurgists are taught and trained to think that *purity is better* and, as a result, our rigid Standards are given to the concept that good properties, structure and composition can exist only if purity prevails. And, if purity is to rule, then virgin material usage will also continue to be the preference of American primary metal producers. This is to say that, with the beginning of the Jet-Age, the aerospace metals Industry has concentrated practically all of their metallurgical design efforts toward the problem of getting higher concentrations of gamma prime (γ') so that higher strengths might exist at higher temperatures. This madness for more and more γ' is based on the simplistic view that *more γ' is better*! As a result of this totalitarian approach, we now have alloys and mixtures (e.g. directionally-solidified eutectics or rapidly-solidified powders) for which basic metallurgical parameters are either unknown or controversial... our meek acceptance of massive γ' concentrations and ultra-pure materials may have cost us more than that which we paid for higher hot strength. This ill-defined progress has left us with dwindling mineral reserves and metallurgists who worship the dual idols of purity and γ'. To this, my friend from India would say that American metallurgists will become good metallurgists only when they learn *to do it better more cheaply*.

As a necessary first-step toward this goal of doing it better more cheaply, American material standards need revision to reflect the changes that occur through the recycling of "old material" versus the recycling of "new material". For example, the "Cleanliness Charts" of ASTM should be accompanied by what can only be called "Dirtiness Charts". By the same token, the structure - property correlations of the AISI should be revised in terms of compositional variations caused by recycling "Grade I" versus "Grade II" scrap. If recycled stainless steel from India is inventable but unidentifiable, then American metallurgists need to invent more so that they may identify more. And, if our material *Standards are raised down* to permit more recycling, who knows exactly what may result... it could be that we would, at some point in the future, be better and more wiser with a greater endowment of regenerative resources for raw materials (and tantalum is no exception to this rule). In brief, research must be given to the development of new manufacturing technologies and revised materials Standards through recycling. A wider use of recycling may also be stimulated through adoption of favorable tax or regulatory policies by the appropriate Government agencies.

Another method to improve the tantalum situation would be to enhance the utilization of both substitutions and stockpiles. In previous discussion, it was pointed out that neither substitutions nor stockpiles are now being used to any appropriate extent... consumers resist any change called "substitution" and producers, if permitted, will always prefer to "hoard" their stockpiles. At this stage, it suffices to state only that there is no enforcement mechanism to ensure the use of either substitutes or stockpiles... this matter needs rectification. But, what can be said about the use of "substitution-stockpiles"?

Recent breakthroughs in an area called "Computer-Harmonics-Applications-Tailoring"[63] allows the development of what some choose to call "substitution-stockpiles". If all the attributes are known for a given materials application and if all materials selection criteria are properly integrated by an appropriate computer program... substitutes can be identified for further refinement and stockpiling. Although the techniques of computer harmonics are still in the infancy stage and, as yet, deal only with non-aerospace applications, the approach still merits consideration as a possible mechanism to improve the tantalum situation. Clearly, this area of computer harmonics will someday be an important tool that is best utilized by Integrated-Computer-Aided-Manufacturing (ICAM) design methods and processes.

In summary, the methods to improve the tantalum situation must include some immediate attention to these important facts and/or issues:

- The 3.4 million pounds of identified and "uneconomic" tantalum deposits in the United States need development.
- New tantalum recovery processes need to be established.
- Low-grade tin slags are a prime source of tantalum and these are not now being properly evaluated.
- Our net reliance on imports must be curbed through a better control of exported ore deposits.
- Tantalum utilizations by industry-at-large must be prioritized.
- Tantalum substitutes need to be enforced.
- The terminus point for the existing World's supply of tantalum ore (1989) must be circumvented.
- Cartels need to be countered by collective-embargos of the 'other kind' (food, clothing, medicine, technology and the necessities of all mankind).
- Environmental restrictions must be relaxed on matters of vital concern to the Nation's greatest needs, priorities and long-term interests.

- Allocation of tantalum ores by this Nation to other nations must be regulated.
- Apathy about the critical/strategic metals shortages must be eliminated through improved dissemination of reliable information at reputable information centers (Universities, not Air Force bases... in this way, the military bias will be disguised and, hopefully, ignored).
- Tantalum production must be a function that Government can monitor.
- Retirement-for-cause property of the U.S. Air Force should remain the property of the U.S. Government...tantalum of this type should not be used as tantalum for toys... such tantalum should be converted *by* the Government and *for* the Government.
- Are mineral resources within the U.S. being controlled by the consortiums of other nations?
- Do consortiums control what Congress cannot control?
- Recycling programs must be established.
- Greater recycling efforts need to be stimulated.
- New manufacturing technologies require development.
- Existing standards need revision.
- Oceanographic mining methods must be exploited.
- Is metallurgical purity the real solution?
- Is more gamma prime (γ') really better?
- Stockpiles must be monitored.
- Substitution-stockpiles need to be evaluated.

In brief, we need to attack this problem of the strategic/critical metal crisis so that *it may be done better more cheaply.*

CONCLUSION

Because of a deep concern about the limited supply of tantalum resources for the Aerospace industry, the possible formation of tantalum cartels and overt political activities by some tantalum-rich nations, this study on the tantalum situation was initiated and thereby justified. Although of short duration and limited scope, this study attempts to focus on the tantalum problems that face primarily the Aerospace industry of today and in the future. Specific recommendations are given with the intention that these suggestions might lead to some definite undertakings for meeting the projected needs for tantalum metal.

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APPENDIX

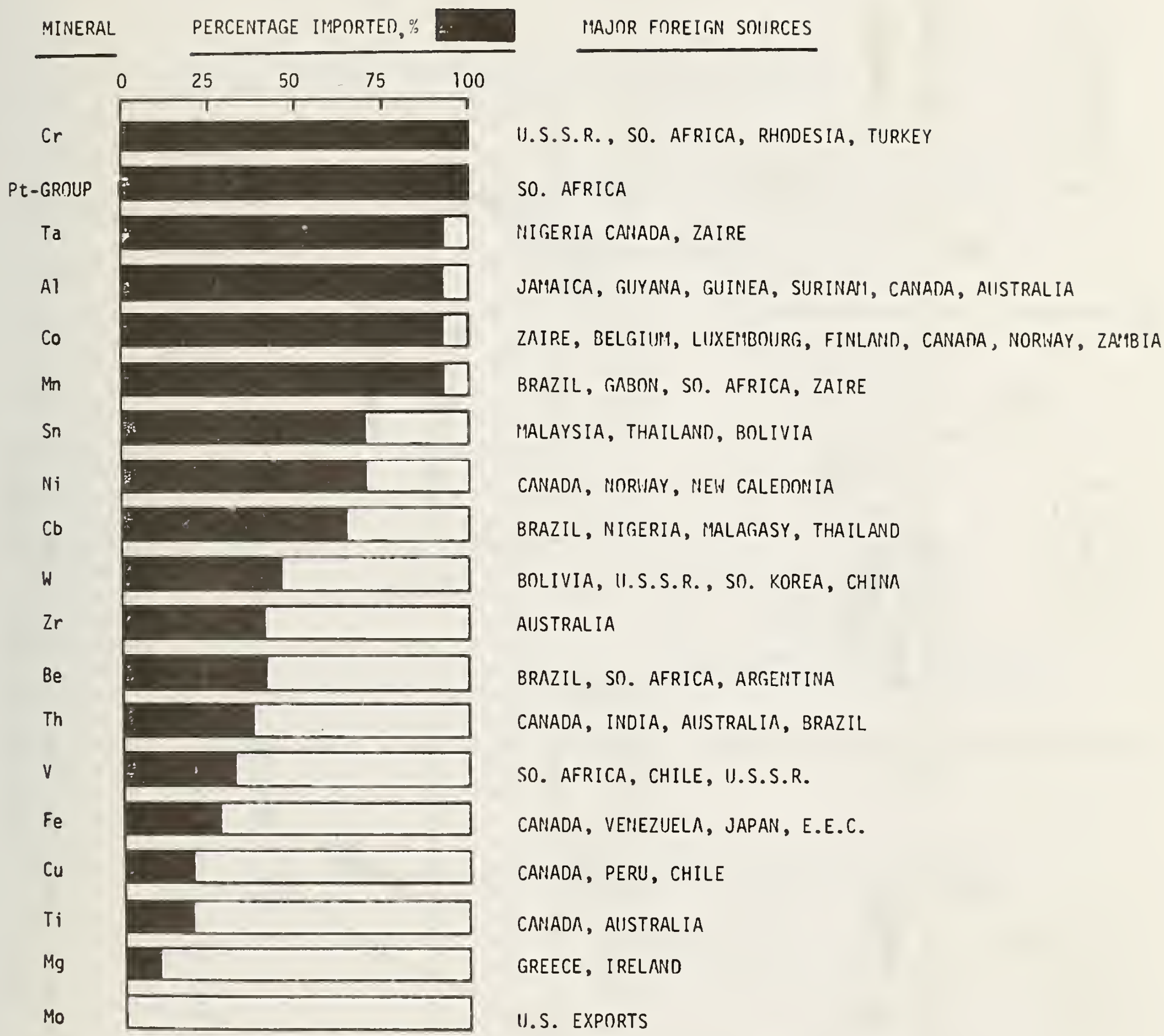


Figure 1. Sources of U.S. Mineral Supply and Percentage Imported. (Taken from Reference 1)

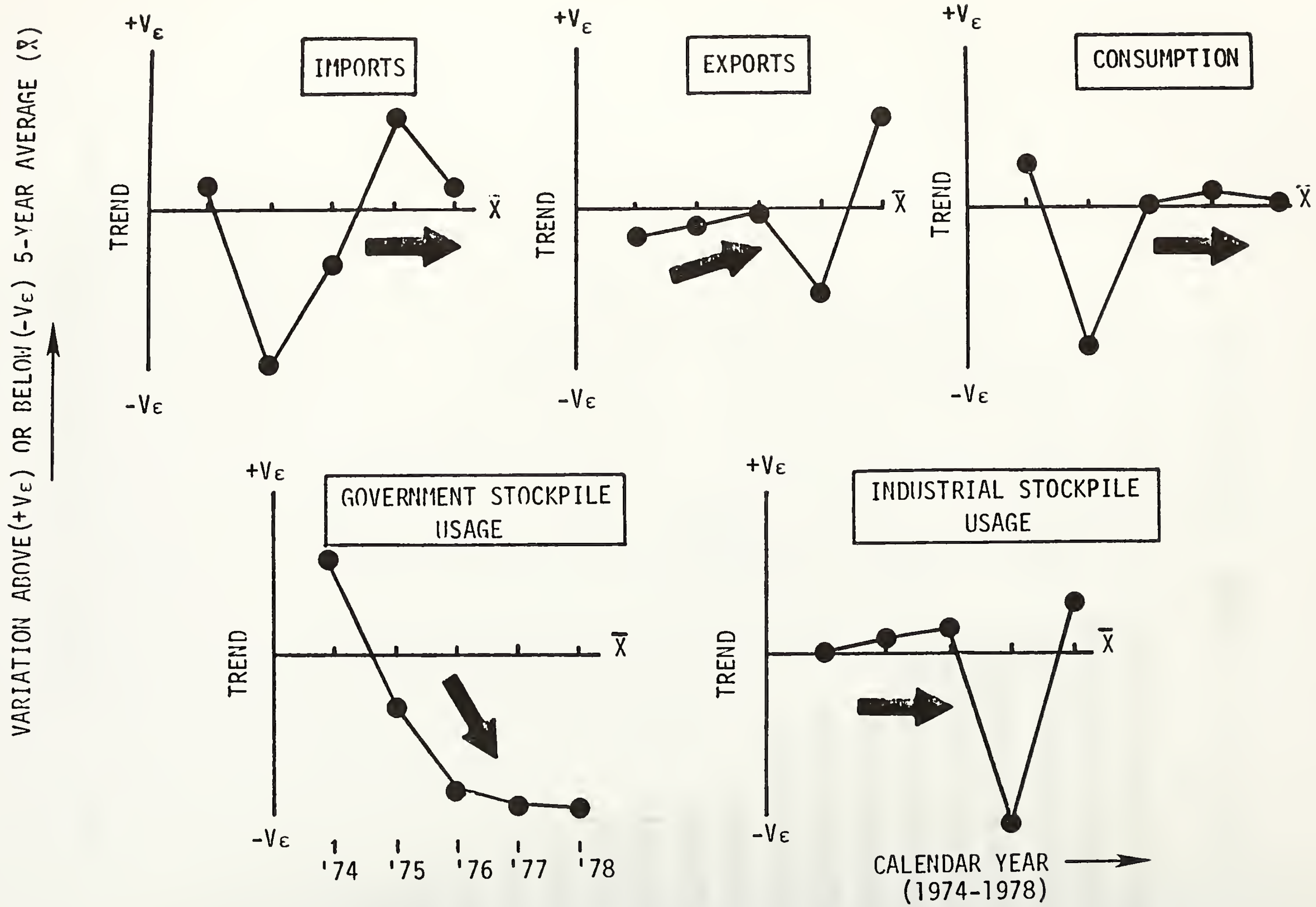


Figure 2. Market Variations for Tantalum Ores as a Function of Time. (Data Taken from References 57 and 61).

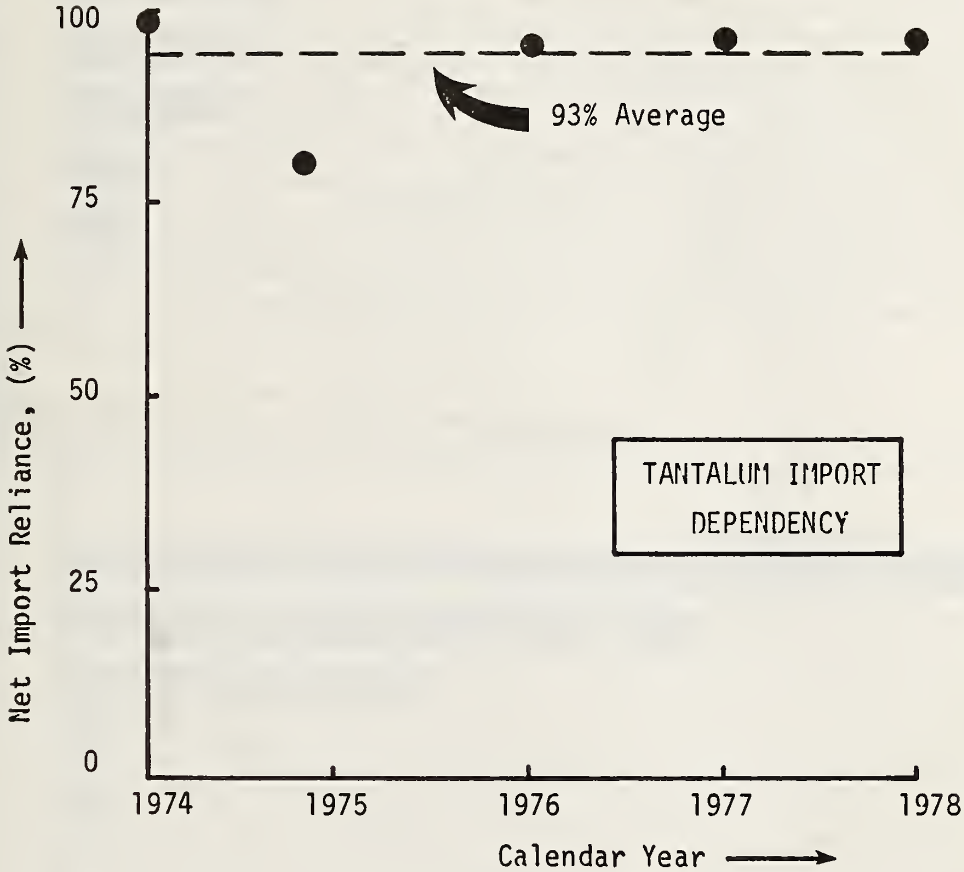


Figure 3. Net Import Reliance for Tantalum as a Function of Apparent Consumption (Taken from Reference 57).

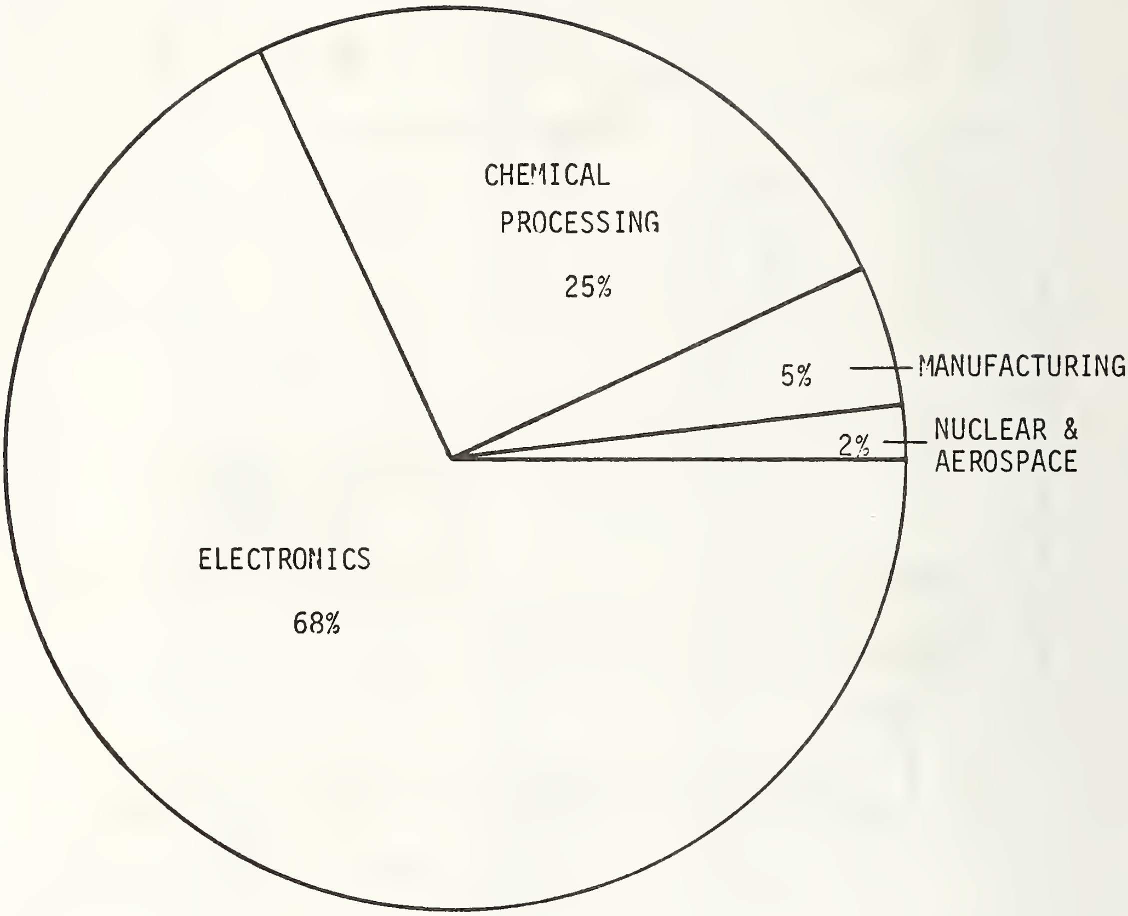


Figure 4. Composite Structure Chart for the 1978 Usage of Tantalum Metal (Data Taken from Reference 57).

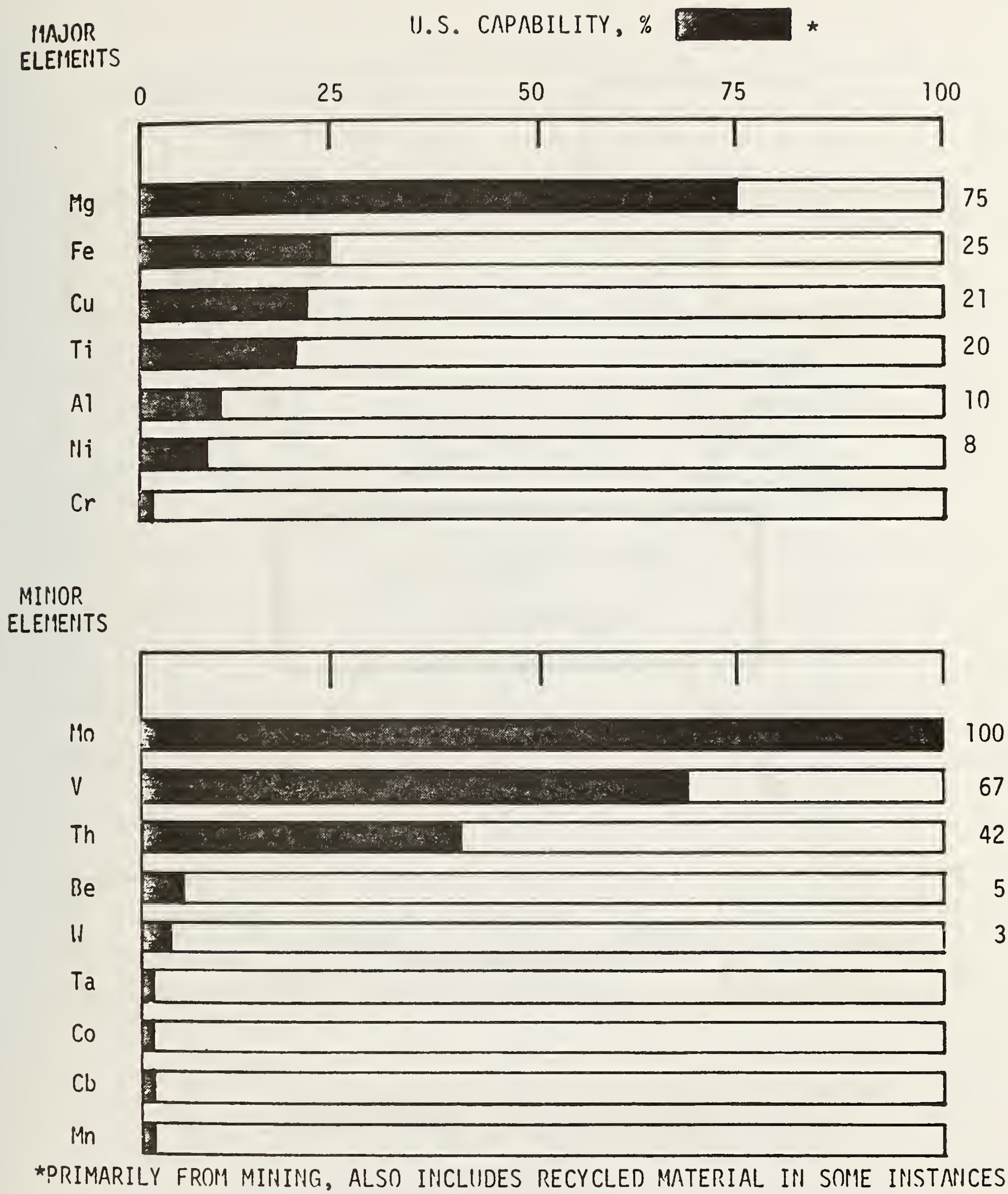


Figure 5. Capability of U.S. to meet total U.S. Requirements in Year 2000. (Taken from Reference 1).

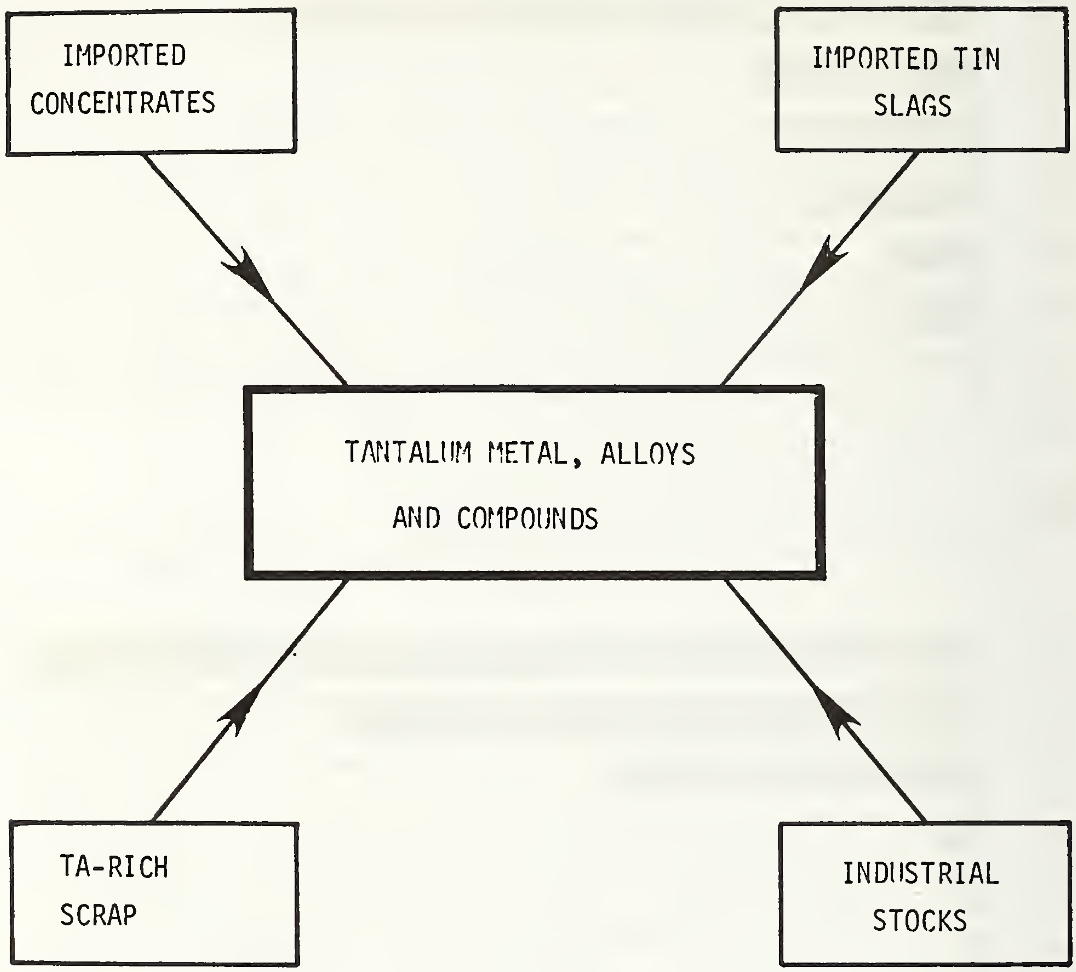


Figure 6. Sources of Domestic Production for Tantalum Products (Taken from References 3 and 57-61).

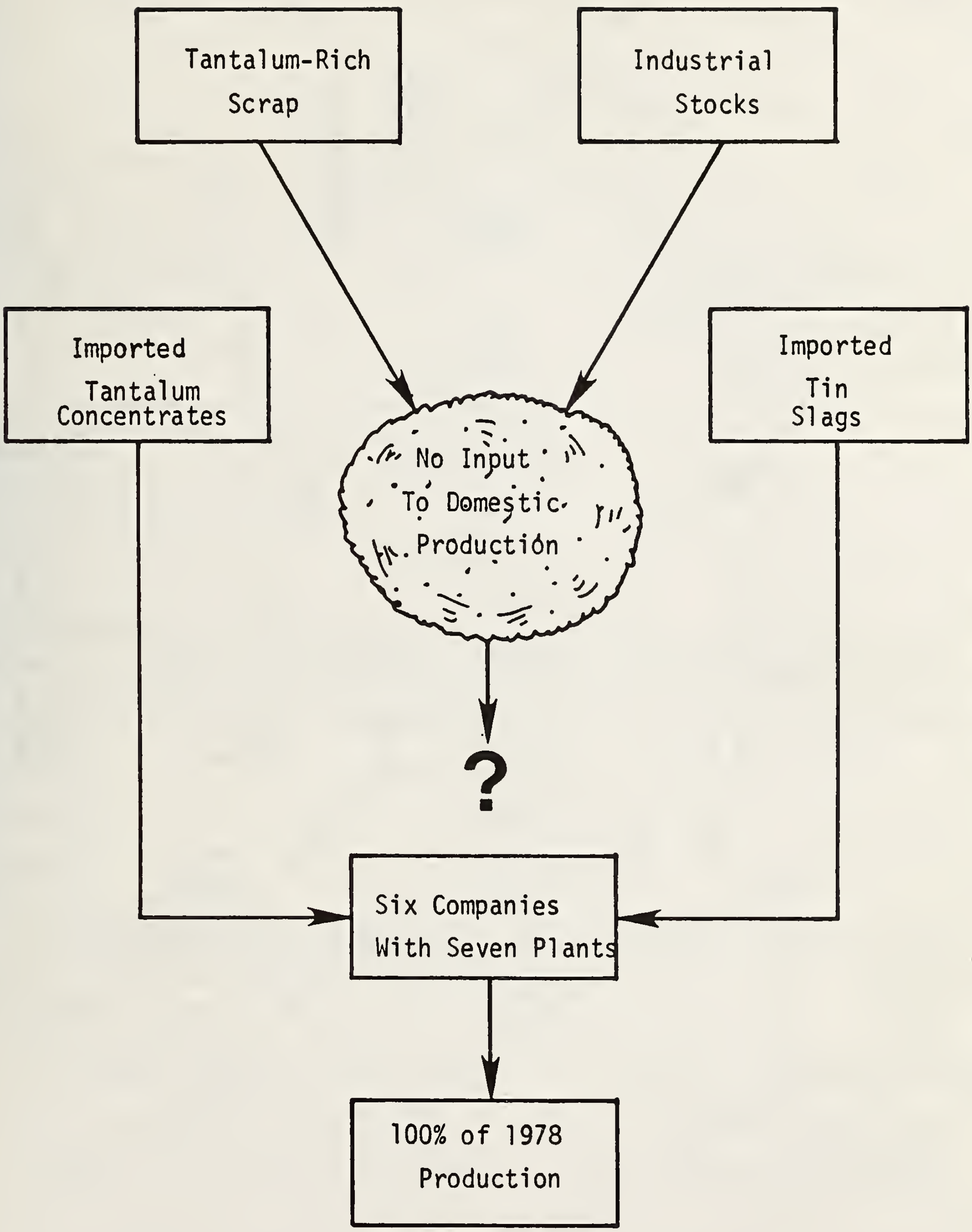


Figure 7. Allocation Problem in the Domestic Production of Tantalum Products (Taken from Reference 60).

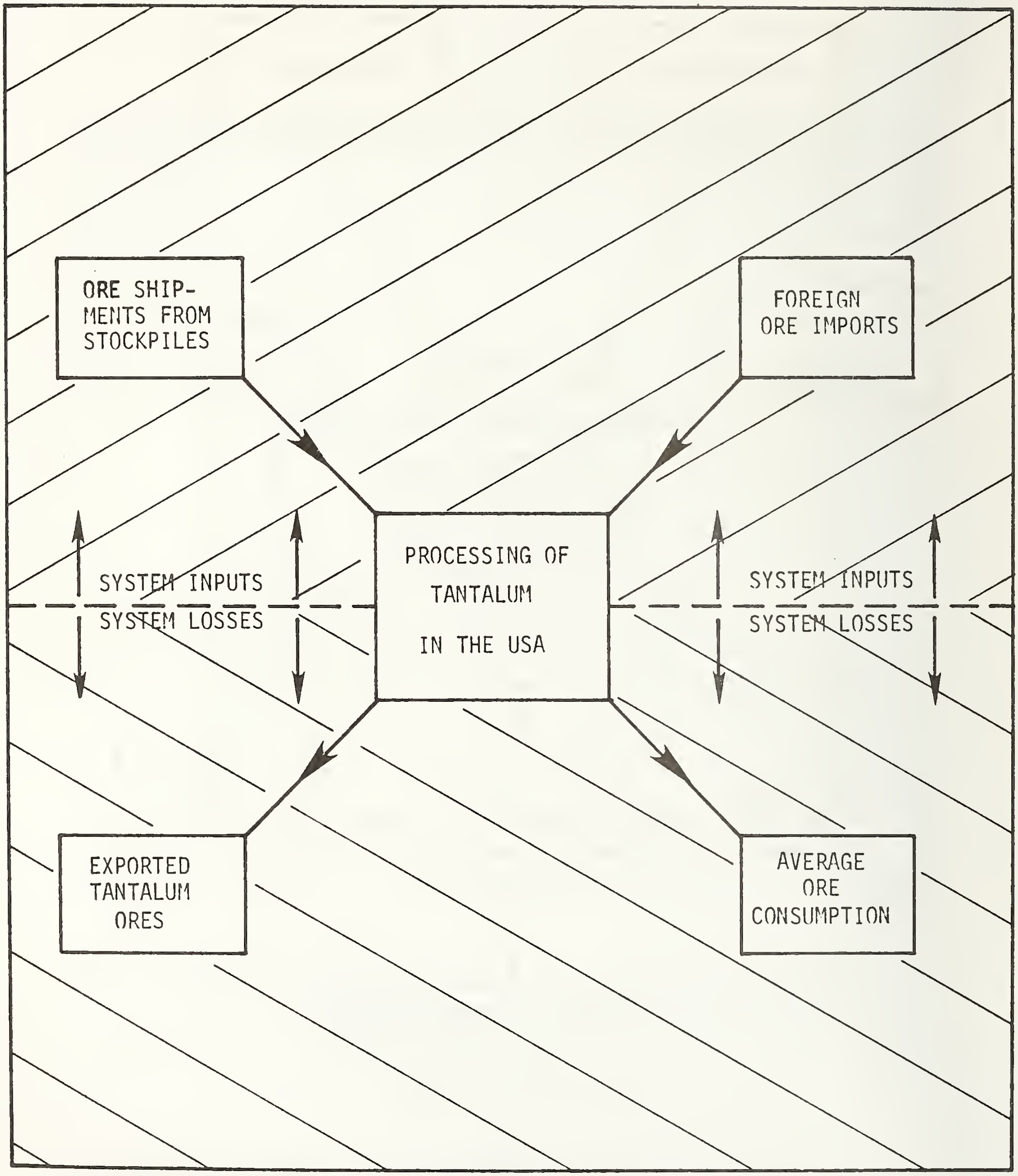
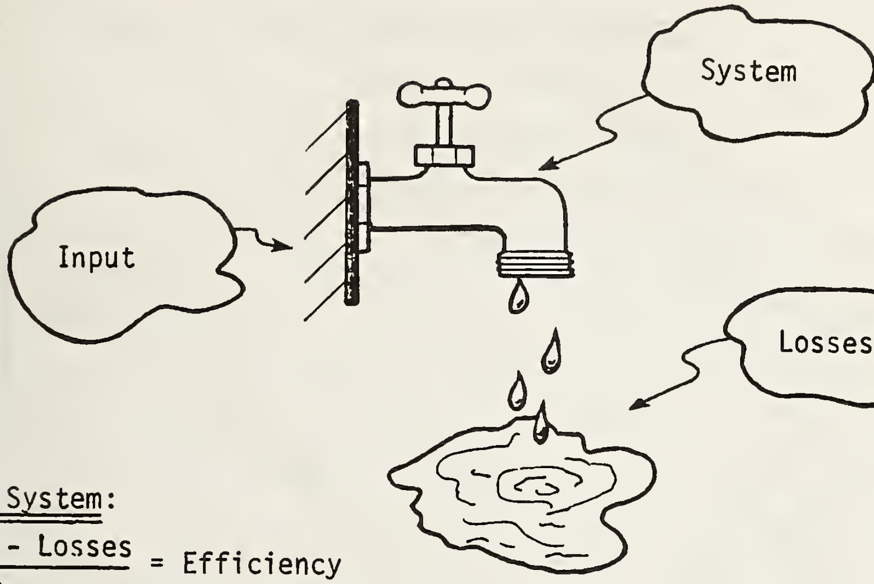


Figure 8. How Tantalum Ores *are* processed
(Data Taken from Reference 60).



For A System:

$$\frac{\text{Input} - \text{Losses}}{\text{Input}} = \text{Efficiency}$$

Process Control Charts for Tantalum Usage

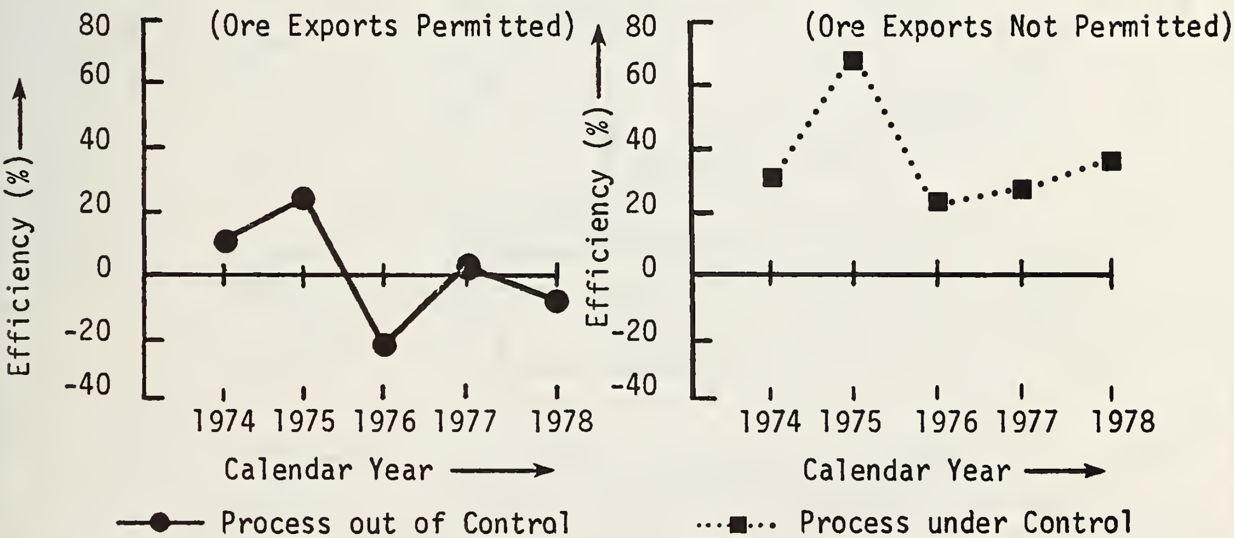


Figure 9. Efficiency Consideration for Tantalum Ore Consumption.

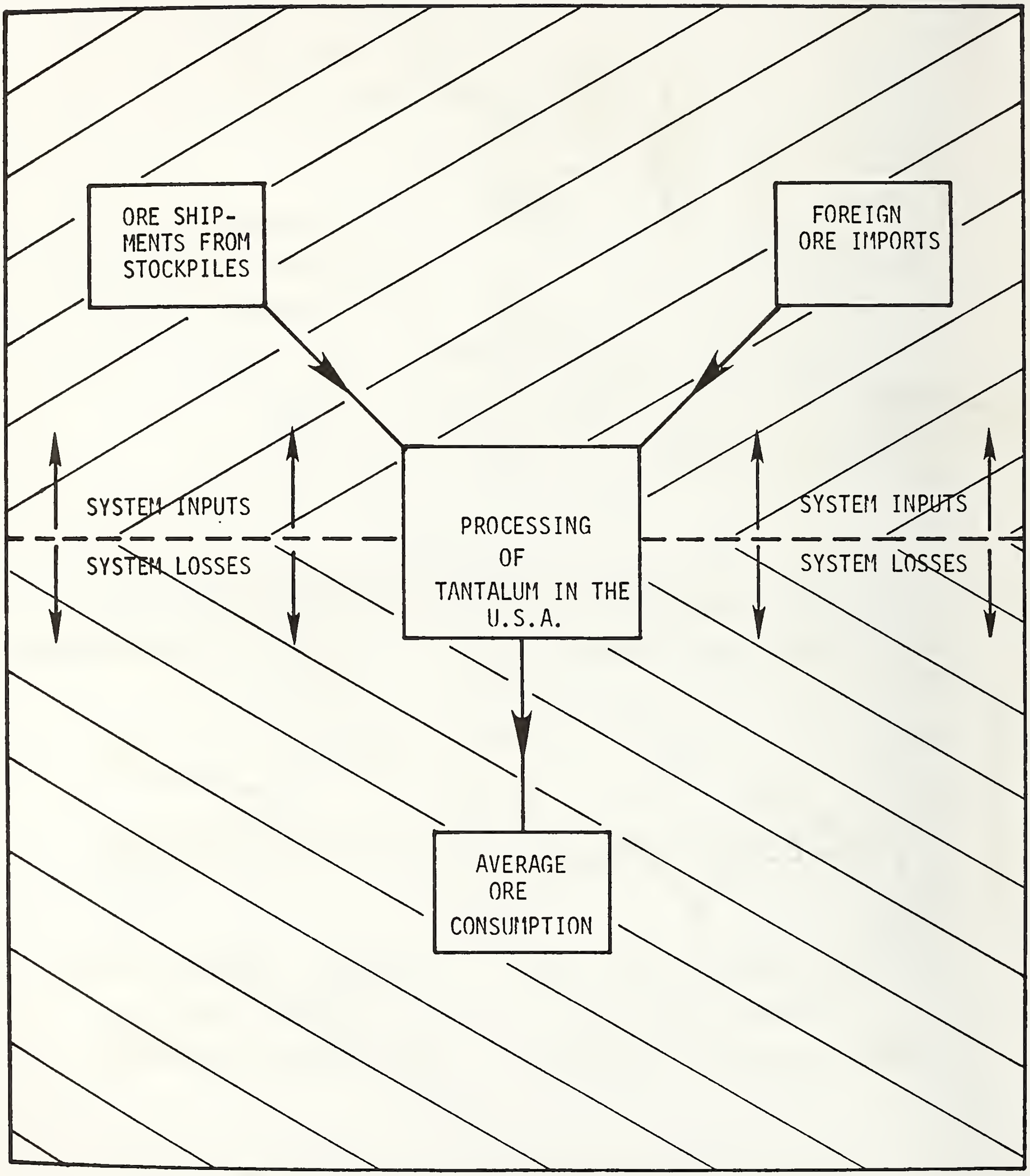


Figure 10. How Tantalum Ores *should* be processed
(Compare to Figs. 8 and 9).

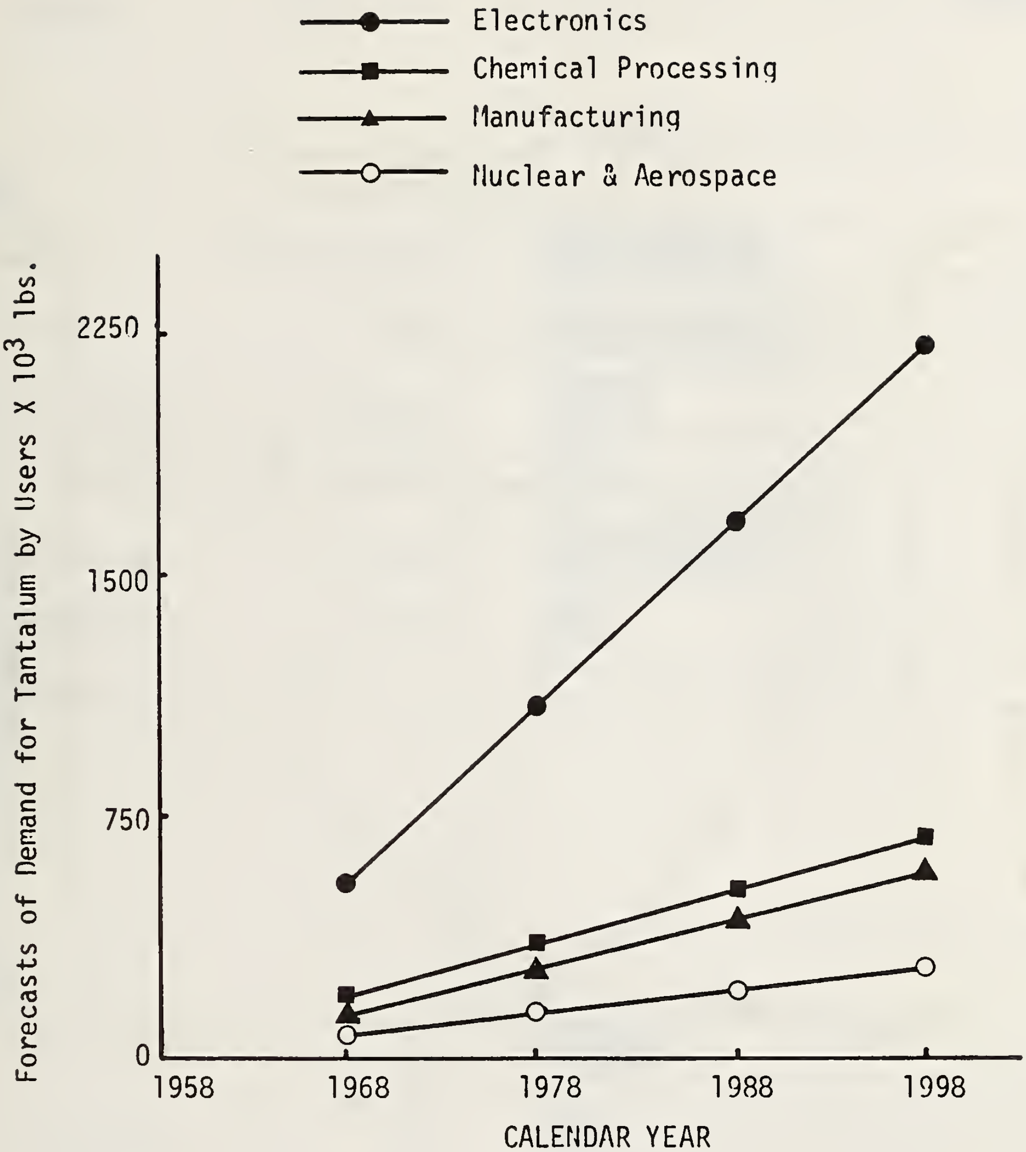


Figure 11. Future Needs for Tantalum Products (Data Taken from References 3 and 57).

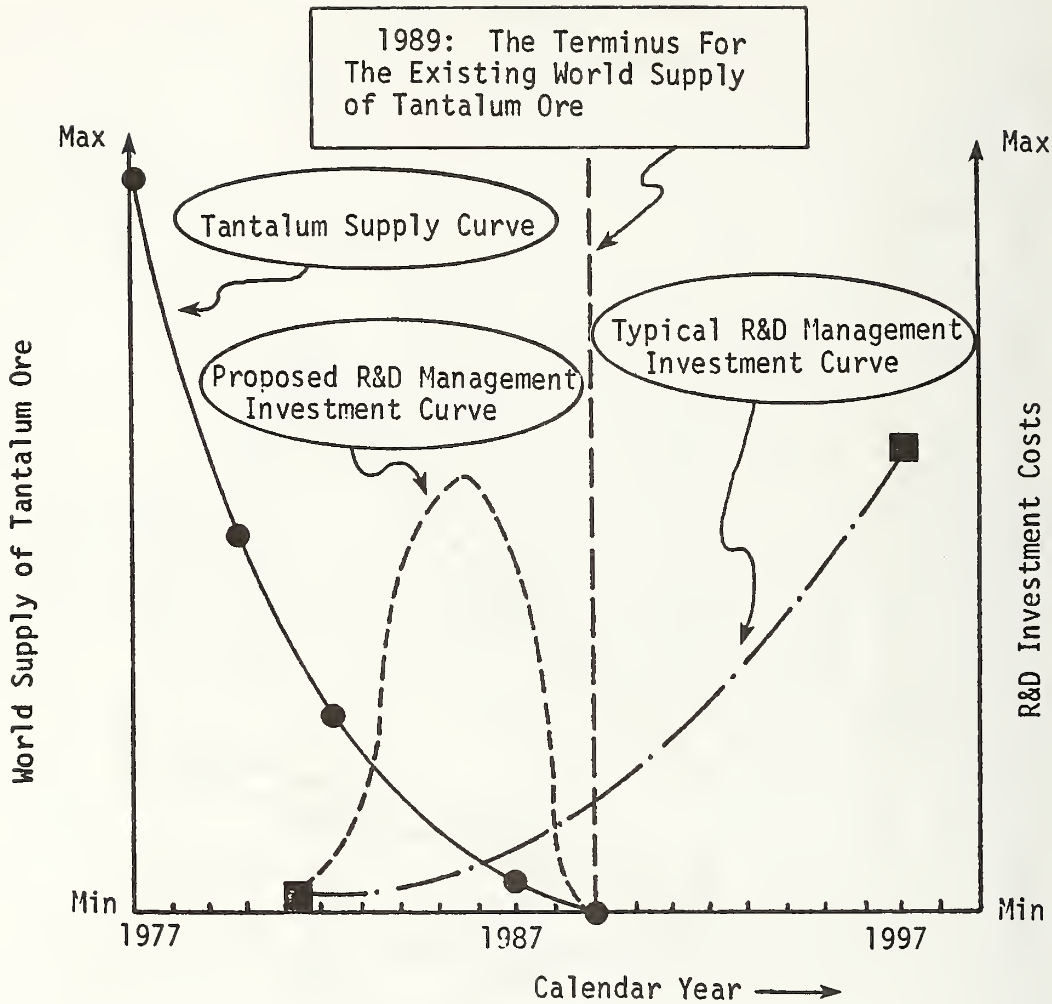


Figure 12. What is Needed *Now* to Eliminate the Tantalum Metals Crisis.

ELEMENT	SHORT TONS
MAJOR	
IRON	46 400 000
COPPER	473 000
ALUMINUM	250 000
CHROMIUM	60 000
NICKEL	73 900
MAGNESIUM	2 700
TITANIUM	--------
MINOR	
TIN	13 000
TUNGSTEN	250
COBALT	65
TANTALUM	62
PLATINUM GROUP	10

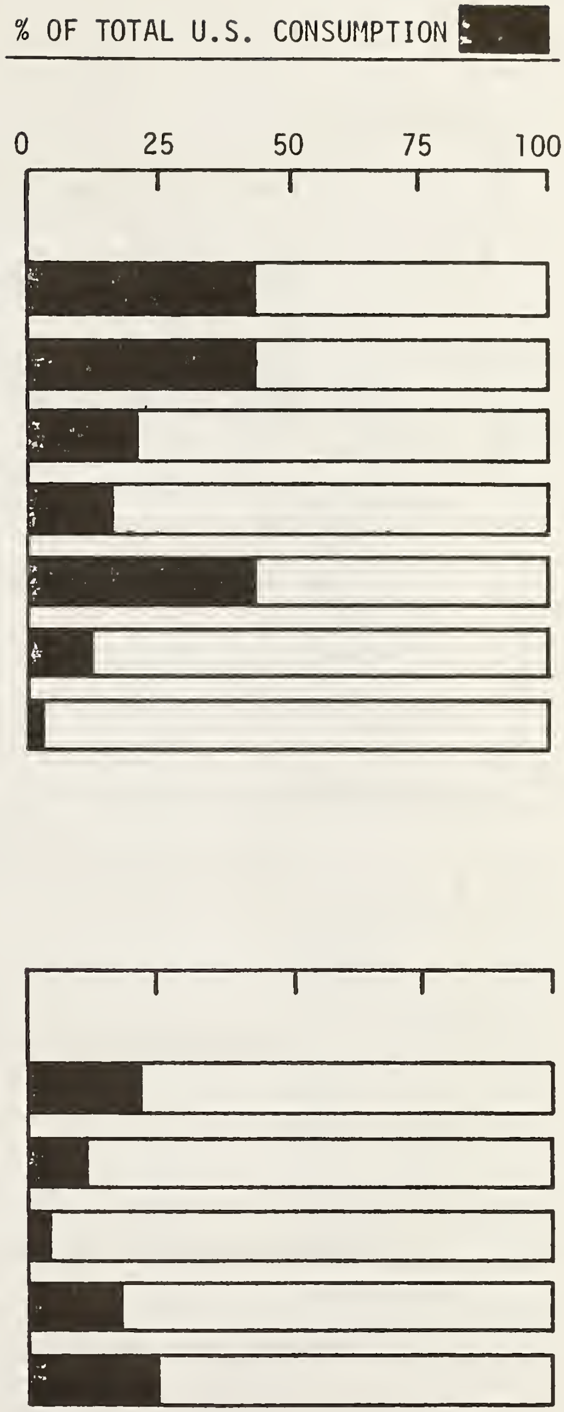
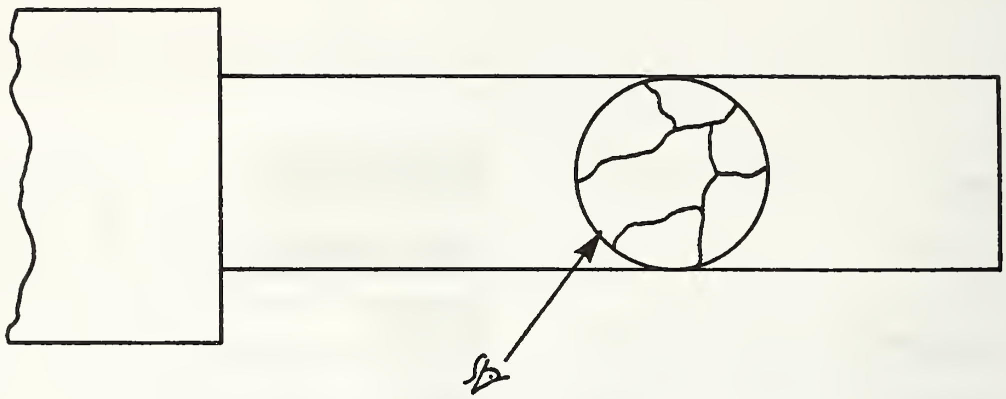
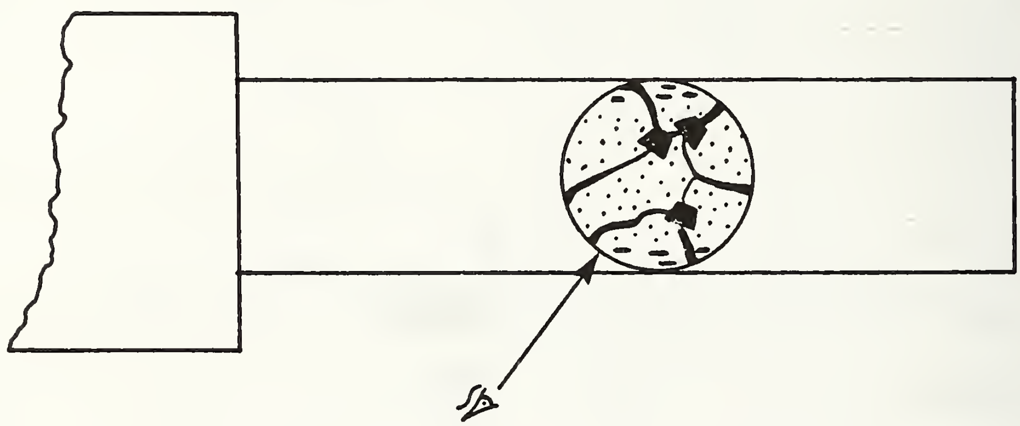


Figure 13. U.S. Consumption of "Old Material"
(Taken from Reference 9)



a) The Microscopic Appearance of "New Material".



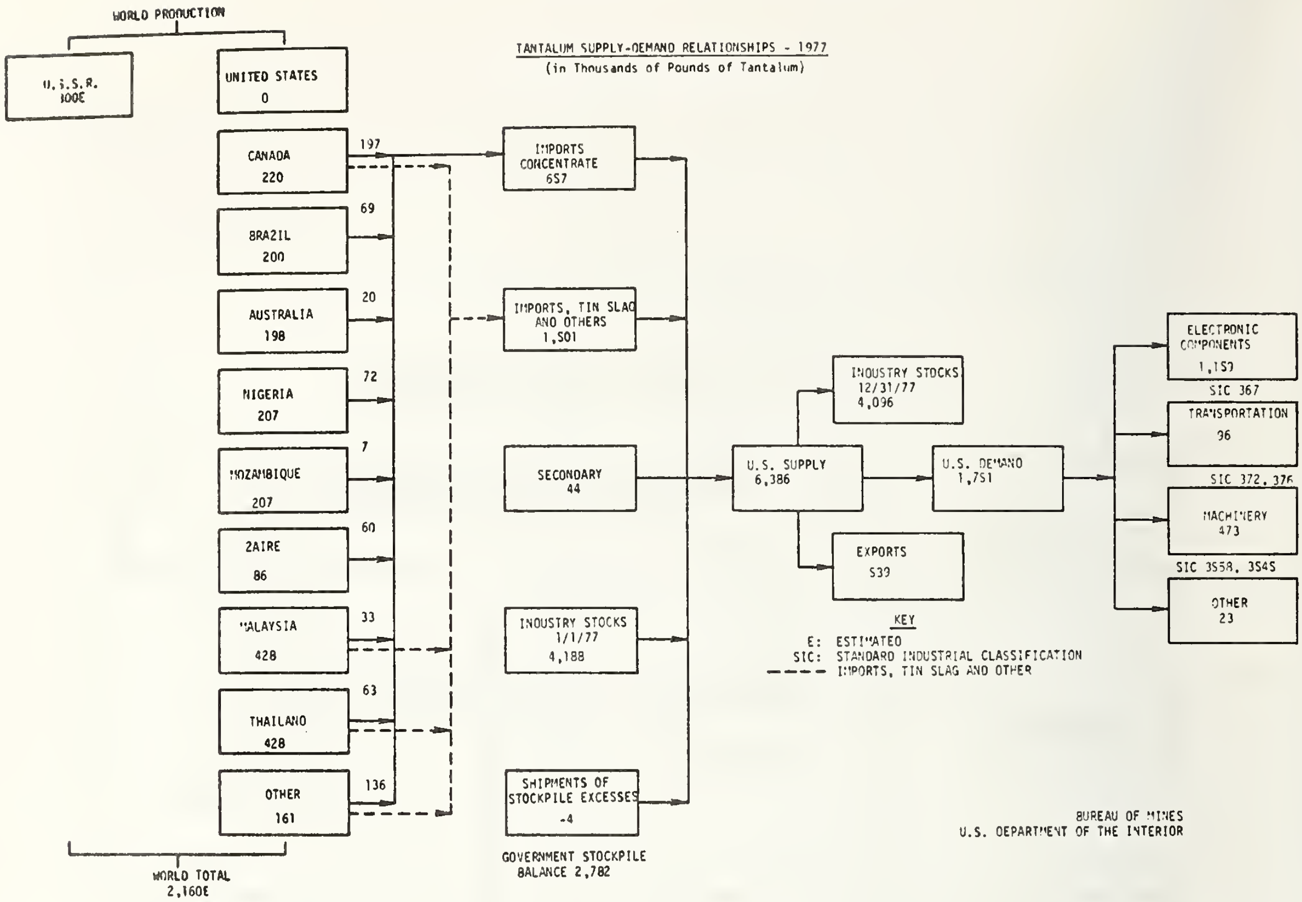
b) The Microscopic Appearance of "Old Material"

Figure 14. The Problem of Recycling "Old" Jet Turbine Blades - Exaggerated to Demonstrate the Difficulty of Metallurgical Recovery.

TABLE I. THE PROBLEM OF U.S. RESERVES

U.S. RESERVES	Importance to *all* Aerospace needs	
	Major	Minor
ABUNDANT	Copper Iron Magnesium Titanium	Molybdenum Thorium Vanadium Tungsten Zirconium
SCARCE	Aluminum Chromium Nickel	Tantalum Cobalt Columbium Manganese Tin Beryllium Platinum Osmium Ruthenium Iridium

TABLE II. TANTALUM* SUPPLY-DEMAND



TANTALUM SUPPLY-DEMAND RELATIONSHIPS, 1968-77
(Thousand pounds)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
World mine production										
United States	0	0	0	0	0	0	0	0	0	0
Rest of world	2,400	2,001	1,591	1,999	1,868	1,991	1,930	1,780	2,000	2,160
Total	2,400	2,001	1,591	1,999	1,868	1,991	1,930	1,780	2,000	2,160
Components of U.S. supply										
Domestic mines.	0	0	0	0	0	0	0	0	0	0
Secondary	e10	e35	e25	e30	e40	e40	e50	e5	e50	44
Government releases	150	215	162	6	88	266	884	87	8	[1] (4)
Imports[2]	1,660	962	967	1,023	1,157	1,248	1,730	933	1,310	2,158
Industry stocks, Jan. 1	4,187	4,614	4,287	5,063	4,740	4,254	3,983	4,214	4,591	4,188
Total U.S. Supply	6,007	5,826	5,441	6,122	6,025	5,808	6,647	5,239	5,959	6,386
Distribution of U.S. supply										
Industry stocks, Dec. 31	4,614	4,287	5,063	4,740	4,254	3,983	4,214	4,591	4,188	4,096
Exports	210	230	234	201	250	322	435	428	443	539
Government accessions	693	18	0	0	0	0	0	0	0	0
Industrial demand	490	1,291	[3] 903	1,181	1,521	1,503	1,998	220	1,328	1,751
U.S. demand pattern										
Electronic components	214	598	420	547	820	967	1,376	133	962	1,159
Transportation	182	349	211	257	254	150	156	14	69	96
Machinery										
Chemical equipment	19	55	73	89	132	96	98	24	102	161
Metalworking machinery	53	253	166	233	256	269	322	38	97	312
Total	72	308	239	322	388	365	420	62	[illegible]	473
Other	22	36	33	55	59	21	46	6	[illegible]	23
Total U.S. primary demand (industrial demand less secondary)	480	1,256	878	1,151	1,481	1,463	1,948	215	1,278	1,707

e Estimated

[1] Net change in inventory report

[2] Includes concentrates, tin slag and other.

[3] Adjusted to reflect revision in industry stocks.

*(Taken from Reference 61)

TABLE III. WORLD RESOURCES OF TANTALUM IN METRIC TONS OF Ta_2O_5*

Location	Resources Currently in Production			
	In Tin Ore	Independent of Tin Ore	Total	Life in Years (1)
Australia	160	----	160	2
Malaysia	2,250	1,100	3,350	21
Thailand	4,500	--	4,500	15
Nigeria	500	100	600	9
Zaire	1,800	---	1,800	40
Rwanda	50	---	50	11
Mozambique	---	500	500	7
Rhodesia	N.A.	N.A.	N.A.	N.A.
South Africa	---	20	20	10
South West Africa	400	---	400	
Brazil	450	---	450	4
Canada	---	550	550	4
Spain and Portugal	500	---	500	11
Egypt	---	---	---	---
Total	10,610	2,270	12,880	12 (2)

(1) Estimate at end 1977

(2) At 1977 production rate.

N.A. = Not Available

*(Taken from Reference 62)

United States Department of the Interior

BUREAU OF MINES
2401 E STREET, NW.
WASHINGTON, D.C. 20241

IN REPLY REFER TO:
EBM:MR:MRT

January 30, 1981

Dr. John B. Wachtman, Jr.
Director, Center for Materials Science
National Bureau of Standards
U.S. Department of Commerce
Washington, D.C. 20234

Dear Dr. Wachtman:

We are pleased to accept your invitation to participate in the Aerospace Industry Materials Needs Workshop on February 9-10 at the National Bureau of Standards. Information on attendees will be given to you by telephone.

We have prepared the enclosed statement which you requested on the Bureau of Mines research concern related to the material needs of the aerospace industry. Others in the Bureau may be giving you statements on the supply concern.

If there is anything further you need from us in our cooperation on this activity, please let me know.

Sincerely,

CHKenahan

Charles B. Kenahan
Deputy Director for
Minerals Research

Enclosure

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

MINERAL RESOURCES TECHNOLOGY PROGRAM

PROGRAM SUMMARY

The national security and economic well-being of the United States is seriously threatened by inability to guarantee access to the critical and strategic mineral resources upon which our industrial economy is built. The Mineral Resources Technology Program is aimed at anticipating and providing solutions to the technological aspects of this important national problem which includes those of the aerospace industry. Through both in-house and contract research, the program generates the technology base by which minerals and mineral raw materials are mined, processed, refined, and developed into materials. A strong technological base provides the options to solve unanticipated problems likely to occur in a rapidly changing world with increasing competition for limited resources. In addition, to help promote a sound economy, the program develops and transfers to industry specific mining and minerals processing technology to maximize the use of domestic resources; to improve productivity; to promote wider use of abundant materials as substitutes for scarce minerals; and to promote conservation of our non-renewable mineral resources by reducing waste in the minerals and related-products industries.

The program division works closely with other Bureau divisions, other Federal agencies, industry, and academia to insure that the resulting research will be as effective as possible in addressing national needs.

The Mineral Resources Technology program includes research, development, demonstration, and technology transfer activities in the following subprograms:

- Advancing Mineral Science and Technology
- Conserving Domestic Mineral Resources (includes recycling)
- Developing Domestic Mineral Resources (includes materials substitution and performance)

The Mineral Resources Technology program includes research that will benefit the aerospace industry. This includes research for developing domestic resources of aluminum, chromium, cobalt, nickel, platinum, titanium, and tungsten; recycling critical metals from superalloy and electronic scrap and industrial wastes; and projects directed toward developing substitutes for critical and strategic materials. These include research on coatings, high-temperature alloys, titanium, sialon ceramics, rapidly solidified ceramics, reinforced metal-matrix composites, cobalt-free carbide cutting tools, hard materials, magnetic materials, platinum substitutes, and improved soldering and brazing systems.

1/30/81

GENERAL ELECTRIC

CORPORATE
OPERATING
SERVICES

GENERAL ELECTRIC COMPANY, 1285 BOSTON AVE., BRIDGEPORT, CONN. 06602

MATERIAL RESOURCE AND
TRAFFIC OPERATION

February 5, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Building B308
Washington, DC 20234

Dear Dr. Wachtman:

You will find attached comments submitted in response to the "Invitation for Expression of Public and Private Sector Materials Needs and Recommendations for Federal Action" published in the Federal Register, Friday, January 9, 1981. These comments represent my personal views, developed through experience in the Material Resource and Traffic Operation of the General Electric Company, including interactions with informed individuals in the technical and procurement functions of General Electric's Aircraft Engine Group.

Very truly yours,

R.P. Carreker
Manager, Material Resource Analysis

RPC:pp
Encls.

February 5, 1981

Submission to the Department of Commerce Workshop on Critical Materials Needs in the Aerospace Industry, Gaithersburg, Maryland February 9-10, 1981

The Department of Commerce should be encouraged to focus on the materials needs of the aerospace industry in responding to the directive of Section 5(c) of the Materials and Minerals Policy Research and Development Act of 1980 (PL 96-479). We understand that directive to require the Secretary of Commerce to report to the Congress before October 21, 1981 on the critical materials needs in a specific case related to national security, economic well-being and industrial production. The aerospace industry certainly meets these criteria and it certainly has critical materials needs which are not fully assured. It will be a service to the aerospace industry and to the nation if this study focuses on aerospace materials needs with sufficient intensity and specificity to identify, describe and propose remedies for the real supply risks and bottlenecks that constrain this industry.

The General Electric Company participates in the aerospace industry in a number of ways, but most notably as a leading producer of engines for both military and civil aircraft. The modern "jet engine" achieves remarkable performance through design ingenuity utilizing special materials near their limits of strength and temperature. High strength alloys operating at high temperatures in minimum weight parts translates to more speed, lower fuel consumption, and greater payloads. Availability of the materials used in these alloys is essential for the production of aircraft engines to meet the needs of national security and our modern economy.

Those who contemplate actions to alleviate potential supply problems should have an appreciation of the effort and time required to permit new formulations, new alloys, or even new sources of raw material to be used in an aircraft engine. The excellent safety record of this complex machinery that works under severe conditions is due, in large part, to the stringent specifications and qualification procedures that are normal in the aircraft engine business. Specifications extend to raw material sources and processing procedures, and changes must be preceded by extensive qualification tests.

Current major materials supply concerns to GE's Aircraft Engine Business involve:

a) <u>Cobalt</u>, which is an ingredient of alloys used in critical components in hot sections of the engine, contributes strength at high temperatures.

b) <u>Chromium</u>, which is also essential in these alloys, because it contributes to strength and to resistance to oxidation at high temperature.

c) <u>Tantalum</u>, <u>rhenium</u>, and <u>hafnium</u>, which are used in small percentages in alloys for severe service at high temperature, contribute an extra margin of strength.

d) <u>Titanium</u>, which is used at intermediate temperatures, combining necessary strength with relatively low density, thereby improving the thrust-to-weight ratio of the engine.

Supplies of several of these elements are at risk.

Cobalt has been the subject of much concern and much attention in the last two years. The bare facts are well publicized: it is an essential ingredient in alloys for high temperature service. Its use as a binder of hard particles in hard facing applications, in carbide cutting tools and in diamond tools and dies are also important to the aerospace industry. Cobalt supply was curtailed and its price increased very markedly following the 1978 invasion of the Shaba province of Zaire. That made most everyone acutely aware that the USA imports all of its cobalt, and that most of the supply comes from Zaire and, recently, Zambia. But, a perceptive analysis will look beyond that import dependence to note:

a) the current state of affairs in Zaire and Zambia makes further supply interruptions possible;
b) the contribution of U.S. stockpile actions to the cobalt shortage and to market uncertainty, thereby discouraging decisions to invest in new capacity;
c) the current very high price in spite of the accumulation of large unsold inventories;
d) the existence of a potentially viable domestic source of cobalt (The Blackbird Mine in Idaho);
e) the uncertainty about future supplies that may come from the large quantitites of cobalt containing nodules on the bottom of the sea.

Chromium provides essential oxidation resistance to all high temperature alloys. The U.S. imports all of its chromium, either as chromite ore, as ferrochromium, as refined chromium metal, or in stainless steel. The big picture about chromium is that it is widely used in stainless steels, low alloy steels and cast irons, and that there is plenty of chromite ore in the world with South Africa and Zimbabwe having the most, the best, and the cheapest to produce. By combining its low cost chromite with low cost energy, South Africa has become the dominant producer of ferrochrome. With so much of the Western World's chromium supply coming from southern Africa, the potential for interruption by political events is recognized.

The all important little picture is that the most critical aircraft engine components (the turbine blades) require pure electroytic chromium, not the ferrochrome used in stainless steel.

The quantity of electrolytic chromium used by the USA is less than one percent of ferrochromium consumption. There is but one domestic producer, who supplies less than half of the market. The balance comes from Japan and England. A perceptive analysis will examine the question of whether the country should rely so heavily on imports for supply of this intermediate form of chromium.

Tantalum, rhenium, and hafnium are relatively rare materials that, when used in very small amounts in high temperatures alloys, contribute very useful properties. They are expensive; moreover their prices are highly volatile. Applications of promising alloys are being delayed by the erratic price behavior of these metals. For example, tantalum ore, (tantalite) sold for $25.00 per pound in June 1978 and for $80.00 twelve months later and as high as $115 in 1980. A large portion of our tantalum supply is obtained as a by-product of tin production. Rhenium is derived as a by-product of some molybdenum production that is, itself, the by-product of some copper production. It sold for $600 per pound in 1975, $2500 in 1980, and currently sells again for $600. Hafnium has a somewhat less dramatic price history, but it is obtained as a by-product of zirconium production which is used primarily in the currently depressed nuclear industry. These materials are in short supply. They are produced as by-products or co-products from other metals production. Demand is erratic. It is extremely difficult to use materials exhibiting such volatile market characteristics in a long cycle product like an aircraft engine. Yet, they do hold the promise of superior performance, of better engines. A perceptive analysis would consider the reasons for such volatile prices and might identify ways to bring more stability to the markets.

Titanium supply problems have not been due to the lack of suitable ore (even though nearly all of that ore is imported), but to the lack of in-place domestic capacity to process the ore to useful metal. GE has experienced the shortage situation in the form of very long lead times to procure forgings for use in rotating applications and a marked increase in the price of such parts. That situation can be traced back to a shortage of domestic capacity to produce titamium "sponge." There are three domestic producers of titanium sponge who have supplied 75 to 90 percent of the domestic requirement in recent years. The gap has been filled by imports from Japan, UK, and sometimes USSR. Titanium has been through several cycles of boom and bust since the 1950's, largely related to cycles in military procurement. In 1980 the heavy demand for commercial aircraft engines created needs for titanium that could not be met by the domestic producers. Imports increased markedly and the price of sponge increased from $4 per pound to $7. A perceptive analysis of the titanium supply situation would illuminate the relationships among government procurement actions, the state of the domestic titanium industry and the role of imports. It would recognize the impact of material shortages on the cost and time to produce aircraft engines for civilian and national defense needs.

In summary, General Electric has experienced problems in the supply of critical materials needed for production of aircraft engines, and future problems are anticipated. This inquiry is addressing an area where there are real tangible industrial production issues to be resolved in the interest of national security and economic well-being.

I would like to express some reservation about the potential scope of the inquiry and the prospective report to Congress next October, as indicated by the announcement of this workshop. The scope seems too broad and the time too short to permit analysis at the level of detail that will lead to effective solutions to the problems that exist. An appropriate response to the directive of PL96-479 to report on "critical materials needs in a specific case" should be more specific than five materials, several scenarios, and the aerospace industry.

R.P. Carreker
Manager-Material Resource Analysis
Material Resource and
Traffic Operation
General Electric Company
1285 Boston Avenue
Bridgeport, CT 06602

American Iron and Steel Institute

1000 16th Street, N.W., Washington, D.C. 20036

February 5, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B308
Washington, D. C. 20234

Dear Dr. Wachtman:

The American Iron and Steel Institute, which represents 63 domestic steel producers who together account for 93 percent of U. S. raw steel production, would like to respond to the invitation for expression of public and private sector materials needs and recommendations for federal action (46 Federal Register 2375). Specifically, we would like to comment on (1) the particular materials to be examined, and (2) the current and anticipated problems with these materials.

In our view the following criteria should be used by Commerce in making its decision whether particular commodities should be studied:

(1) Degree of import dependence (we recommend a threshhold of 75 percent), and

(2) Political stability and orientation of major supplier nations.

We have concluded that, of those materials which are vital to the aerospace industry, those which should be studied are as follows (listed in order of relative importance):

Chromium
Cobalt
Columbium
Titanium
Nickel
Aluminum

Our reasons for selecting these materials relate to the strategic and critical importance of these materials as related to aerospace requirements, the high dependence the U. S. has on imports, and the likelihood of significant and perhaps prolonged disruptions in these imports.

American Iron and Steel Institute

Manganese, while having a very high degree of import dependence, from sources potentially subject to disruption, is omitted only because of its lesser significance as an aerospace material.

In undertaking its study, we urge that Commerce examine problems associated with the U. S. strategic stockpile of the materials reviewed. We are concerned that Government holdings do not, in many instances, meet projected needs (or goals) and that much of the stockpiled material is not of such quality or condition as would make it usable by U. S. consuming industries.

Sincerely,

Gerald W. Houck, Jr.
Director
Energy Affairs

:clc

Tool and Stainless Steel Industry Committee

1055 THOMAS JEFFERSON STREET • WASHINGTON, D.C. 20007
337-6000

February 4, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building
Room B 308
Washington, D.C. 20234

SUBJECT: Aerospace Materials
Needs "Cobalt"

Dear Dr. Wachtman:

I am sending this letter on behalf of the Tool and Stainless Steel Industry Committee (TSSIC), an association of seventeen specialty steel producers, in response to your Federal Register notice of January 9, 1981 inviting expression of public and private sector materials needs and recommendations for federal action. 46 Fed. Reg. 2375.

The U.S. specialty steel industry is extremely concerned about the availability of critical raw materials to meet the needs of the aerospace industry. We are concerned about the high dependence of the United States on foreign sources of supply, and the inadequacy of the U.S. defense stockpile both in terms of quantity and quality. One of the most critical items from our standpoint is cobalt. The following outlines some of the most current problems. Many of these same problems would also apply to chromium, columbium, and nickel and we would be happy to provide more details on these elements as well. We have established the Critical Materials Subcommittee as a permanent committee to closely review and consider problems in this area.

The Critical Materials Subcommittee of TSSIC is all too familiar with the price explosion in cobalt that started in February/May 1978 with the international problems in Zaire and Zambia - that had brought the price of cobalt in the USA to a level 3.9 times higher, and dramatically affected superalloy costs for Department of Defense needs.

Similarly, we understand the history of USA consumption nd the present quantity of cobalt in the GSA stockpile as to:

1. Present annual consumption levels in the 16-18 million pound range.

2. The present GSA stockpile level of approximately 43,000,000 lbs. and the recent upward revision of the GSA goal to over 80,000,000 lbs. (similar to older objectives).

3. And finally, the key concern and the key question - namely, the quality of the 43,000,000 lbs. now in the stockpile compared to 1981 and onward Defense needs.

GSA computer printouts confirm that the material in the stockpile was purchased prior to 1954 and probably prior to the March 10, 1953 Specification No. P-13-R. None of this 43,000,000 pounds consists of high purity Electrolytic Cathodic Cobalt, but all of it is granules or rondelles (containing higher levels of residual elements). It is well known that these residuals are catastrophic for the manufacture of Aircraft Rotating Parts.

Further, from releases made from the stockpile in the early 1970's, individual member companies of the specialty steel industry can confirm that the "listed chemistries" for the stockpile lots are not accurate by 1980 standards due to:

a) 1950 methods of measuring to the then Specification No. P-13-R.

b) No sampling plan stated in the specification to verify that the sample chemistry analyzed and listed truly represents the analysis of the stated lot.

SUGGESTED STOCKPILE OBJECTIVES

Quality

Defense Department objectives need not require that all cobalt in the stockpile meet the most strict requirement; namely, that for Aircraft Rotating Parts. In brief, a pragmatic view suggests:

1. The present inventory of granules and rondelles can be used for making high speed steel, tool steel, Alnico magnets, and carbide tooling.

2. That FEMA ask industry to confirm that GSA's proposed new Specification No. P-13-R3 of June 28, 1979 is basically adequate for most Aircraft "Non-Rotating" Parts, medical, and energy applications.

3. That FEMA ask industry to supply the new suggested specification for cathodic cobalt for Aircraft Rotating Parts. Limits must be set for residual quantities of Zn, Zn+Cd, P, Sn and Sb as well as various gas contents. (The TSSIC Subcommittee has a suggested speicfication.)

4. GSA's specification must include a sampling plan in the specification to assure that for future purchases the supplier's reported chemistry is checked and that it represents the chemistry of each 250 kg drum in the lot indicated. The TSSIC Subcommittee can supply a suggested sampling plan.

Quantity

At meetings with GSA on October 31, 1979 and DOD on December 11, 1979 the following general suggestions were made and these still appear correct; namely, that

1. 25-30% of the stockpile meet a new cathodic specification for rotating parts.

2. 40-60% of the stockpile meet the new granule/cathode Specification No. P-13-R3.

3. 25-30% of the stockpile can remain in present (pre 1954) quality.

If 1981 to 1985 budgetary limits dictate no total increase in the stockpile quantity above 50,000,000 lbs. to 60,000,000 lbs., it would appear that USA can live with that limit if the quality of the stockpile is balanced in the above proportions.

ECONOMIC IMPLICATIONS

Cobalt prices (stabilized 1980) are showing weakness in the world markets, and eventually may decline somewhat. Substantial purchases by GSA could probably be made over the next five years or so of cathodic cobalt without major impact on the price if concurrently GSA sells approximately equivalent quantities of the present (pre 1954) stockpile of granules and rondelles. The low quality stockpile cobalt could probably be sold at $18.00-$20.00 per pound (versus a 1954 purchase price of $2.50 per pound) and the cathodic material could be purchased at $22.00-$25.00 per pound. A five-year program at 5,000,000 lbs. per year would place the inventory in good balance for Defense needs at an out-of-pocket cost of only perhaps $25,000,000 per year.

If I or the TSSIC Critical Materials Subcommittee can be of any assistance to you in researching or pursuing your policy goals, please call.

Sincerely,

John L Wandrisco

J. L. Wandrisco
General Manager - Marketing

JLW:aap

cc: David A. Hartquist
W. R. Solomon, Jr.
W.J. Pendleton

ALUMINUM COMPANY OF AMERICA
1200 RING BLDG., WASHINGTON, D. C. 20036

ALCOA

1981 February 05

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B308
Washington, D. C. 20234

Dear Dr. Wachtman:

Attached are Alcoa's comments and recommendations regarding actions to be considered by the Department of Commerce in response to P.L. 96-479.

Please advise me if you wish me to present them at your forthcoming workshop so that viewgraphs can be made.

These points and comments can be covered in a five minute talk not counting any discussion that might occur.

Sincerely,

Gregory B Barthold

GREGORY B. BARTHOLD
Manager, Technical Programs

GBB:ljs

Attachment

Aerospace Industry Considerations - Aluminum

Today's Conditions

A. The U. S. imports almost all of its metal grade ore either in the form of bauxite or alumina.

B. The industry's raw material base is broadly dispersed so that any interruption of supply at one source can be accommodated from other sources. The industry has researched a number of possible alternatives to bauxite and has developed the technology to use them. All are processes that would use domestic sources.

C. The National strategic stockpile contains a sufficient amount of bauxite to meet defense requirements for aluminum until such time as facilities to process alternative domestic ores can be brought on stream.

D. U. S. domestic expansion of refining capacity and primary ingot production has slowed down considerably. The ability to build power capacity at a reasonably competitive cost is so constrained by the regulatory process as to virtually eliminate aluminum smelting expansion domestically.

E. The U. S. aluminum industry is expanding its metal production capabilities outside the United States in such places as Brazil and Australia partially because these countries continue to demand a growing share of downstream production. They have the ore, they want to refine it, and produce the metal to gain the added value. They have the electrical energy, and the will to meet the challenge of growth of power supply and the environmental consequences.

F. The industry's technology base is very strong. New higher strength, lower density, higher modulus alloys in both ingot technology and rapid solidification technology are emerging from our laboratories especially for the aerospace industry. In addition, our process efficiency in energy use is improving with the application of new smelting technology and improvements on the conventional reduction process.

G. Fabricating facilities for aerospace grade sheet, plate, forgings and extrusions are being expanded to meet the forecast of increased demand. The airlines' current cash flow problem has reduced the demand for aircraft that was experienced last year and was the cause of the extended deliveries experienced by some builders. More recently the aluminum industry's expansion plans have been stretched out to keep capacity in balance with forecast demand.

H. Our international trading competitors have a more advantageous tax policy than exists in the United States. This tax policy allows them to modernize facilities and increase productivity. In the long run they will become more price competitive in fabricated products to the disadvantage of our domestic industry.

I. The balance between capacity and demand in the aluminum industry is extremely delicate and fragile but it must be achieved because the cost of idle facilities in a capital intense business is too high to endure in today's high interest economy. A standby surge capacity cannot be afforded.

J. A surge capacity for national security requirements, however, does exist. The aluminum industry's current production for defense requirements is approximately 1% of total production. The balance - 99% is for commercial applications, i.e., automobiles, beer cans, siding, electrical cable, foil, etc. These uses would lose their place in line as non-essential in a national emergency thus releasing a great portion of that 99% to defense applications. The convertibility of fabricating facilities from non-defense to defense can easily be accomplished. There would be some bottlenecks. Advance planning as to the type and quantity of aluminum would be needed to provide for a quick transition. The bottlenecks that occurred during the past two years have been recognized and additional capacity is being added. Current capacity expansions include heat treated sheet and plate, large press extrusions, and intermediate and large press forgings.

K. Recycling, mainly of used beverage containers is becoming a more and more important source of raw material to the aluminum industry. Recycling consumes five percent of the energy required to make virgin metal. Thus the use of recycled metal is an extremely energy-efficient process.

L. Substitution research and development to uncover replacements for critical alloying elements is worthwhile. The aluminum industry is highly dependent upon manganese as an alloying element. A potential manganese shortfall could occur. The elements of cobalt and chromium while not as important to aluminum as they are to steel, are used in small quantities in some of the new alloys being developed in both ingot metallurgy and rapid solidification technology.

Recommendations:

For the primary aluminum industry to remain competitive and also expand domestically . . .

1. Long term power at competitive prices must be available. Current regulations inhibiting the growth of power must be removed.

2. A balance between environmental goals and national defense needs must be achieved. Opening western lands to selected mining of critically short minerals should be allowed. Water rights to exploit domestic aluminum ores must be provided.

3. U. S. tax policy should be changed to allow for faster depreciation of facilities so that expansion and modernization and greater productivity can occur.

The Defense Department should provide industry with detailed information regarding its weapons requirements for both peacetime and mobilization scenarios so that industry can plan to meet these needs.

Research to develop substitutes for critical elements that are in short supply should be encouraged.

The aluminum industry, although critical to aerospace, is in comparatively good health. Those materials and minerals that are subject to geopolitically caused shortages or those that are naturally scarce should receive our attention. Aluminum is not in this category. Federal actions that would assist the domestic health of industry in general should be favored instead of those actions that would discriminate in favor of one material.

Materials

WALTER R. HIBBARD, JR.

A REVIEW OF RECENT policy studies relating to materials and minerals suggests that there are two predominant issues: (1) The need to create a cooperative environment between government and industry in order to assure a strong future in the field of materials. (2) The deterioration of long-range research and the emphasis on short-term development that have been brought on by profit squeeze, energy costs, and environmental and regulatory restrictions. The symptoms of these maladies have been studied and reported in detail, but the disease, namely, a national policy of protecting society from industrial excesses, thoughtlessness, or environmental and social neglect by means of regulations, must be directly addressed.

Government policy consists of actions such as legislation and regulation which are implemented and enforced. Therefore, statements of policy, without action, are not policy. For example, despite declarations of government officials to the contrary, the effect of United States energy policy has been to increase the use of imported oil and gas by regulation, to curtail the use of coal and nuclear energy sources by regulation, and to blame any problems that arise on industry. The enforcing persons play key roles in policy implementation.

Congress, in response to single-issue lobbying dramatized by the media, has legislated controls and regulations over every aspect of the materials cycle as follows:

Mining:	Mine Health and Safety Act of 1977 Surface Mining Control and Reclamation Act of 1977 Land Policy and Management Act of 1976
Refining:	Clean Air Act of 1970 (amended 1977)
Processing:	Water Pollution Control Act of 1972 (amended 1977) National Environmental Policy Act of 1975
Design:	Design Liability actions
Manufacture:	Occupational Health and Safety Act of 1970 National Energy Act of 1978
Assembly:	Power Plant and Industrial Fuel Use Act of 1978

Walter R. Hibbard, Jr., is University Distinguished Professor of Engineering at Virginia Polytechnic Institute and State University.

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Use:	Consumer Product Safety Act of 1973
Recycling:	Resource Recovery Act of 1970 Resource Conservation and Recovery Act of 1976 Energy Tax Act of 1978
Disposal:	Solid Waste Disposal Act of 1965 Toxic Substances Control Act of 1976

Serious concern for the depressed condition of the materials industry in the United States has been expressed in numerous reports; several major reports are listed in the Appendix at the end of this article.

The regulatory laws have led to the proliferation of regulations by avid bureaucrats. But concerns for the conserving of materials have led merely to studies and reports with no policy implementation. As a result, regulations are shaping the destiny of the materials industry in the United States economy.

Regulations and their enforcement have substantially affected energy aspects of the materials cycle from production, to fabrication, to use, and finally to disposal. For example, regulations have caused severely inflated costs. They have added nearly $5 billion to the Federal budget of 55 agencies whose 126,000 regulators force the expenditure of $102 billion per year by industry for compliance and information. Compliance with pollution regulation requires expenditures of $47.6 billion per year, of which air pollution accounts for $13.1 billion per year. More positively, however, benefits arising from air-pollution control are estimated to have saved $22 billion in costs of health care, property damage and harm to fish and wildlife.

Regulation also directly affects exploration and supply; it has halted the expansion of United States basic-materials capability and led to increasing imports; it has had an impact on the recycling process; it has generated substitution incentives by limiting access to sources of scarce materials; and it has imposed conservation measures and dictated energy use.

In addition, there is an enforcer-violator type of situation where the enforcer changes the rules periodically and serves as both judge and jury in cases of alleged infraction. This situation subsequently leads to an adversary relationship that generates an environment of suspicion and distrust, and deeply erodes the possibilities for cooperation between industry and government.

Regulation now anticipates and legislates new technology before it exists. Scrubbers and catalytic afterburners are examples. Nearly one-third of United States industrial research and development (R&D) is estimated to be involved in some way in reducing the costs imposed by regulation.

As a result, we are now entering an age of little new-materials R&D of a long-term innovative sort, particularly in the area of new processing discoveries.

As an example, the passenger automobile is regulated to be safer, less polluting, more energy-efficient and more durable within a certain time limit As a result, R&D in the auto industry is concentrating on these factors (which are not mutually self-consistent) and this has caused United States companies to manufacture overseas with foreign technology, and to import into the United States.

The basic materials industries are also trying to modify their existing facilities to satisfy regulatory guidelines while expanding their operations overseas to produce basic materials and, sometimes, manufacture products and components for importation into the United States.

In general, then, R&D has been forced to focus on short-term development of solutions to the problems created by profit squeeze, regulation, and energy use. Even university research has responded to funding directed at environmental protection and energy conservation. And as a result, long-range research has deteriorated.

Science and technology policy probably cannot rectify this situation, since existing antimaterials policy stems primarily from grass-roots, single-issue laws. Congress is likely to change these laws only under pressure, and voters will press for change only when their quality of life seems threatened.

Materials Issues

Materials issues relate to a variety of needs in our society. We must provide an adequate supply of basic materials by reducing imports or assuring their availability. We must increase domestic productivity. We must minimize negative environmental impacts and energy costs, and we must conserve and recycle materials. At the same time that we seek to fulfill these needs, we must respond to government regulations that often seem at cross purposes with economic goals.

United States basic-materials industries are expanding overseas where there are more incentives for productivity and there is greater government cooperation. Aluminum imports have increased by more than 100 percent since 1975, and these are largely used by United States industry. Concurrently, imports of refined copper have increased by 242 percent, and iron and steel by 44 percent. Imports of raw and processed materials have increased to $20 billion per year. The net value of imports relative to exports has grown from approximately zero to $6 billion per year.

Although there is a world surplus of the aforementioned materials, user industries seek lowest prices with little concern for an ailing domestic minerals industry. They argue that domestic resources are conserved and pollution is avoided by not mining and refining those materials in the United States. However, this policy has seriously affected employment in the industry. Between 1975 and 1978, unemployment increased by 1,000 workers in the aluminum industry, by 4,500 in the copper industry, and by 55,000 in the iron and steel industry.

In the basic materials, certain overseas locations offer comparative advantages relative to those of the United States. There are richer ores, cheaper energy, lower labor costs and, in some instances, tax advantages and ready capital access. In general, pollution-control regulations are less stringent and safety regulations are more compatible with standards of industrial procedures. In fact, except for copper, many of the overseas resources are owned or operated by United States corporations that are importing into the United States market as well as into Europe and Japan. Overseas processing is expanding into the primary processing of shapes at the source. The prospect of a major imbalance in the domestic capacity of metals-producing industries (relative to demand) over the next decade appears almost certain, because existing United States facilities may become economically unprofitable.

In addition, American companies are gradually stepping up overseas manufacture of consumer goods and components for machinery and electronics using foreign materials and then importing them into domestic markets. This suggests that American goods are no longer cost-competitive.

An even higher percentage of basic materials being imported both in their primary state and in consumer products implies both positive and negative effects. The resulting manufacturing costs in the United States are lower because of richer ores, lower labor costs, and regulations that are less restrictive and less costly to comply with. Less pollution is created at home and energy resources are conserved. On the negative side, however, domestic employment in these industries and their supporting services will decrease. Adverse pressure on the balance of payments will continue and uncertainties about supply reliability will increase.

By contrast, Germany and Japan thrive on imported materials. But in those countries industry has a more congenial relationship with government, the legislature, the media, and thus the people. Moreover, these governments assume a more direct role in assuring supplies and maintaining balances.

Energy and Environment

Materials production is energy-intensive, and necessitates major programs of energy conservation in its industries. Because of the cost and quantities of energy used, materials fabricators and product manufacturers are designing products with materials and processes that reduce energy consumption while increasing productivity. For example, an energy-conserving set of processing, forming, and fabrication operations would involve lighter weight and more unitized construction (to reduce energy in joining and assembly).

Moreover, the development of suitable materials for energy-generating and energy-conversion systems is critical in several cases, such as coal conversion and solar-electric power, and may be the rate-limiting factor in their commercial feasibility. Such energy-conserving measures, however, often confront environmental restrictions that frequently call for an increase rather than a reduction in energy consumption. Thus, seeking to achieve both energy conservation and compliance with environmental regulations poses a considerable challenge for materials R&D.

Recycling

Materials recycling is encouraged by several Federal acts but is limited in practice to those situations where a cost advantage exists. Manufacturers such as Western Electric, General Motors and General Electric are recycling significant amounts of materials internally. More designs simplifying recycling are needed and may emerge where profitable.

Recycling to minimize energy requirements and to minimize imports can be cost-effective, and regulations may require it. The Resource Conservation and Recovery Act of 1976 requires that all waste materials be stored in a sanitary land fill and that open dumping cease and its effects be repaired. This law provides incentives for the recycling of materials, particularly municipal waste. The technology is available to accomplish this objective, but institutional, capital-formation, and waste-collection problems exist. Again, technology leading to improved design of recycling may stimulate this effort. Ease of identification of recyclable materials is essential, as exemplified by the all-aluminum beverage can and the lead storage battery. However, changing the trends of our throwaway packaging is unlikely. Nonreturnable containers with convenience features will probably persist as we continue to generate solid waste. Technology is needed to sort the waste so that it can be recycled in its most useful form. The concept of a waste dump as a man-made resource is intriguing. Most municipal waste may be a useful source of copper, gold, silver and other materials, once the burnables are consumed and the iron, aluminum and glass is removed. Such an approach would be worthy of policy consideration. In the case of hazardous materials which cannot be recycled, intensive study is required to evaluate risks and to find how to neutralize or contain them in a rational, acceptable system.

Conservation

Although at present there may not be a world-wide shortage of materials, it is anticipated that such shortages may develop with respect to selected, critical materials since new supply is not keeping pace with demand. Imports of materials by American firms indicate that price is an important factor, for overseas production costs are generally lower than domestic costs. In addition to cost as a primary motivating factor is conservation. Weight reduction and fabricability are important where energy is a factor. Experience with attempts at fuel conservation has shown that conservation will not be effective unless there are shortages and associated crises.

Conservation of manufacturing materials can result from the use of more durable materials. If, for example, American-made automobiles lasted as long as European-made ones, fewer materials would be required to provide the same functional service. Corrosion has been estimated to cost the American consumer $70 billion annually. In general, technology is available to minimize corrosion, but at a cost that the consumer is apparently not willing to pay. Design for maintenance, servicing and repair has given way to design for replaceable components. There is an urgent need for greater awareness of the cost-effectiveness of maintenance and repair, particularly in view of the impending shortages of some materials and their associated cost increases. New technology is needed to stress designs that incorporate functional materials that do not corrode or wear out and that permit protection and necessary servicing by the owner or maintenance man.

Substitution and Supply

A national policy on materials substitution is lacking. It is clear, and it has been amply demonstrated in our economy, that materials substitution can lead to advantages such as improved fabricability, lower weight, ease of recycling, improved joining and assembly, improved corrosion resistance, improved wear resistance, improved responsiveness of availability to abundance or scarcity, and lower cost. The supply of materials is subject to political factors both here and abroad, and to costs, scarcity, regulation and public opinion. Thus, there is an urgent need for a system that can give early warning of impending shortages in the supply of materials, and that can provide for an orderly transition to substitutes without economic dislocation.

Research and Development

Recent studies indicate that less than one-third of total R&D expenditures is devoted to materials. Current materials R&D is mostly concerned with regulation, antipollution measures, health, safety, energy conservation, and so forth. Little effort is dedicated to the development of new materials, or to durability, availability and the other concerns expressed in this article. As a result, productivity is not receiving its historic R&D impetus.

The most exciting R&D opportunities lie in treating the entire materials cycle as a system. For each stage, a materials objective might be devised as follows: Production should minimize pollution and energy use. Fabrication should be designed for unitized construction. Product assembly should be designed for disassembly and sorting to facilitate recycling. Maintenance may be reduced by designing for durability. (Note that the question of new materials is not the issue. Considerations relating to materials processing and assembly are predominant.)

To achieve these goals, materials R&D must re-emerge under the stimulus of technical opportunity as it did twenty years ago. Science and technology policy can affect this regeneration.

Summary

In summary, key general issues related to materials are:

- Lagging innovation and productivity.
- R&D emphasis on short-term incremental improvements.
- Need for improved cooperation between government and industry.

More specifically, materials issues relate to these needs: (1) alleviation of increasing energy and environmental costs; (2) development of new materials to commercialize new energy processes; (3) more thorough assessment of the risks of hazardous materials and how to contain or neutralize them; (4) conservation of materials by design, substitution and recycling, and provision of alternatives to imports; (5) early identification of supply and availability problems; and (6) recognition of political factors in supply, overseas shifts, regulations, and public opinion.

In light of this overview of issues in the materials area, let me pose several questions on the relationship of science and technology policy and the materials industry:

1. Do we need a national materials policy?
2. How can long-range research and innovation be restimulated?
3. Would the materials industry thrive under a Department of Natural Resources?
4. Should regulations be reviewed in advance to evaluate the science and technology upon which they are based?
5. Is a materials impact study needed with each new regulation or ruling?
6. Is science and technology policy an effective antidote for other national policies that are draining the materials capability of the United States?
7. How can materials issues best be integrated into the current cabinet-level studies on nonfuel minerals policy and on innovation?
8. Is there a recognizable science and technology policy relating to materials?

These questions have no simple answers. They do, however, indicate the range of priorities for policy development and evaluation over the next several years. Because of the complexity of the issues, the magnitude of such an effort is awesome. But is is essential to the overall health of our economy and quality of life.

Appendix: List of Recent Articles Focusing on Depressed Condition of Materials in the United States

1. Materials Policy Commission Report of 1952.
2. National Materials Policy Act of 1970.
3. Mining and Minerals Policy Act of 1970.
4. NAS/NRC/NAE Report of 1972: Elements of National Materials Policy.
5. NAS/NRC/NAE Report of 1973: Man, Materials and the Environment.
6. NCMP Report of 1973: Materials Needs and the Environment, Today and Tomorrow.
7. NAS Report of 1973: Materials & Man's Needs. Materials Science and Engineering (COSMAT).
8. Report of National Commission on Supplies and Shortages of 1977.
9. Five Henniker Conferences on National Materials Policy.
10. OTA, GAO, CRS studies of materials.
11. Several hearings before Congressional Committees on National Materials Policy Bills.

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

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OFFICE OF THE VICE PRESIDENT

January 26, 1981

Dr. Jordan J. Baruch
Assistant Secretary for Productivity,
Technology and Innovation
United States Department of Commerce
Washington, D. C. 20230

Dear Dr. Baruch:

This is in response to your letter of January 9, 1981 to John Geron of my staff, advising of a Workshop on Materials and Minerals Policy to be held on February 9-10, 1981.

The aerospace industry is particularly aware of and concerned with the current problems of materials shortages, as well as the costs of such materials, when available. Accordingly, we believe the Workshop is timely and should result in actions to correct the materials situation.

We have informed our membership of the Workshop and are advised that the aerospace industry will be represented.

Because of the importance of this matter, please feel free to call upon us for any assistance you may deem appropriate.

Very truly yours,

Karl G. Harr, Jr.

MACKAY SCHOOL OF MINES
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DR JOHN B WACHTMAN, JR
NATIONAL BUREAU OF STANDARDS
MATERIALS BUILDING B308
WASHINGTON DC 20234

DEAR DR WACHTMAN, THANK YOU FOR YOUR INVITATION TO PROVIDE A STATEMENT FOR THE WORKSHOP ON FEBRUARY 9TH AND 10TH. HOWEVER, AT THIS STAGE IN THE PROCESS OF DEFINING THE MATERIAL NEEDS OF THE AERO SPACE INDUSTRY I AM AFRAID THAT I HAVE LITTLE TO CONTRIBUTE. MY EXPERTISE LIES AT THE SUPPLY END OF MATERIALS-THE MINERAL RESOURCES THAT ULTIMATELY ARE USED BY AERO SPACE OR OTHER INDUSTRY. I HAVE VIRTUALLY NO KNOWLEDGE OF WHAT MATERIALS ARE USED BY THE AERO SPACE INDUSTRY. FROM A SUPPLY VIEWPOINT, THE CHOICE OF COBALT AND TITANIUM FOR CLOSE EXAMINATION WAS A GOOD ONE, THE FORMER RESPRESENTS MINERAL COMMODITIES IN WHICH THE UNITED STATES IS SERIOUSLY DEFICIENT, WHILE THE LATTER REPRESENTS THOSE THAT WE HAVE IN ABUNDANCE BUT FOR WHICH WE MAY NOT HAVE SUFFICIENT PRODUCTION CAPACITY. I TRUST THE INVESTIGATION WILL START AT THE VERY BEGINNING OF MATERIALS SUPPLY, WITH IDENTIFICATION OF ALL THE MINERAL COMMODITIES REQUIRED BY THE AERO SPACE INDUSTRY-WHICH PROBABLY WILL INCLUDE THE ENTIRE SPECTRUM OF MINERALS.

WHEN THE EXAMINATION REACHES THE STAGE OF CONSIDERATION OF MINERAL RAW MATERIALS SUPPLY, I WILL BE HAPPY TO WORK WITH YOU IN ANY WAY I CAN.

YOURS TRULY

ARTHUR BAKER, 3RD, DEAN

17:39 EST

MGMCOMP MGM

FIBER MATERIALS, INC.
for materials ingenuity

Arlington Virginia

TO: Dr. Bruce Steiner, National Bureau of Standards

FROM: E.N. Hegge, Executive Vice President

DATE: 6 February 1981

SUBJ: Workshop on Critical Materials Needs in the Aerospace Industry

The agenda for the "Workshop on Critical Materials Needs in the Aerospace Industry" appears to address only scientific and engineering aspects of the problem. The economic aspect is of equal importance and should also be considered. The following types of incentives to encourage provate entities to actively participate would be in accord with our free enterprise system and in addition would more clearly define the role of the U.S. Government and reduce its fiscal committments.

1. For critical materials, consider paying the private entity the going interest rate on his purchase and stockpiling of critical materials in return for an equity position when sold. (For example: Banks are beginning to let home mortgages at reduced rates in return for an equity position when property is sold.)

2. Impose duties on imports of selected critical materials to encourage development of domestic sources.

3. Impose taxes on products using selected critical materials to encourage development of substitute materials.

ENH:clm

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Reno, Nevada 89509

February 1, 1981

Dr. John B. Wachtman Jr.,
National Bureau of Standards,
Materials Building B 308,
Washington, D.C. , 20234

Dear Dr. Wachtman:

I recieved information from Senator Howard Cannon on January 31, 1981, regarding the Commerce Department study and workshop scheduled for Feb. 9, 1981 in Washington on critical minerals. With such short notice I hardly think this letter input will be recieved by the deadline set for February 5, 1981.

I believe we should apply Einsteins theory of relativity to every phase of american government and I use it as a basis of my comments as follows;

1. I feel that this great country needs sufficient stockpiles of the critical minerals such as Cobalt, Titanium and other new critical minerals, now and the future.

2. Current problems with these and other minerals are; (a) The locking up in declared wilderness areas by the Bureau of Land Management, and (b) the restrictive regulations by the Bureau of Land Management, which prohibits and discourages prospectors and miners to spend their money and expertise in finding these and other minerals to safeguard this country's freedom which will in turn protect that freedom.

3. Suggestion for corrective action would be to review the Federal Land Policy and Management Act of 1976, and especially the recent (1980) regulations subpart 3809 - promulgated by the Bureau of Land Management.

Sincerely,

Lee S. Smith
c/c to Senator Paul Laxalt
c/c to Secretary James G. Watt, Interior Department

Allied Chemical

Corporate Technology
P.O. Box 1021R
Morristown, New Jersey 07960

Phone: (201) 455-2511

February 3, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B 308
Washington, D. C. 20234

Dear Dr. Wachtman:

Re: Workshop on Critical Materials

Following up our several phone conversations, enclosed is the brief presentation our Mr. Stanley Fass will be prepared to make on February 9. The final list of attendees from Allied Chemical is

Stanley Fass
Dr. Charles Hays
Michael Skrypa

Yours truly,

M J Skrypa

M. J. Skrypa
Product Manager
Consolidated Metal Products

MJS/amw
enc.

January 28, 1981

COMAT PRESENTATION

Stanley Fass

I would like to thank you for inviting Allied Chemical to participate in this workshop on critical materials. It is a distinct pleasure for me to present the innovative developments that are taking place in the Consolidated Metal Products Department of Allied Chemical Corporation in Rapid Solidification Technology and new alloy development. We believe that our efforts represent a major breakthrough in Powder Metallurgy and could
Slide 1 have a significant impact on the critical material shortage.

In the last several years great strides have been made in developing technology, such as Rapid Solidification, that enables us to make high quality powder for aerospace applications. Thus, one will be able to conserve critical materials by consolidating powder to near-net shape and minimize the machining wastes. At Allied Chemical, work is going on that may enable us not only to conserve critical materials but offer a performance effective substitute for these alloys.

Allied Chemical has extended the RST processes developed for Metglas® amorphous alloy ribbon and has produced metal powders of alloys with microstructures that could not be made by conventional casting technology. These alloys are nickel
Slide 2 and iron-based, containing molybdenum and boron but generally do not contain any chromium, cobalt, or tungsten. We believe that some of these alloys will be able to replace cobalt and other strategic metals in certain application areas without

loss of performance and perhaps even improved performance. Although the applications that I will be discussing today are not directly related to aerospace systems, they nevertheless would have an impact in this area.

We have identified a number of application areas that have been chosen for initial field testing and market entry. These

Slide 3 are shown on the next slide. Metal cutting tools, of course, are used extensively in the aerospace industry. Approximately 10% of the cutting tools sold in the U. S. serve that sector. HOT EXTRUSION DIES made from our alloys are being tested in the aluminum and copper industry. Aluminum extrusions play an important part in the manufacture of air frames and surfaces. Plasma spray powders made from Allied Chemical alloys are being evaluated for us as a possible replacement of cobalt-containing superalloy hardfacing powders. Recently, interest has been generated in considering the use of coatings in aerospace applications such as coating turbine blades. Our alloys are also being tested for wear applications. One area where this might impact on the aerospace industry is its use in helicopter gears and bearings. The objective in that case would be to increase performance over conventional gear steels.

Slide 4 The next slide shows some of the typical materials used in the applications we just reviewed. One can see that cobalt, tungsten and chromium are all necessary components of these alloys. Approximately 12% of the cobalt consumption in the U. S. is used in metalwork cutting tools. Similarly,over 50% of tungsten is used in these application areas. Success of our alloys may be able to reduce the consumption of the critical materials.

I would like to spend several moments reviewing some of the data that we have obtained to date that makes us very enthusiastic about our process and alloy systems. The initial cutting tool data was developed for us at Metcut Research, a consultant, in Cincinnati. They recommended that we use M-42, a premium grade HSS containing 8% cobalt, as a standard. They used optimum tool geometry for the M-42 and our material was ground to the same geometry; no attempt was made to optimize it.

Slide 5 The next slide shows the turning test results. As one could see, the M-42 performed optimally in the range of 75-100 SFPM. Allied Chemical's CMP alloys 7007 and 3065 showed the same tool life at approximately twice the cutting speed. Thus, significant increases in productivity or tool life are indicated for our alloys.

Slide 6 The next slide shows the results of the interrupted cut, namely, face-milling tests. The data again shows that the Allied Chemical CMP alloys out-performed the M-42 HSS by over 100% improvement in tool life, at the same cutting speed, or the ability to significantly increase cutting speed and thus productivity while maintaining an acceptable tool life. We realize that these data are still preliminary. However, the potential we have shown to significantly improve cutting tools without the use of strategic materials is enthusiastically supported by a leading HSS cutting tool manufacturer with whom we are embarking on a mutual development program.

CMP alloy 7025 is another alloy that has shown great

Slide 7 promise. The next slide shows the properties of CMP 7025 compared with Stellite 6. The excellent retention of high temperature hardness and the abrasion wear resistance make this alloy look attractive for high temperature applications where wear and abrasion resistance are important properties. Therefore, we embarked on a program of field testing this alloy in copper and aluminum hot extrusion and aluminum die casting. This program is still underway but the preliminary results look very promising. The next slide presents some of the comments

Slide 8 that the users have stated about CMP 7025. In a report to us, a major aluminum company stated that the CMP alloy "performed very similar to carbide but much better than Hot Work Steel". The user anticipates being able to use our alloy for complex profile dies where carbide proves to be too brittle. In another field test copper alloys were extruded through our die insert, with billet temperatures of 800 to over 900°C. The copper company reported obtaining over twice the die life with our alloy compared to the cobalt-based die they presently use.

At Woodstock Die Casting, which is a subsidiary of Allied Chemical, field testing is still underway. Over 20,000 castings on our die have taken place and the product quality has remained constant and the die has shown no wear. Woodstock also reported that the die gave excellent release even when subject to extremes in temperature variations and molten metal flow. These field tests are continuing and we expect that in the near future several alloys will have been qualified for commercial use.

Our technical people believe that the success of the CMP alloys is based largely on our unique Rapid Solidification Process. Our process is different, and we think better, than conventional PM processes and even other RST processes. For

Slide 9 example, CMP powders have a very consistent and homogeneous microstructure. Thus, each powder particle is essentially identical to each other and this is true because each particle is cooled unidirectionally at over 1 million °C. In atomization processes one obtains aggregates of large crystallites or powders that range from amorphous, to cellular to dendritic structures. The presence and location of ultra-fine grain intermetallic compounds in consolidated CMP materials result in greatly improved chemical and mechanical properties. Our RST process also provides excellent yields without requiring large amounts of recycle or powder classification. The flowability and tap density are good and the process is scalable. For example, Allied has a Metglas casting unit that can process 1 ton/hr of material.

In summary, we believe that Allied Chemical has developed a unique, economic RST process and excellent new alloy systems that could have a significant impact on both improved product performance and a reduction in the use of strategic materials. We have described some of the areas that we are actively engaged in. I would like to show, in conclusion, some areas that we
Slide 10 believe we could make significant contributions. In some of these areas we have already begun discussions with government agencies. We solicit the comments and interest of both the government and private industry to pursue these possible applications as well as any other areas that may be appropriate.

Thank you very much.

SF/amw
1/28/81

ALLIED CHEMICAL CORPORATION

CONSOLIDATED METAL PRODUCTS DEPT.
(CMP)

NEW DEVELOPMENTS IN METALLURGY AT ALLIED CHEMICAL

- UNIQUE ALLOY SYSTEMS
  - IRON & NICKEL BASED
  - CONTAINS MOLYBDENUM & BORON
  - LITTLE OR NO COBALT, CHROMIUM OR TUNGSTEN
- RAPID SOLIDIFICATION TECHNOLOGY

INITIAL APPLICATION AREAS

- METAL CUTTING TOOLS
- HOT WORK TOOLS
- PLASMA SPRAY HARDFACING POWDERS
- WEAR RESISTANCE PARTS

SOME OF THE ALLOYS THAT

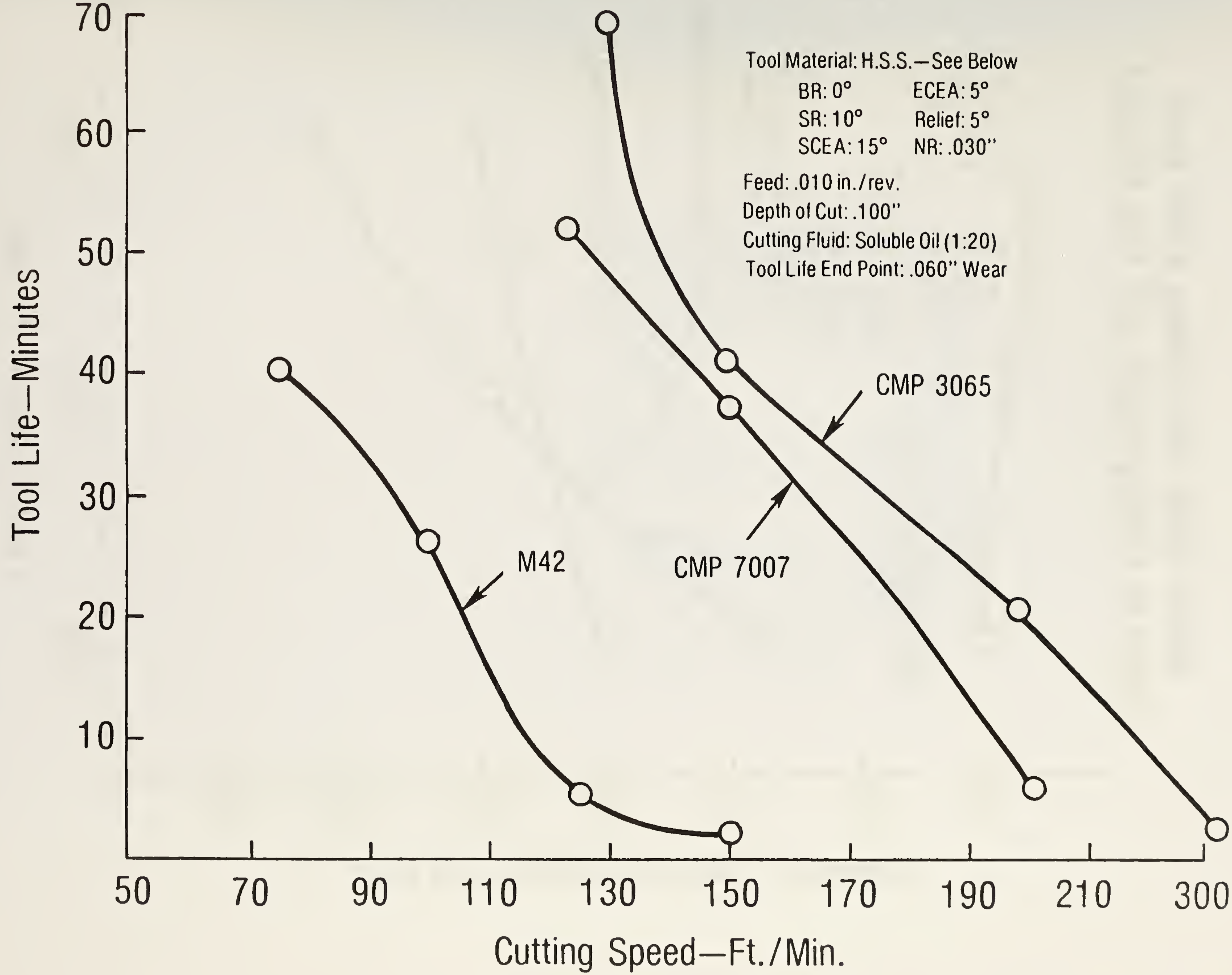
CMP ALLOYS ARE BEING EVALUATED IN COMPARISON

	Cr	V	W	Mo	Co	Fe	Ni
M-42	3.8	1.2	1.5	9.5	8.0	Bal	--
T-15	4.0	5.0	12.0	---	5.0	Bal	--
WC	---	---	85-94	---	15-6	---	--
Stellite*6	29	---	2	5.5	Bal	3	3

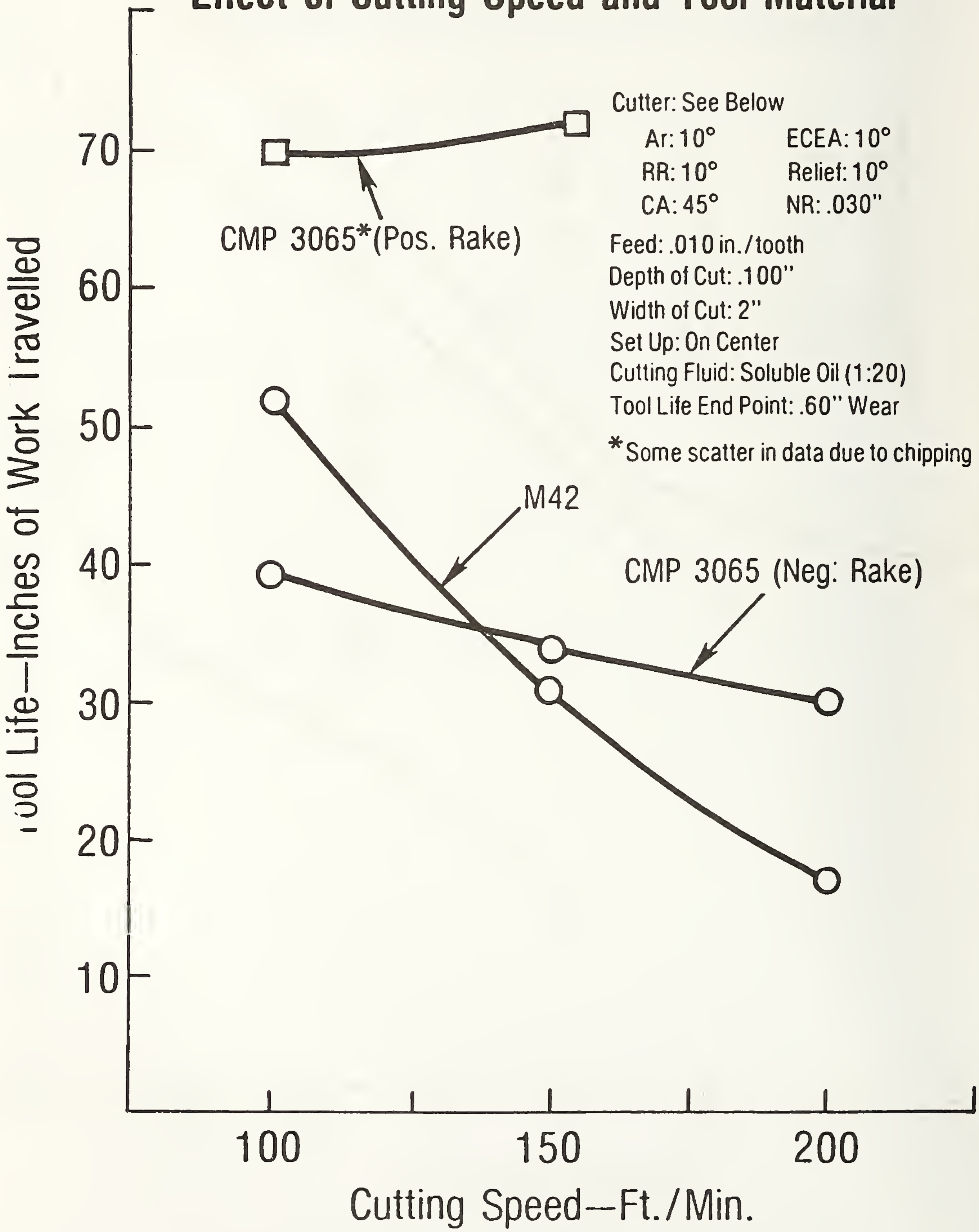
*Registered Trademark of Cabot Corp.

SF
1/29/81

Turning 4340 Steel, Quenched and Tempered 302 BHN
Effect of Cutting Speed and Tool Material



Single Tooth Face Milling 4340 Steel
Effect of Cutting Speed and Tool Material



PHYSICAL PROPERTY COMPARISON

STELLITE 6* VS. ALLIED CHEMICAL CMP 7025

Property	Wrought Stellite 6	Allied Chemical CMP 7025
Hardness, Rockwell C		
Room Temp.	45	50
@ 1000 °F	34	50
@ 1200 °F	31	48
@ 1400 °F	26	31
Elongation	0-1%	4-6%
Modulus of Elasticity	28.0 M psi	31.0 M psi
Charpy V-Notched Impact St.	4 ft-lb	3.5 ft-lb
Yield Strength @ 0.2% Offset	92 ksi	205 ksi
Ultimate Tensile Strength	148 ksi	265 ksi
Abrasive Wear, CM^3/Rev	32.5	34

*Registered Trademark of Cabot Corp.

PRELIMINARY FIELD TESTING RESULTS

LOOK VERY PROMISING

ALUMINUM HOT EXTRUSION - CMP ALLOY

"PERFORMED VERY SIMILAR TO CARBIDE BUT MUCH BETTER THAN HOTWORK STEEL"

COPPER HOT EXTRUSION - CMP DIE OUT PERFORMED COBALT-BASED DIE BY OVER TWO TO ONE

ALUMINUM DIE CASTING - CMP DIE GIVES EXCELLENT RELEASE EVEN WHEN SUBJECT TO EXTREMES IN TEMPERATURE VARIATIONS AND MOLTEN METAL FLOW

ALLIED CHEMICAL'S RST PROCESS

- UNIFORM & HOMOGENEOUS MICROSTRUCTURE
- GOOD POWDER PROPERTIES I.E.
  FLOWABILITY, TAP DENSITY
- EXCELLENT YIELD
- COOLING RATE OF OVER 10^6 °C/SEC
- PROCESS SCALABILITY

POSSIBLE FUTURE APPLICATIONS

GAS TURBINE & DISKS

AIRCRAFT STRUCTURAL COMPONENTS

PENETRATOR & ARMOR

HELICOPTER GEARS & BEARINGS

MCDONNELL AIRCRAFT COMPANY

Box 516, Saint Louis, Missouri 63166 (314) 232-0232

02 February 1981
WLH764-0281-1

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B308
Washington, D.C. 20234

Enclosure: (1) "Definition of Aerospace Industry Materials Needs"

Gentlemen:

This letter and Enclosure (1) is in response to a letter from Mr. Jordan J. Baruch dated 09 January 1981 to R. J. Alagna, Staff-Vice President Material, McDonnell-Douglas Corp. Due to the short time available for response, Mr. Alagna assigned the response to the McDonnell Aircraft Co. component (also located in St. Louis) for our corporate response.

It is our intention to have two representatives at the 9-10 February Workshop. I will attend representing the McDonnell Aircraft Co. and Mr. Roger Maples will represent the Douglas Aircraft Co.

In support of your request for prior input by 05 February 1981, the following comments and enclosure is provided. It should be recognized that the timing for our response does not permit MDC the opportunity to prepare an in-depth written evaluation of the <u>many</u> aspects and questions contained in the Federal Register listing, but based on the telecon with Mr. Goodman, it is believed that this response will be sufficient for your needs. In further support of your invitation, the MDC representatives at the Workshop will be able to expand on any of the specific subjects.

It is believed that the opinions provided herein are relative to all of the MDC components, both military and commercial, and represent a fair assessment of our corporate position. The supplemental charts and graphs of Enclosure (1) report were prepared by McDonnell Aircraft Co. for a prior response to a Government task force in July 1980. The data is representative of the past, current and anticipated near-term market conditions. Further, many of the recommendations contained therein should be very pertinent to your study.

The supplemental "Estimated Usage" values for titanium, aluminum and steel are provided to give you a perspective of material volume usage by MDC.

MCDONNELL DOUGLAS CORPORATION

02 February 1981
WLH764-0281-1

Summary Conclusions:

The on-going surveillance by various MDC task forces in Engineering, Procurement and Manufacturing, as well as other key personnel, regarding MDC needs versus supply availability indicates no immediate shortages of minerals or materials adversely impacting contractual deliveries, nor would a reasonable increase in aerospace requirements put MDC in a position beyond our control. However, there are several potential production constricting supply concerns resulting from mineral/material shortages and/or capacity constraints in the event of a major surge in aerospace activity. Based on the intent of your investigation to identify and recommend solutions to reduce/eliminate such potential constraints, the following areas are recommended for consideration.

Our single greatest concern (and continual surveillance) is titanium product leadtime. Other potential concerns are hard aluminum alloy capacity, raw materials such as cobalt, chromium and molybdenum bearing steels, particularly as they apply to machine tools. One aspect of the study addresses material conservation. In our opinion, one of the most constructive would be the establishment of a large 200,000 Ton forging press.

Salient issues relating to each specific concern are delineated in Enclosure (1). The concerns defined in Enclosure (1) inevitably point out that the single most significant aerospace material supply concern is capacity. The suppliers are specialized in products unique to the aerospace industry, i.e. titanium, precipitation hardened stainless steels, and hard alloy aluminum. The resolution to the capacity problems is to encourage expansion of facilities by:

(1) Enacting long-term military procurement policies to enable requirements to be determined on an accurate and long-term basis;

(2) Institute favorable financial policies to encourage facilities expansion, such as favorable depreciation rates, investment credits and accessible capital financing loans.

Further, investigation of potential material shortages should include:

(1) Improved procedure in the stockpiling of critical materials like titanium sponge;

(2) Improved procedures in the stockpiling of foreign dependent materials like cobalt, chromium, platnum and alumina, with a method for their release in a timely manner at times of peak demand;

02 February 1981
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(3) Requiring recycling of titanium, cobalt, chromium and molybdenum bearing scrap back to domestic producers and discouraging export of this scrap.

I hope you find our opinions of value and wish you success in the complex and broad spectrum of your assignment.

Yours truly,

MCDONNELL DOUGLAS CORPORATION

William L. Hodge

William L. Hodge
Branch Manager-Purchasing
McDonnell Aircraft Co.

WLH:jp

MCDONNELL-DOUGLAS CORPORATION

Response

To

DEPARTMENT OF COMMERCE
Office of the Secretary

"DEFINITION OF AEROSPACE INDUSTRY MATERIALS NEEDS"

"Invitation for Expression of Public and Private Sector Materials Needs and Recommendation for Federal action."

Enclosure (1) to
WLH764-0281-1
02 February 1981

General Statement:

It is MDC's position that there are no current problems that are beyond our control and that in a fairly wide band of aerospace activity none are anticipated. Only in a significant resurgence of military and/or commercial production rates could the following areas discussed potentially create concerns, or if in the event some few strategic materials become non-existent, serious ramifications occur.

In summary, our opinions conclude that while there are some strategic minerals and materials that under extreme conditions could impact our corporation, the majority of potential concerns center around conversion capacity of these materials with the resultant lengthening of leadtimes and high prices. This combination of problems could affect our corporation and the aerospace industry in many ways. As such, the emphasis of this position paper is directed to the potential problems of conversion capacities. The major solution to these potential capacity conversion problems, both in terms of national security and economics, points toward encouragement by the U.S. Government to provide financial incentives for plant and equipment expansion by the private sector.

Specific Review:

MDC is constantly reviewing/monitoring all aspects of the many factors that could potentially impact our business, not the least of which are potential supply problems. Task forces in Engineering, Procurement and Manufacturing along with other key personnel are constantly assessing the impact on product lines of increasing leadtimes, limited quantities and alternates available. Changes in design, materials, processes and machine tool usage are made on the basis of these assessments. The results are as follows:

1. We foresee little likelihood of a potential problem in any non-metallic area. The usage of composites, for example, while having expanding applications, will not, in our opinion, be a problem in the future. It should be remembered that aerospace products, by their very nature, are extremely complex, consisting of literally millions of different components, each of which has some relative potential to create shortages. If infinite details were listed, such things as resistors, capacitors, integrated circuits, printed circuit boards, etc., might fall into consideration, but, in our opinion, such items should not be the focus of this study.

2. Steel is used in limited applications on aircraft due to its high density, but is widely used for tooling requirements. Much of the steel used by MDC both for airframe and tooling requires cobalt or chromium and molybdenus alloying elements. It should be recognized that as alloying elements, the actual quantities of these materials is very small. There is a recognized shortage of these materials due to our reliance on foreign imports from countries with unstable political situations, as well as a shortage of vacuum furnace capacity.

2. (Continued)

However, since the alloying elements required for airframe and tooling applications is small compared to usage in industry as a whole, this problem is much broader than just an aerospace problem. Because of this, the shortages of cobalt, chromium and molybdenum has impacted MDC to a lesser degree than other industries, it is still of major concern for aircraft engine manufacturers and specialized sub-tier suppliers of such commodities as aircraft generators and cutting tools. Recommended solutions include:

(a) Stockpiling of cobalt, chromium and molybdenum, but with at least a portion of each <u>accessible</u> at times other than that of a national emergency.

(b) Recycling of steel scrap bearing these alloys back to <u>domestic</u> producers.

(c) Encourage additional furnace capacity by long-term military procurement policy and favorable financial policies.

3. <u>Aluminum</u> is produced from bauxite and alumina, which is 93% imported. In the absence of an OPEC-type cartel, there should be no raw material supply problem in the foreseeable future. Smelting capacity is no problem since the aerospace industry consumes only a very small quantity (5%) of all the aluminum produced. The potential constraining factor is most likely <u>hard alloy plate</u> and, in particular, heat treating facilities. MDC is well aware of the $200 Million Alcoa expansion program, which will certainly reduce the potential concern, but in the event of a major change in aerospace requirements may still represent a constraint. Resolution of the potential shortage of hard alloy plate capacity might include:

(a) Long-term military procurement commitments;

(b) Favorable financial policies.

Attention should also be given to a review of the stockpiling policies of bauxite and/or alumina due to our current overwhelming dependence on foreign imports. Reference supplemental data for additional details.

4. Leadtimes for <u>titanium mill products</u> currently vary from 45 weeks to 85 weeks. There is no shortage of the raw materials rutile, illmenite, chlorine. The potential constraints are in the secondary <u>processing</u> operation of sponge production and conversion. Only three domestic sources manufacture sponge with the balance supplied by foreign sources, primarily Japan. Although domestic sponge production has increased 25% since 1979, and will increase another 16% by 1982, the industry still must depend on <u>foreign sponge</u> supply to meet demand. Resolution of this potential might include:

4. (Continued)

   (a) Opening up of the U.S. stockpile at peaks of high demand combined with a well-structured replenishment program.

   (b) Military procurement policies should be formulated to provide long-term commitments that would justify additional expansion.

   (c) Encourage capital investment in titanium processing facilities through favorable financial policies.

   Reference supplemental data for additional details.

5. Large press capacity is a potential area of concern under certain circumstances, but an even bigger consideration in this area should be the potential for conservation of materials based on the fabrication of a big (200,000 Ton) press. Specifically, it is probable that under less than a major increase in aerospace requirements, the current large press capacity (50,000 Ton) available today is probably sufficient to meet aerospace needs. This position is strongly held by the major U.S. forging press companies. However, it is our opinion that significant savings on material (i.e., titanium, aluminum and steel) as well as machine time, could be achieved with a big press in the 200,000 Ton range allowing more refined forgings and, therefore, smaller quantities of forging stock and less machine time and off-fall. Preliminary analysis indicates that the estimated cost of such a press and associated support facilities, would cost approximately $200 Million in 1980 dollars, which could be fully offset by the dollars saved in reduced material and machine time in one, or the most two, new military aircraft programs, while potentially providing product improvement in these aircraft by allowing fly-weight reductions.

   The side benefits of such a press would be increased capacity in general and the safety to our country of an ability to react in a timely manner in the event of a national emergency. Further, such actions might significantly improve the U.S. aerospace competitive advantage in the world market for commercial aircraft. The Government should consider taking the necessary actions to encourage such expansion and major capital expenditures, similar to those taken in the early 1950's that produced the current large press capacity.

6. Milling machine capacity, particularly efficient multi-spindle numerically-controlled milling machines, are believed to be an aerospace industry concern. MDC believes that our unique in-house capabilities, combined with a broad subcontractor base, will be sufficient to handle our needs. Further, it is our opinion that expanded facilities will be generated, within the private sector, as demand dictates, particularly if the Government could establish financial incentives to do so. The major concern at MDC would be if cobalt and molybdenum alloyed cutters were not available to allow maximum utilization of these major pieces of equipment. As such, MDC does not list this as a high priority area for potential investigation, believing other areas are of more importance within the parameters of commerces' states goals.

7. Many other product forms can trace their potential problems directly back to the materials discussed herein. Fasteners, ball bearings and hydraulic fittings are constrained primarily due to a shortage of titanium and precipitation hardening-type steels, and to a lesser degree by fabrication capacities. The magnitude and diversity of this area is not recommended for this investigation.

8. Substitution of materials in existing and new aerospace applications can present substantial problems. Alloy selection is based upon minimizing weight to achieve desired performance. The highest strength material consistent with good toughness and corrosion resistance is generally used. Alternate materials may require resizing of parts to reduce operating stresses. In some cases, this is not possible because of restricted part envelope based upon design of surrounding structure; where it is possible, a performance reduction is incurred due to weight increase. If a major redesign is undertaken, a costly full-scale static of fatigue test may be necessary.

- Finis -

SUPPLEMENT TO ENCLOSURE (1)

OF

MCDONNELL-DOUGLAS CORP

Response To

DEPARTMENT OF COMMERCE
Office of the Secretary

"DEFINITION OF AEROSPACE INDUSTRY NEEDS"

02 February 1981

WLH764-0281-2

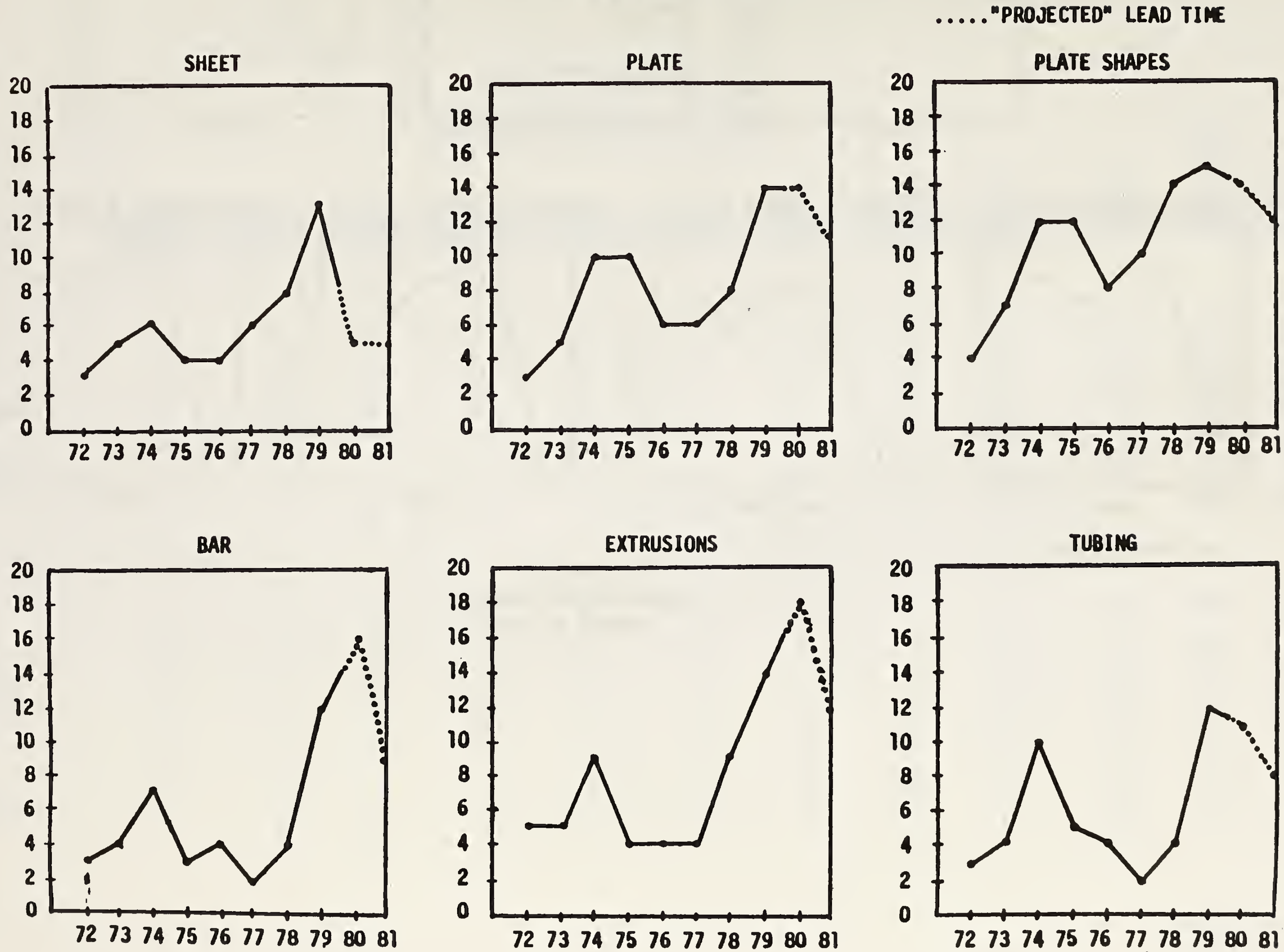
MCDONNELL DOUGLAS CORPORATION
ESTIMATED REQUIREMENTS FOR STRATEGIC MATERIAL
CALENDAR YEAR 1981 - 1984

1,000 POUNDS INCREMENTS

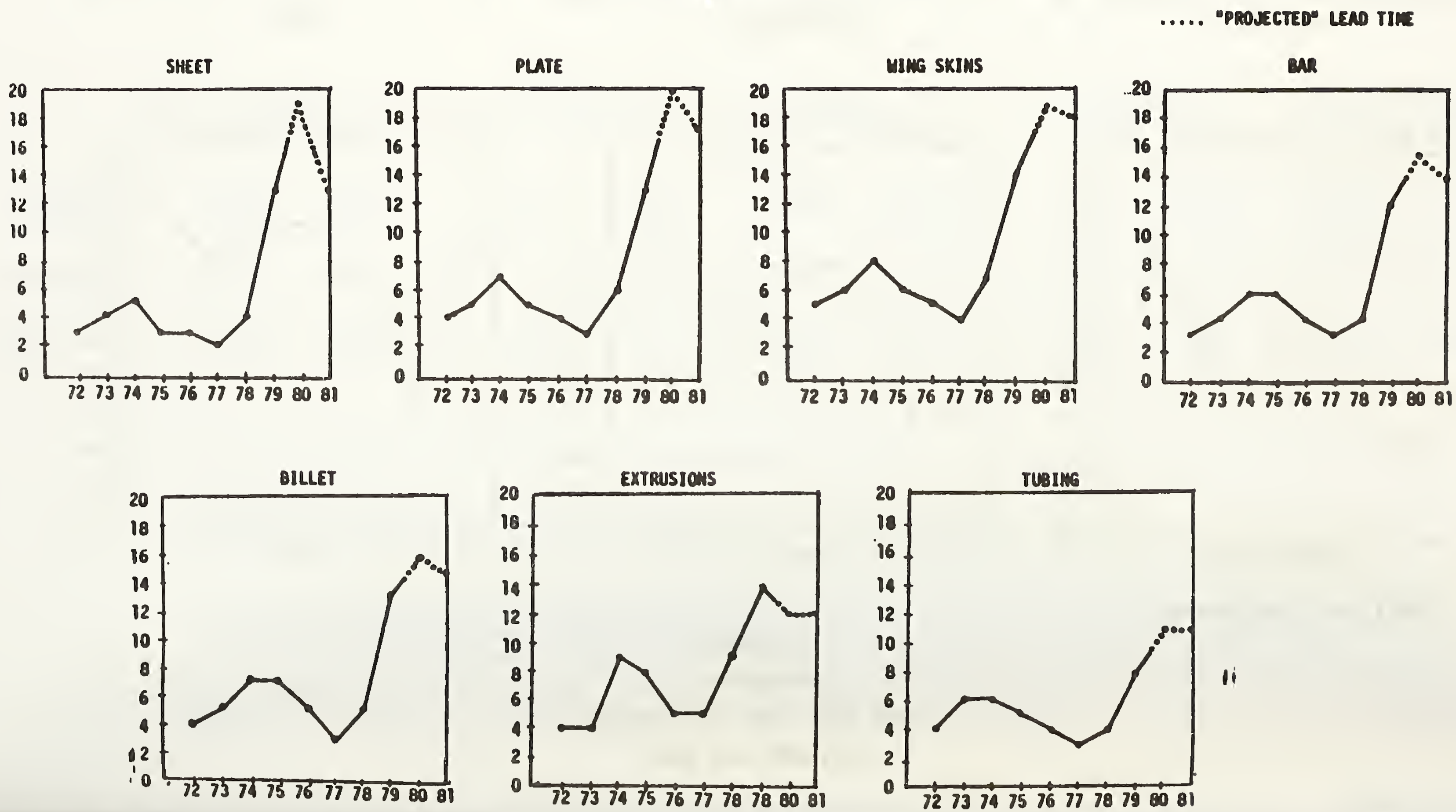
	1981		1982		1983		1984		TOTAL	
	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
TITANIUM	6,500	6,500	6,300	4,900	7,700	3,800	8,700	3,700	29,200	18,900
ALUMINUM	30,800	30,800	29,000	25,900	34,900	25,900	34,900	23,300	129,600	105,900
STEEL	4,900	4,900	5,000	4,700	6,400	5,500	6,400	5,300	22,700	20,400

- HIGH/LOW CATEGORIES REPRESENT POTENTIAL BUILD RATES
- POUNDAGE FIGURES ARE BASED ON STRUCTURAL DELIVERED WEIGHTS, INCLUDING LANDING AND ARRESTING GEAR.
- TO CONVERT THESE WEIGHTS TO MILL EQUIVALENT WEIGHTS, THEY SHOULD BE INCREASED BY APPROXIMATELY 30%.
- THIS REPORT DOES NOT INCLUDE TOOLING STEEL AND NO ATTEMPT IS MADE TO DIFFERENTIATE COBALT, CHROMIUM, AND MOLYBDENUM BEARING STEELS FROM COMMON CARBON STEEL.

LEAD TIME ANALYSIS
RAW MATERIAL MILL LEAD TIMES
ALUMINUM
(MONTHS)



LEAD TIME ANALYSIS
TITANIUM - MILL LEAD TIMES
(IN MONTHS)



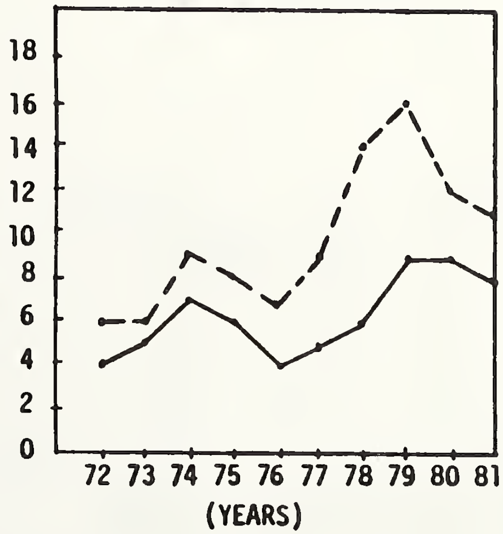
LEAD TIME ANALYSIS

RAW MATERIAL - MILL LEAD TIMES

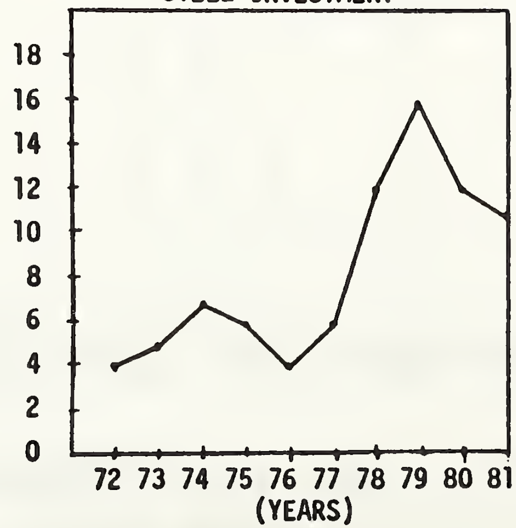
	1972 (MONTHS)	1973 (MONTHS)	1974 (MONTHS)	1975 (MONTHS)	1976 (MONTHS)	1977 (MONTHS)	1978 (MONTHS)	1979 (MONTHS)	1980 (MONTHS)	1981 (MONTHS)	1972 TO 1981 (MONTHS)	% OF CHANG
ALUMINUM												
SHEET	3	5	6	4	4	6	8	13	5	5	+2	67
PLATE	3	5	10	10	6	6	8	14	14	11	+8	267
PLATE SHAPES	4	7	12	12	8	10	14	15	14	12	+8	200
BAR	3	4	7	3	4	2	4	12	16	9	+6	200
EXTRUSIONS	5	5	9	4	4	4	9	14	18	12	+7	140
TUBING	3	4	10	5	4	2	4	12	11	8	+5	167
TITANIUM												
SHEET	3	4	5	3	3	2	4	13	19	13	+10	333
PLATE	4	5	7	5	4	3	6	13	20	17	+13	325
WING SKINS	5	6	8	6	5	4	7	14	19	18	+13	260
BAR	3	4	6	6	4	3	4	12	15	14	+11	367
BILLET	4	5	7	7	5	3	5	13	16	15	+11	275
EXTRUSIONS	4	4	9	8	5	5	9	14	12	12	+8	200
TUBING	4	6	6	5	4	3	4	8	11	11	+7	175

LEAD TIME ANALYSIS
RAW MATERIAL - CASTINGS
(IN MONTHS)

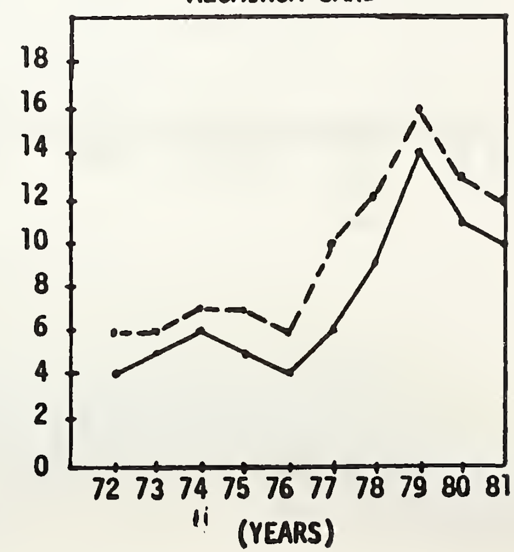
ALUMINUM INVESTMENT



STEEL INVESTMENT



ALUMINUM SAND



—— SMALL/MEDIUM
- - - - LARGE

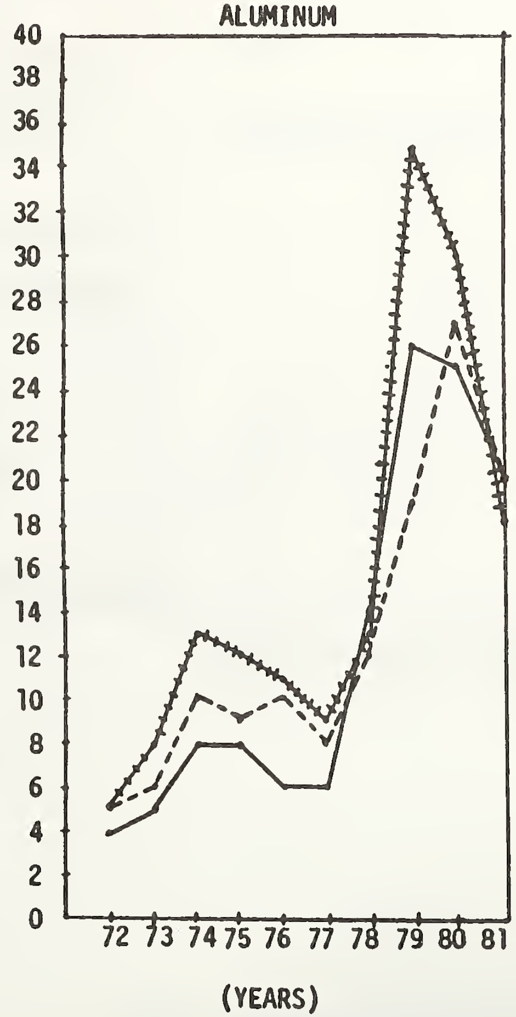
Note: LEAD TIMES "PROJECTED" JULY 80 AND UP

W29-14

LEAD TIME ANALYSIS
RAW MATERIAL - CASTINGS

	1972 (MONTHS)	1973 (MONTHS)	1974 (MONTHS)	1975 (MONTHS)	1976 (MONTHS)	1977 (MONTHS)	1978 (MONTHS)	1979 (MONTHS)	1980 (MONTHS)	1981 (MONTHS)	1972 TO 1981 (MONTHS)	% OF CHANG
ALUMINUM INVESTMENT												
SMALL	4	5	7	6	4	5	6	9	9	8	+4	100
MEDIUM	4	5	7	6	4	5	7	9	9	8	+4	100
LARGE	6	6	9	8	7	9	14	16	12	11	+6	100
STEEL INVESTMENT												
SMALL/MEDIUM	4	5	7	6	4	6	12	16	12	11	+7	175
ALUMINUM SAND												
SMALL/MEDIUM	4	5	6	5	4	6	9	14	11	10	+6	150
LARGE	6	6	7	7	6	10	12	16	13	12	+6	100

LEAD TIME ANALYSIS
RAW MATERIAL - FORGINGS
(IN MONTHS)



SMALL
MEDIUM
LARGE
MEDIUM/LARGE

Note: LEAD TIMES "PROJECTED"
JULY 80 AND UP

LEAD TIME ANALYSIS

RAW MATERIAL - FORGINGS

	1972 (MONTHS)	1973 (MONTHS)	1974 (MONTHS)	1975 (MONTHS)	1976 (MONTHS)	1977 (MONTHS)	1978 (MONTHS)	1979 (MONTHS)	1980 (MONTHS)	1981 (MONTHS)	1972 TO 1981 (MONTHS)	% OF CHANG
ALUMINUM												
SMALL (INCLUDES PRESSINGS)	4	5	8	8	6	6	14	26	25	20	+16	400
MEDIUM	5	6	10	9	10	8	12	19	27	20	+15	300
LARGE	5	8	13	12	11	9	13	35	30	18	+13	260
TITANIUM												
MEDIUM/LARGE	7	9	18	13	13	11	15	35	36	24	+17	242
SMALL	5	6	9	9	8	7	12	20	24	19	+14	280

W29-16

ALUMINUM TOTAL MARKET

AEROSPACE AS A % OF TOTAL CAPACITY
(MILLIONS OF POUNDS)

	1977	1978	1979	1980	1981
SHEET	1.2	1.4	1.6	1.9	2.0
PLATE	32.3	31.7	39.0	39.6	41.3
BAR	3.6	4.1	4.0	4.8	5.5
TUBE	1.7	1.8	2.0	2.6	2.6
EXTRUSIONS	1.8	2.4	2.8	2.9	2.9

ALUMINUM SHEET-AEROSPACE

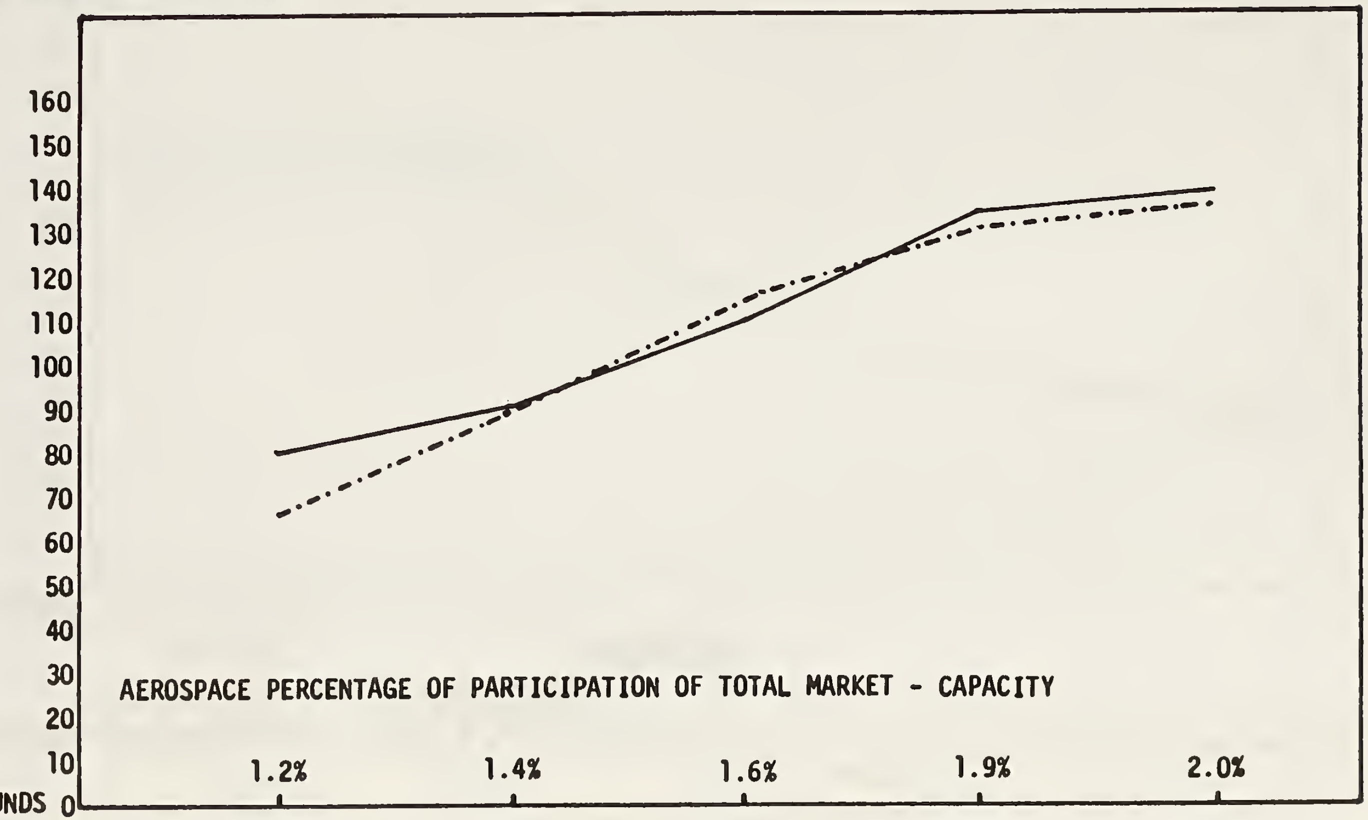
MONTHS

1980 CURRENT LEAD TIME RATIO : 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

QUEUE TIME

FAB TIME

SUPPLY DEMAND RATIO 1977-1981:



TOTAL INDUSTRY CAPACITY (MIL OF LBS)	1977 6,550	1978 6,580	1979 6,750	1980 6,880	1981 7,000

NUMBER OF SUPPLIERS: 5 1977; 5 1978; 5 1979; 5 1980

NUMBER OF SUPPLIERS IN 1980 SAME AS 1977 5

ALUMINUM PLATE-AEROSPACE

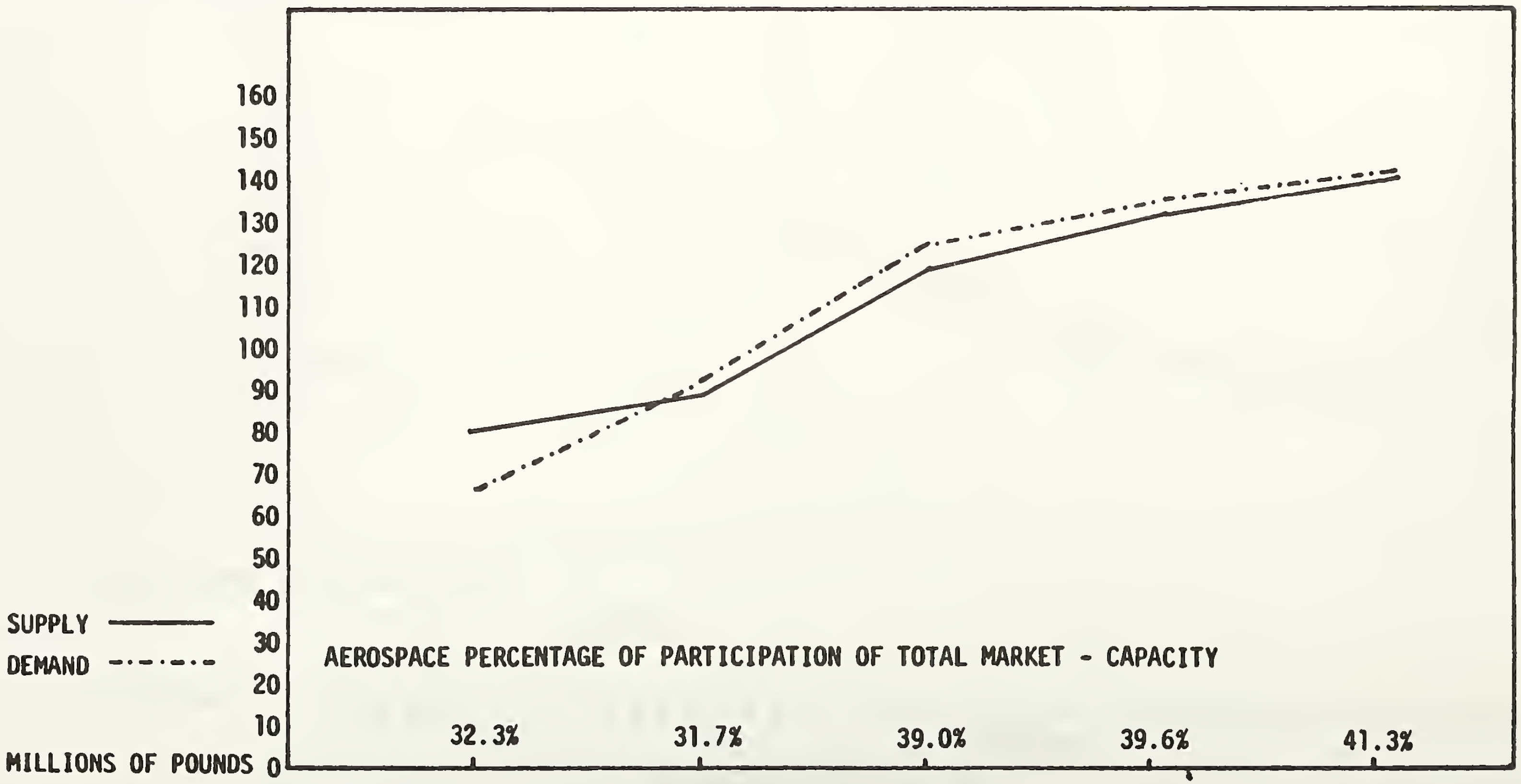
MONTHS

1980 CURRENT LEAD TIME RATIO : 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

QUEUE TIME

FAB TIME

SUPPLY DEMAND RATIO 1977-1981:



TOTAL INDUSTRY CAPACITY (MIL OF LBS)	1977	1978	1979	1980	1981
	247	280	307	330	339

NUMBER OF SUPPLIERS: 4 (1977), 4 (1978), 4 (1979), 4 (1980)

NUMBER OF SUPPLIERS IN 1980 SAME AS 1977 4

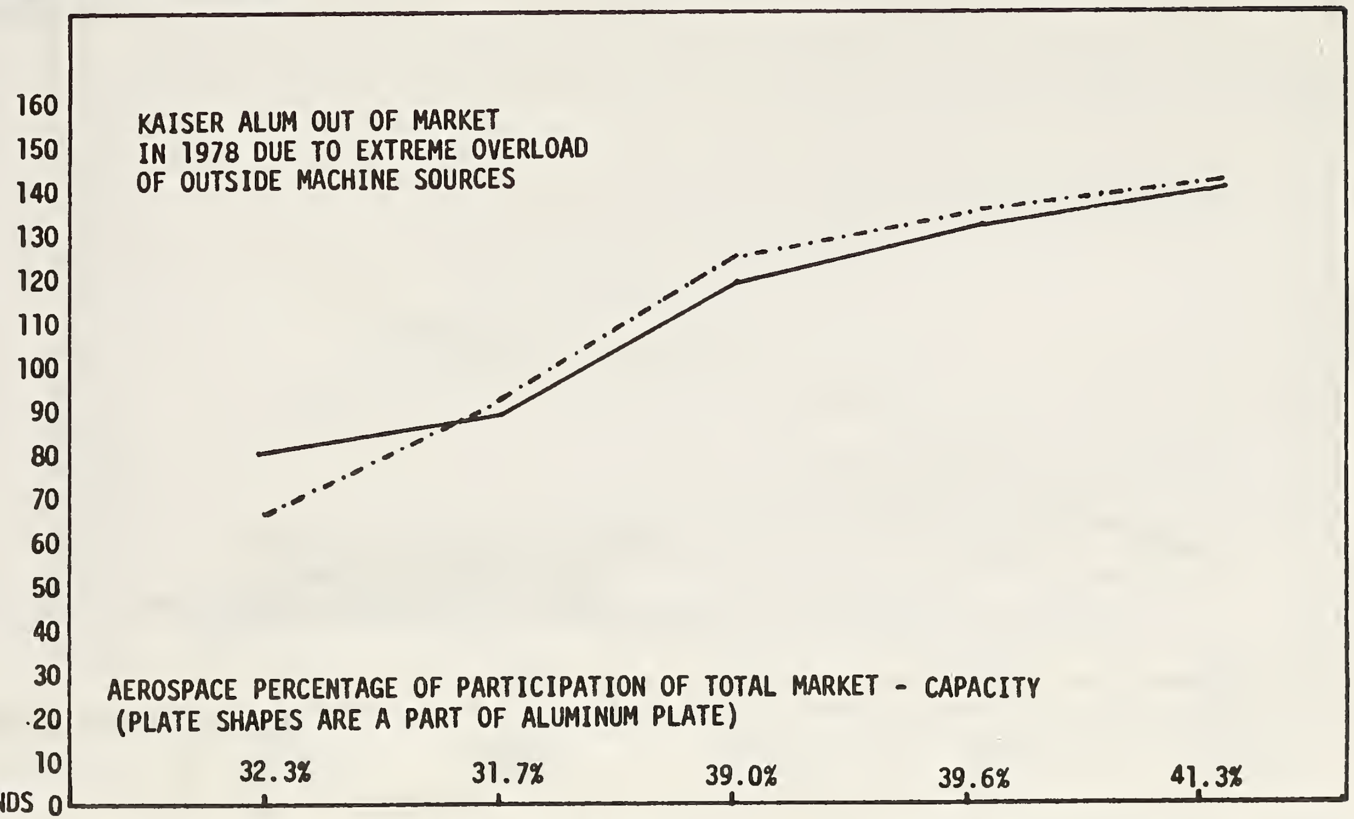
ALUMINUM PLATE SHAPES-AEROSPACE

1980 CURRENT LEAD TIME RATIO :

QUEUE TIME

FAB TIME

SUPPLY DEMAND RATIO 1977-1981:



SUPPLY ———

DEMAND -·-·-·-

MILLIONS OF POUNDS

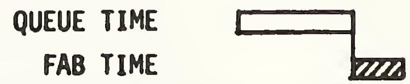
	1977	1978	1979	1980	1981
TOTAL INDUSTRY CAPACITY (MIL OF LBS)	247	280	307	330	339

NUMBER OF SUPPLIERS	3	2	2	2
	1977	1978	1979	1980

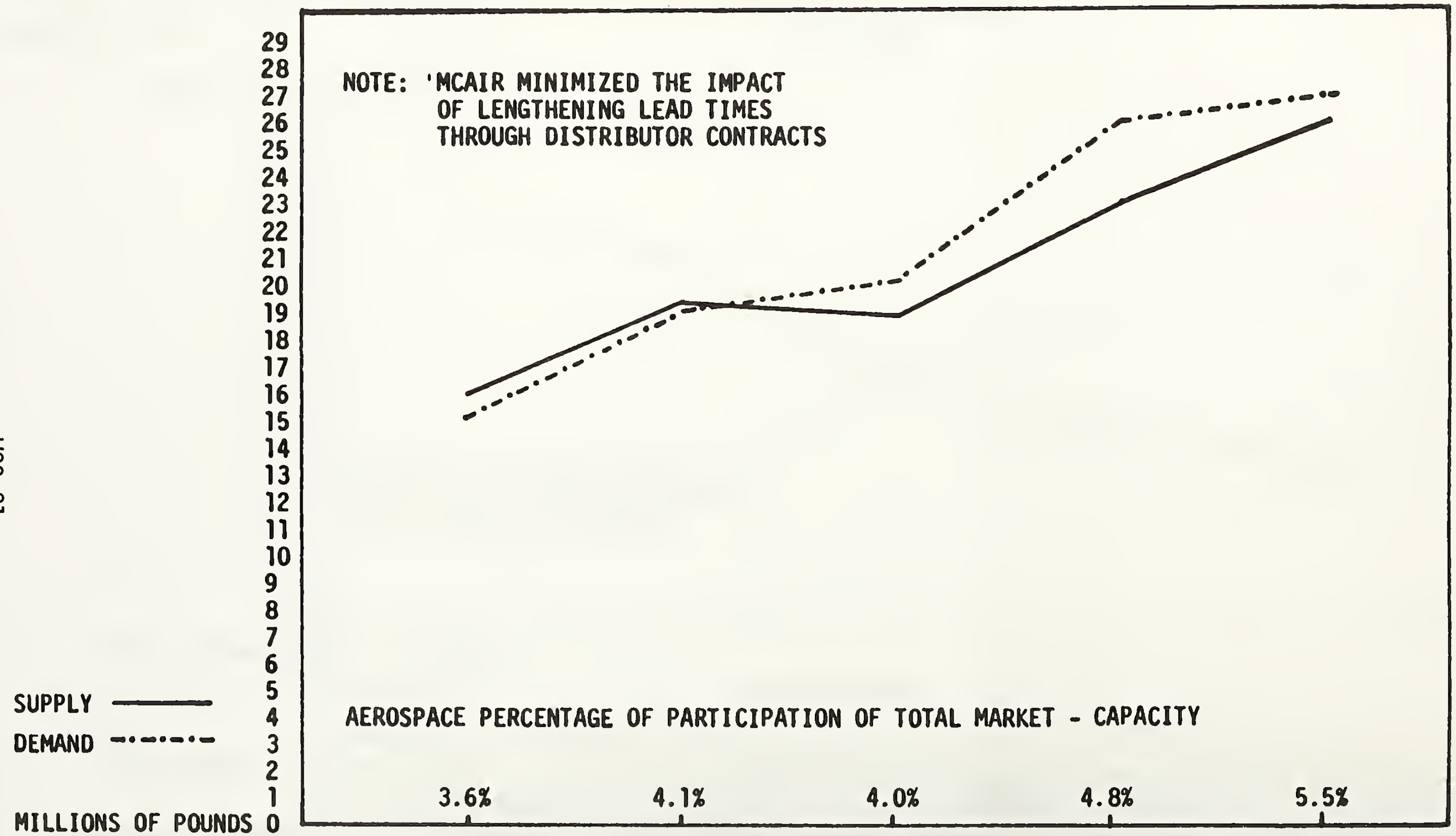
NUMBER OF SUPPLIERS IN 1980
SAME AS 1977 2

ALUMINUM BAR-AEROSPACE

1980 CURRENT LEAD TIME RATIO: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27



SUPPLY DEMAND RATIO 1977-1981:



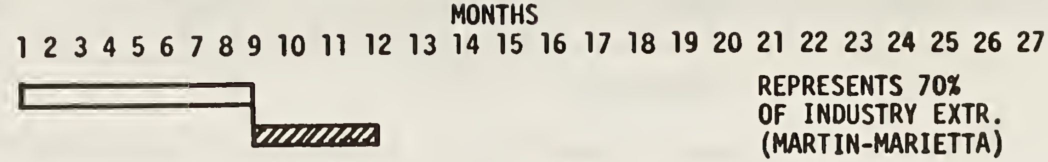
TOTAL INDUSTRY CAPACITY (MIL OF LBS)	1977	1978	1979	1980	1981
	446	470	475	475	476

NUMBER OF SUPPLIERS:	1977	1978	1979	1980
	2	2	2	2

NUMBER OF SUPPLIERS IN 1980 SAME AS 1977 2

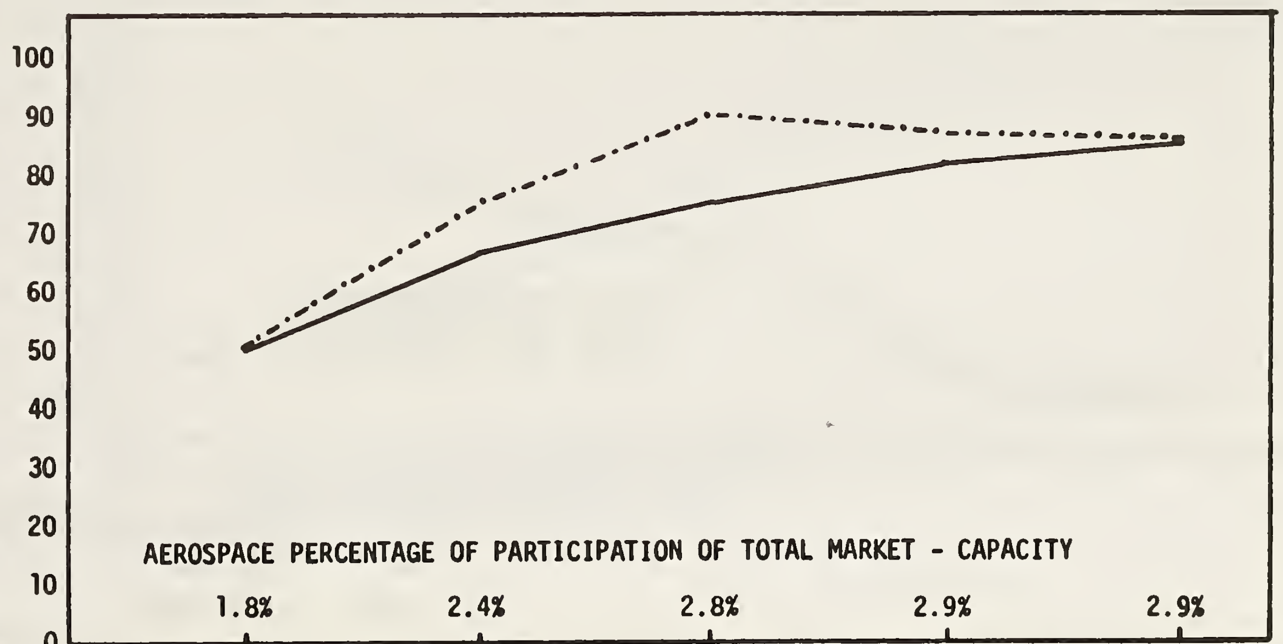
ALUMINUM EXTRUSIONS-AEROSPACE

1980 CURRENT LEAD TIME RATIO:



REPRESENTS 70%
OF INDUSTRY EXTR.
(MARTIN-MARIETTA)

SUPPLY DEMAND RATIO 1977-1981:



SUPPLY ———
DEMAND —.—.—.—

MILLIONS OF POUNDS

TOTAL INDUSTRY CAPACITY (MIL OF LBS)	1977 2,730	1978 2,750	1979 2,800	1980 2,800	1981 2,800

NUMBER OF SUPPLIERS:	5 1977	5 1978	5 1979	5 1980	NUMBER OF SUPPLIERS IN 1980 SAME AS 1977 5

ALUMINUM TUBING-AEROSPACE

MONTHS

1980 CURRENT LEAD TIME RATIO: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

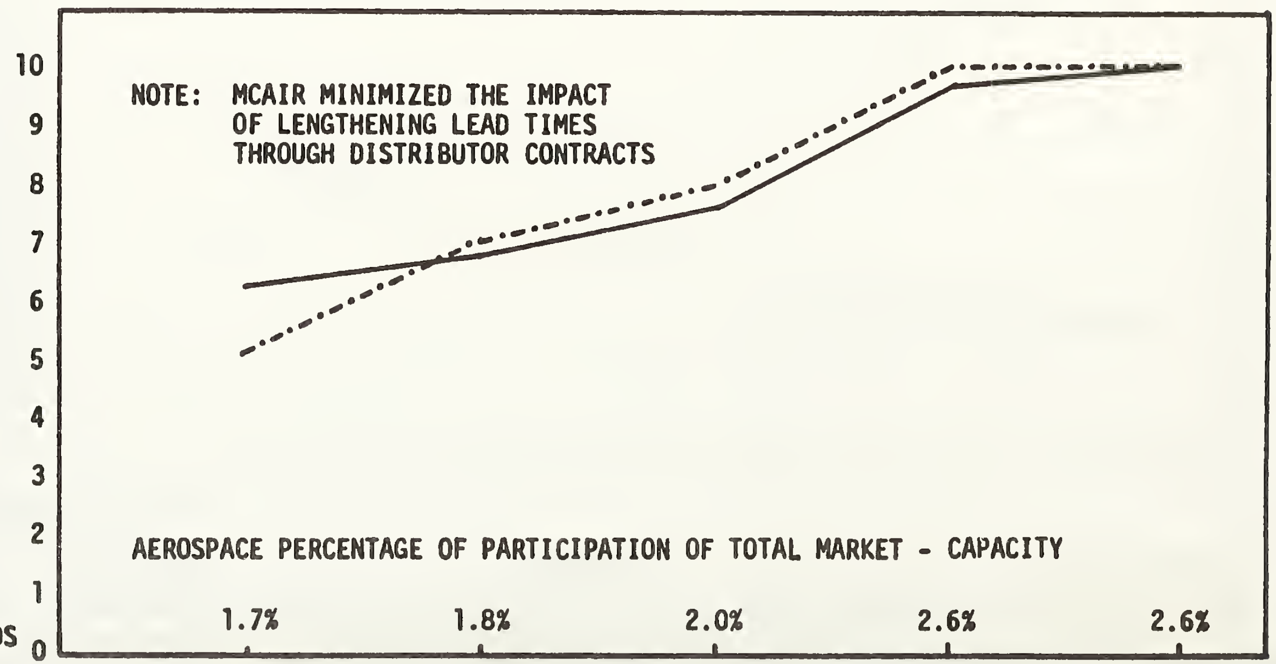
QUEUE TIME

FAB TIME

SUPPLY DEMAND RATIO 1977-1981:

SUPPLY ———

DEMAND -·-·-·-



MILLIONS OF POUNDS

TOTAL INDUSTRY CAPACITY (MIL OF LBS)	1977 375	1978 378	1979 380	1980 380	1981 380

NUMBER OF SUPPLIERS:	2 1977	2 1978	2 1979	2 1980

NUMBER OF SUPPLIERS IN 1980 SAME AS 1977 2

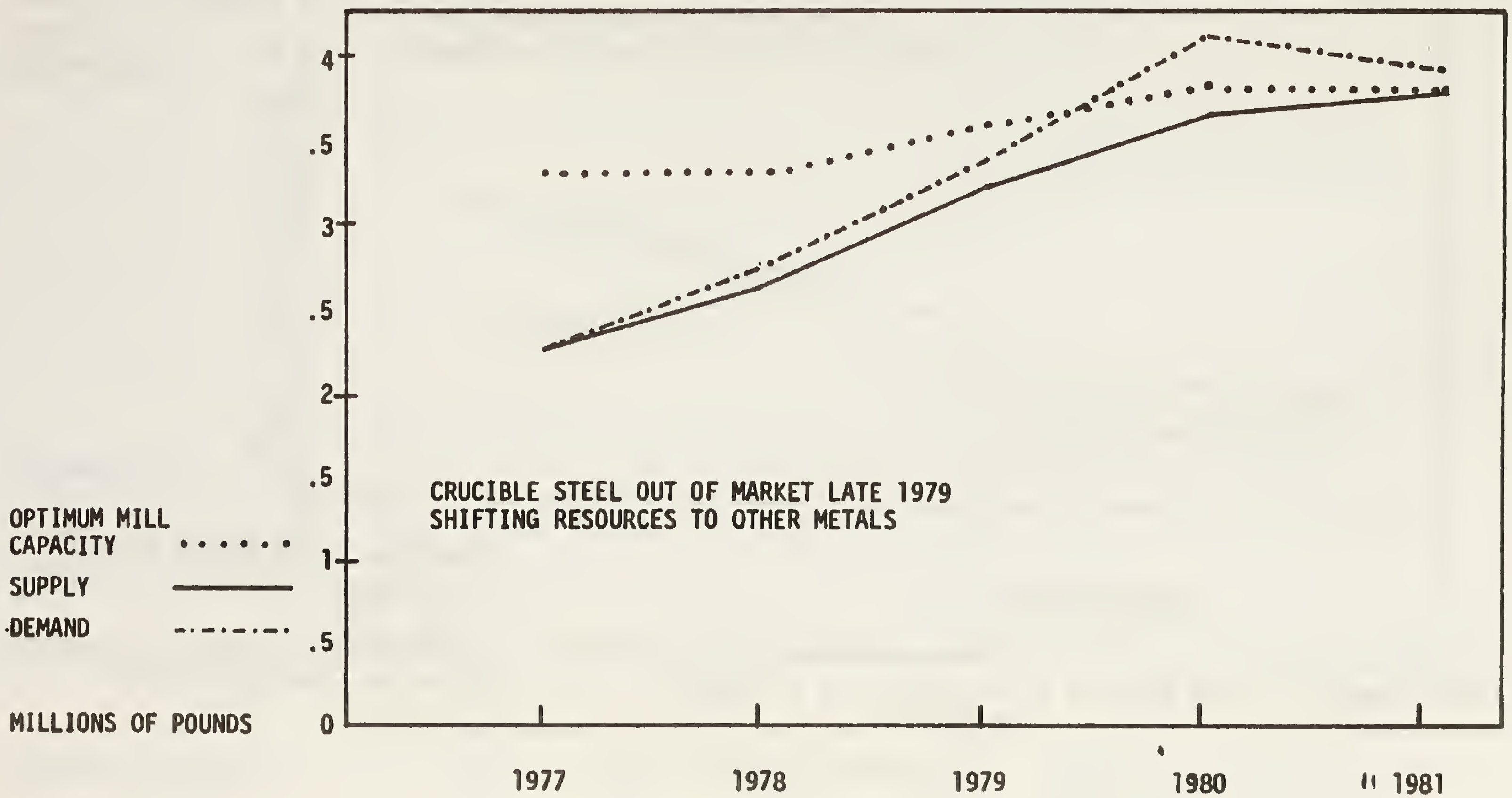
TOTAL INDUSTRY-TITANIUM SHEET

1980 CURRENT LEAD TIME RATIO: MONTHS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25 27

QUEUE TIME

FAB TIME

SUPPLY DEMAND RATIO 1977-1981:

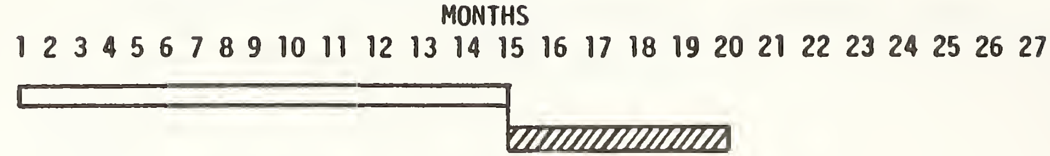


NUMBER OF SUPPLIERS	4 1977	4 1978	3 1979	3 1980	NUMBER OF SUPPLIERS IN 1980 SAME AS 1977 3

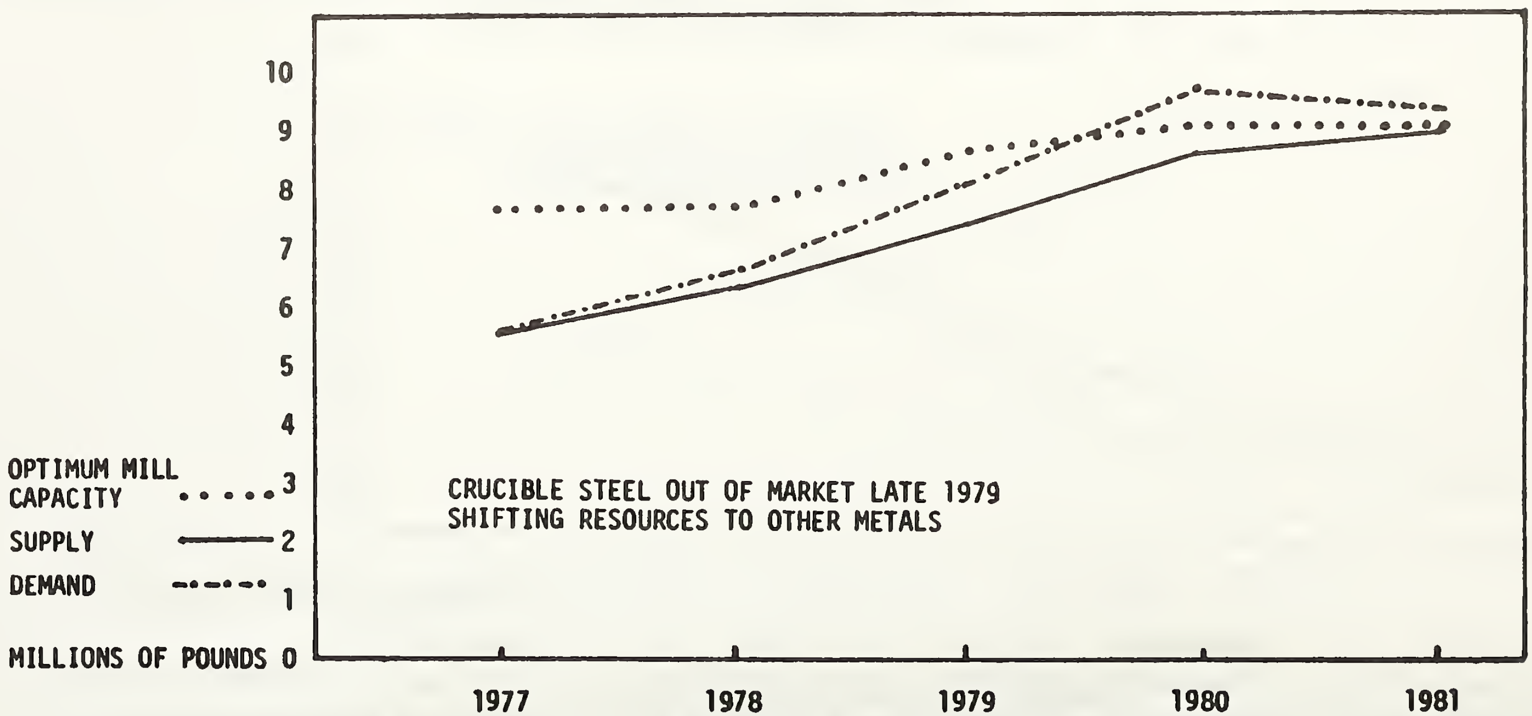
APPROX. MARKET BREAKDOWN - 74% AEROSPACE - 26% COMMERCIAL

TOTAL INDUSTRY-TITANIUM PLATE

1980 CURRENT LEAD TIME RATIO:



SUPPLY DEMAND RATIO 1977-1981:



NUMBER OF SUPPLIERS:	4	4	3	3	NUMBER OF SUPPLIERS IN 1980
	1977	1978	1979	1980	SAME AS 1977 3

APPROX. MARKET BREAKDOWN - 82% AEROSPACE - 18% COMMERICAL

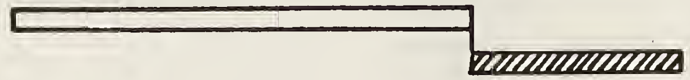
TOTAL INDUSTRY-TITANIUM WING SKINS

MONTHS

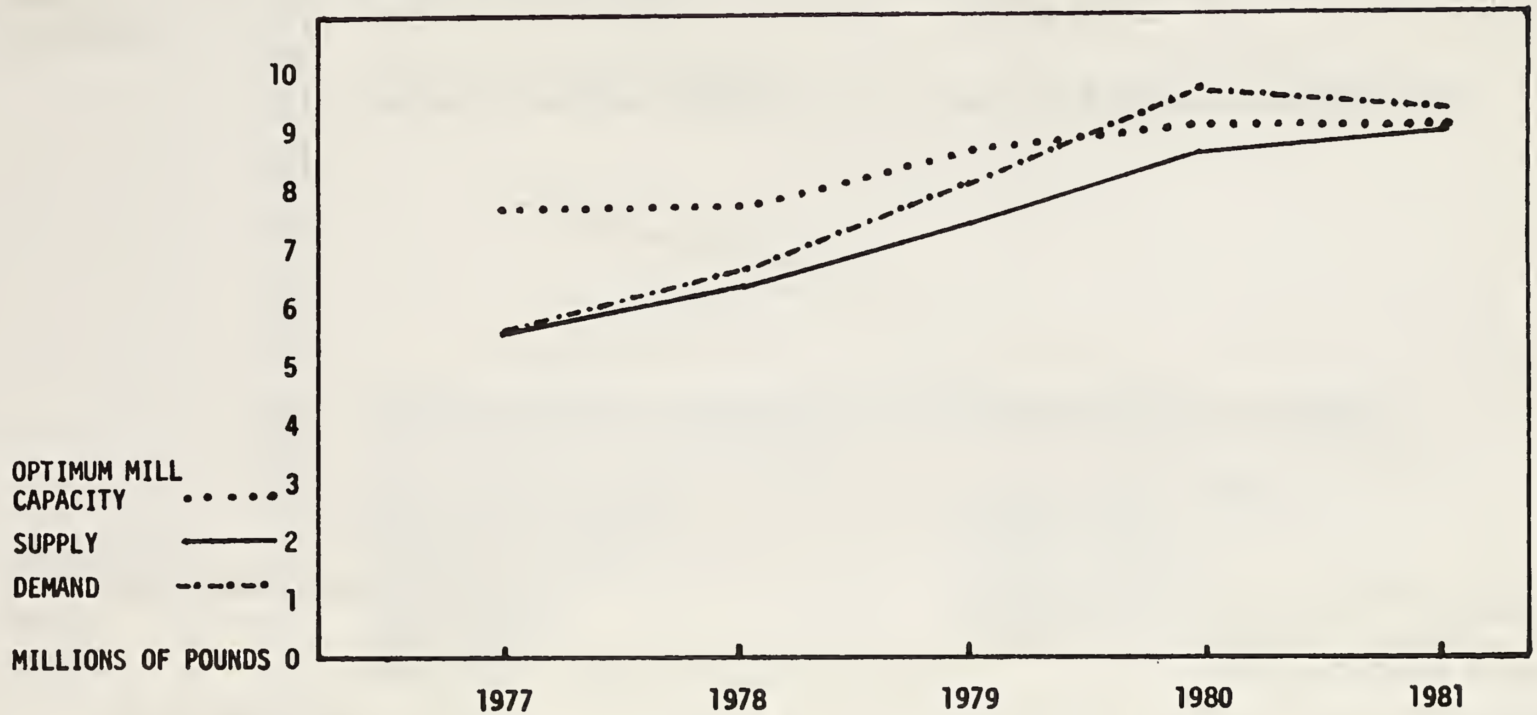
1980 CURRENT LEAD TIME RATIO: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

QUEUE TIME

FAB TIME



SUPPLY DEMAND RATIO 1977-1981:



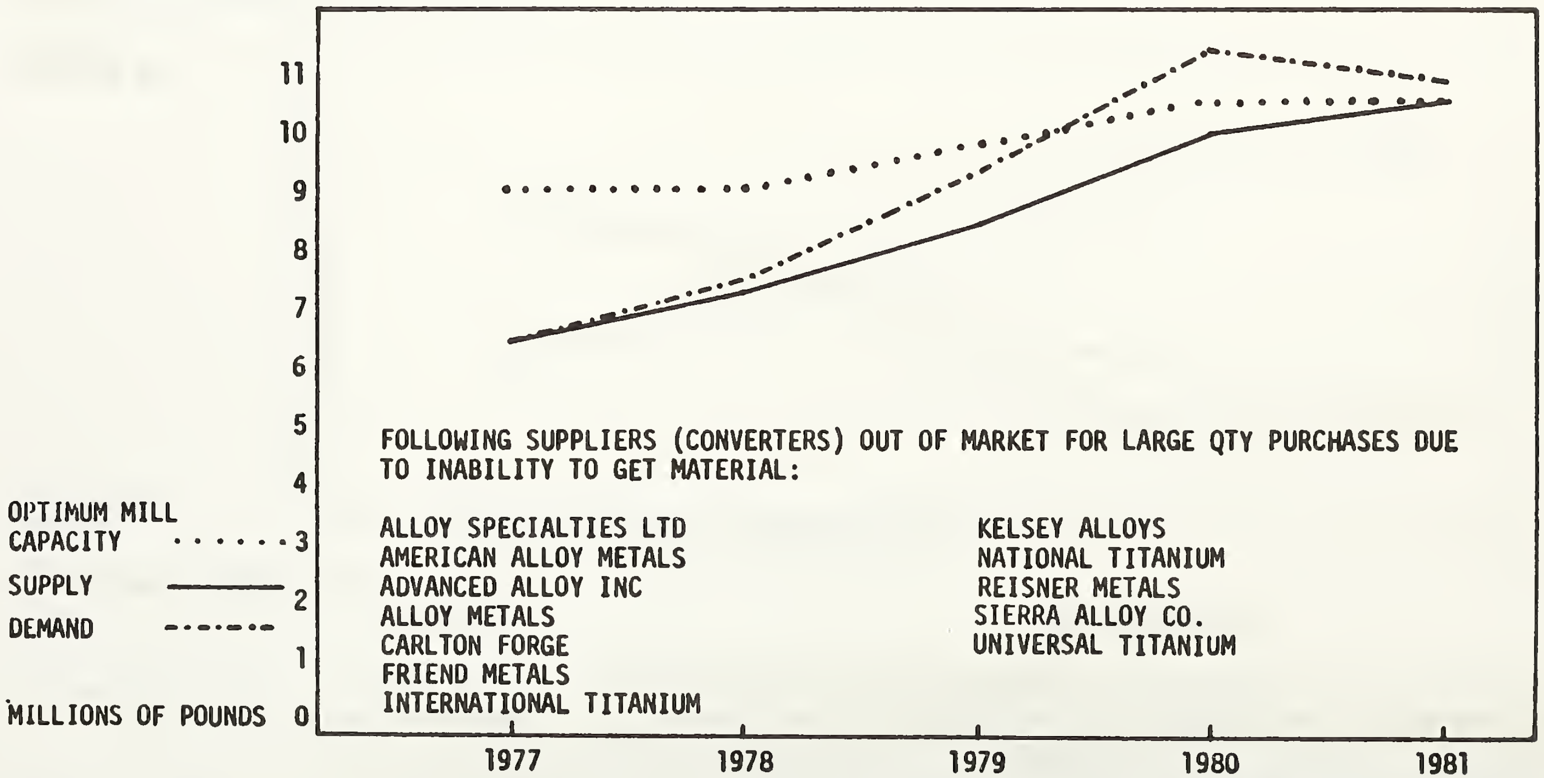
NUMBER OF SUPPLIERS:	2	2	2	2	NUMBER OF SUPPLIERS IN 1980
	1977	1978	1979	1980	SAME AS 1977 2

MARKET BREAKDOWN - 100% AEROSPACE - 0% COMMERCIAL

TOTAL INDUSTRY-TITANIUM BAR

APPROX. MARKET BREAKDOWN -89% AEROSPACE - 11% COMMERICAL

SUPPLY DEMAND RATIO 1977-1981:



NUMBER OF SUPPLIERS:	16	12	4	4
	1977	1978	1979	1980

NUMBER OF SUPPLIERS IN 1980
SAME AS 1977 4 "

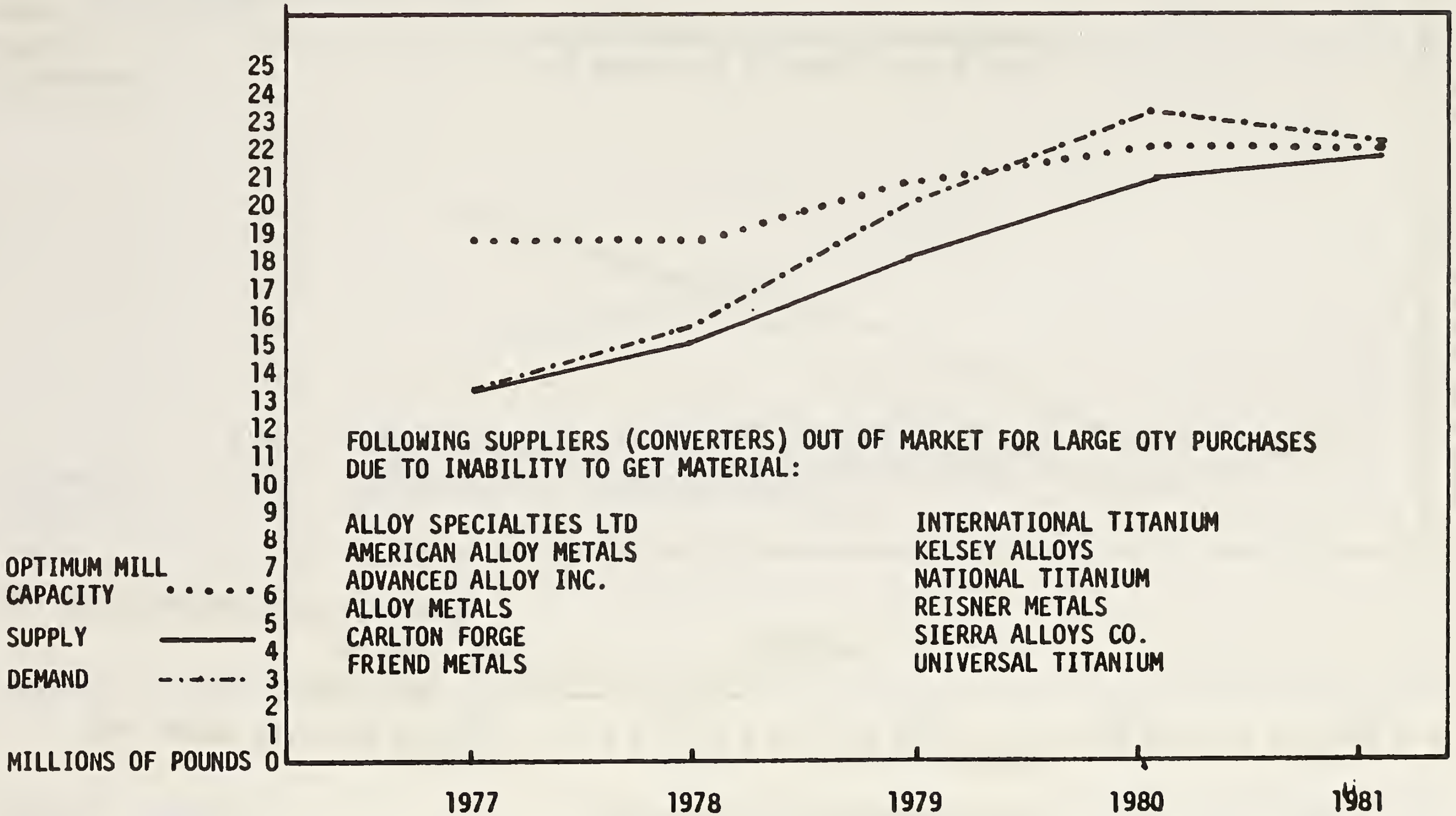
NOTE: MCAIR PROCURES PRIMARILY RECTANGULAR BAR, MAJORITY OF MARKET IS ROUNDS.

TOTAL INDUSTRY-TITANIUM BILLET

APPROX. MARKET BREAKDOWN - 92% AEROSPACE - 8% COMMERCIAL

1980 CURRENT LEAD TIME RATIO:

SUPPLY DEMAND RATIO 1977-1981:



NUMBER OF SUPPLIERS:	16	12	4	4	NUMBER OF SUPPLIERS IN 1980
	1977	1978	1979	1980	SAME AS 1977 4

NOTE: MCAIR PROCURES PRIMARILY RECTANGULAR BAR, MAJORITY OF MARKET IS ROUNDS.

TOTAL INDUSTRY-TITANIUM EXTRUSIONS

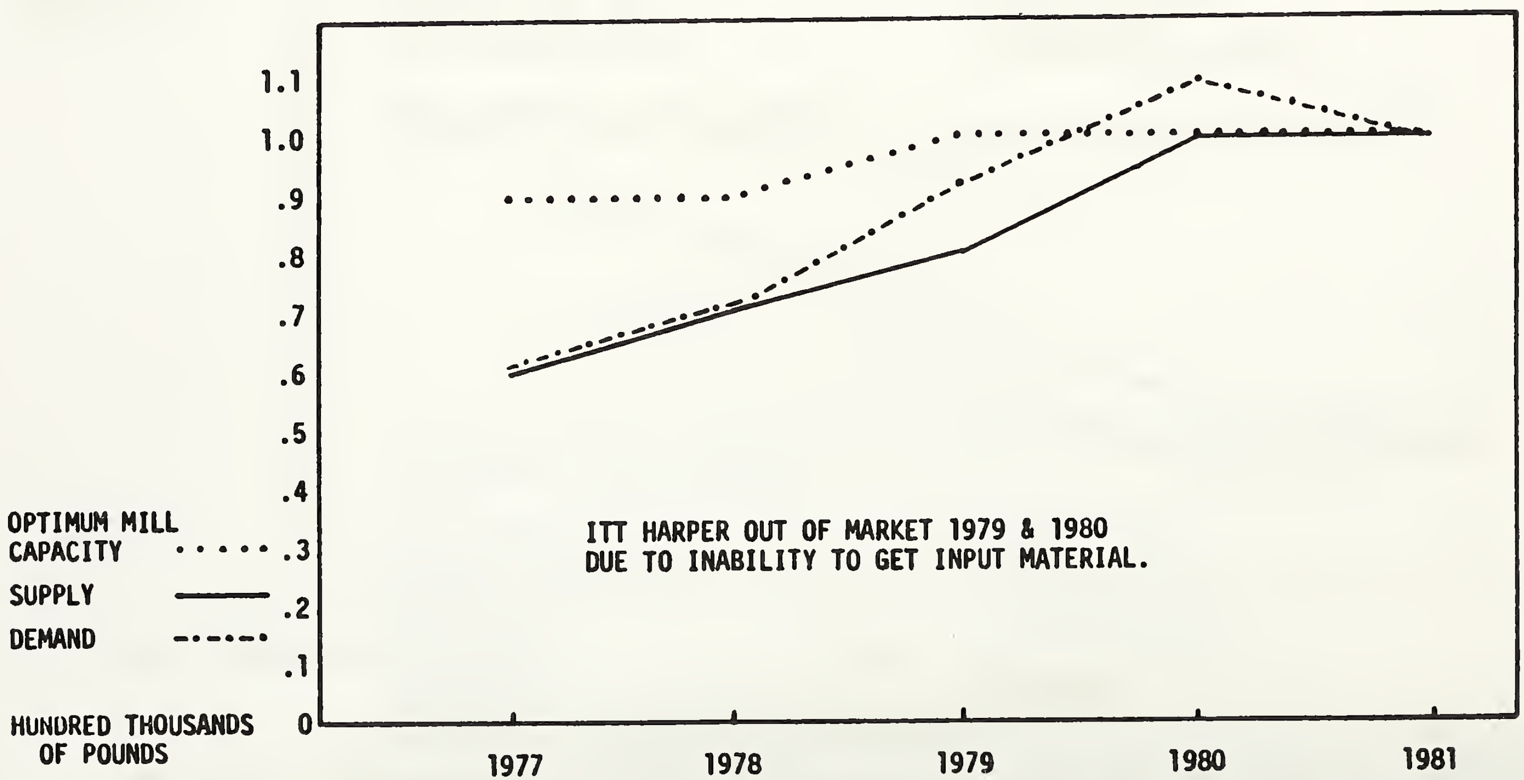
MONTHS

1980 CURRENT LEAD TIME RATIO: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

QUEUE TIME

FAB TIME

SUPPLY DEMAND RATIO 1977-1981:



NUMBER OF SUPPLIERS:	2	2	1	1
	1977	1978	1979	1980

NUMBER OF SUPPLIERS IN 1980
SAME AS 1977 1

APPROX. MARKET BREAKDOWN - 99% AEROSPACE - 1% COMMERICAL

TOTAL INDUSTRY-TITANIUM TUBING

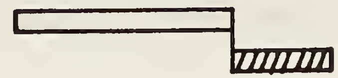
APPROX. MARKET BREAKDOWN - 2% AEROSPACE - 98% COMMERCIAL

MONTHS

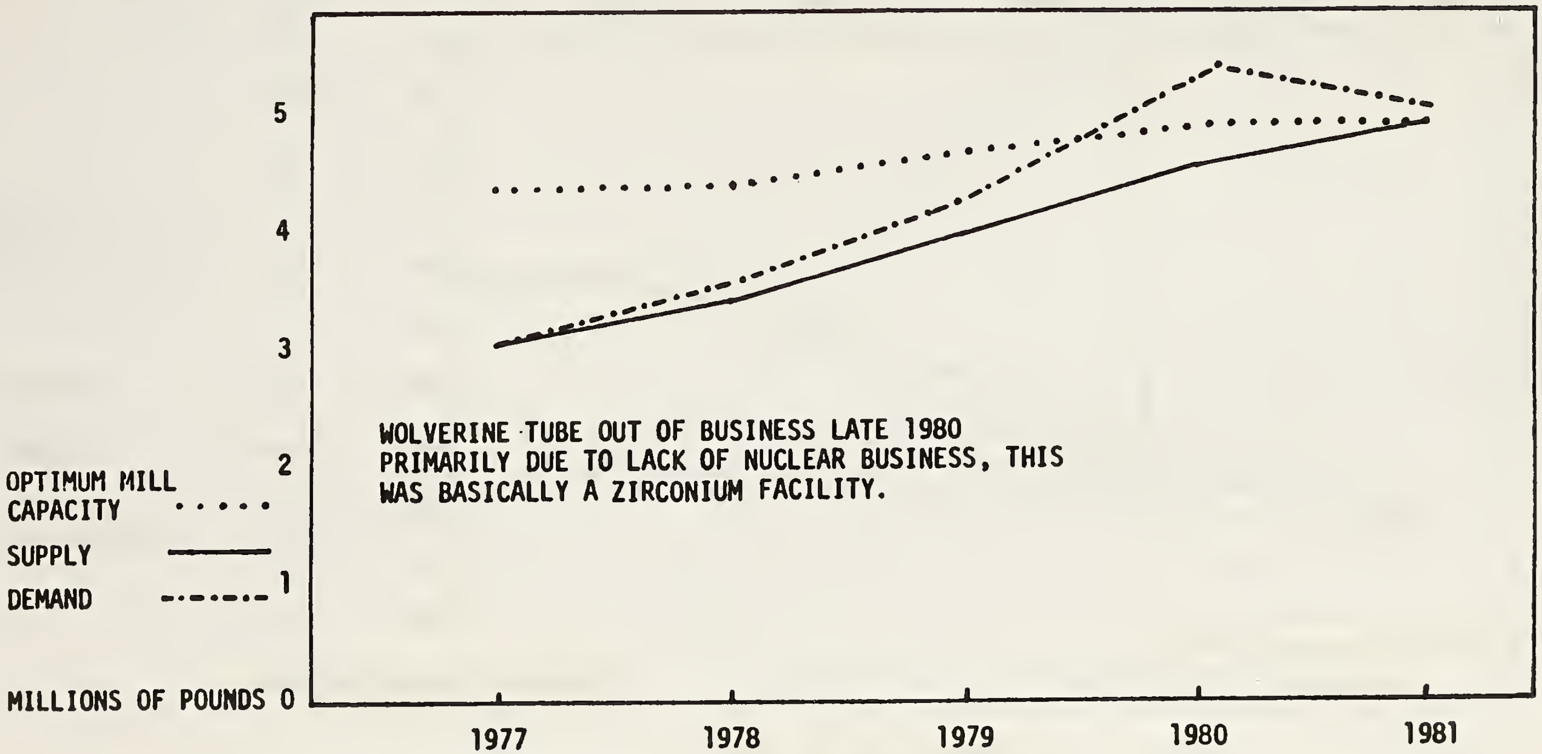
1980 CURRENT LEAD TIME RATIO: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

QUEUE TIME

FAB TIME



SUPPLY DEMAND RATIO 1977-1981:

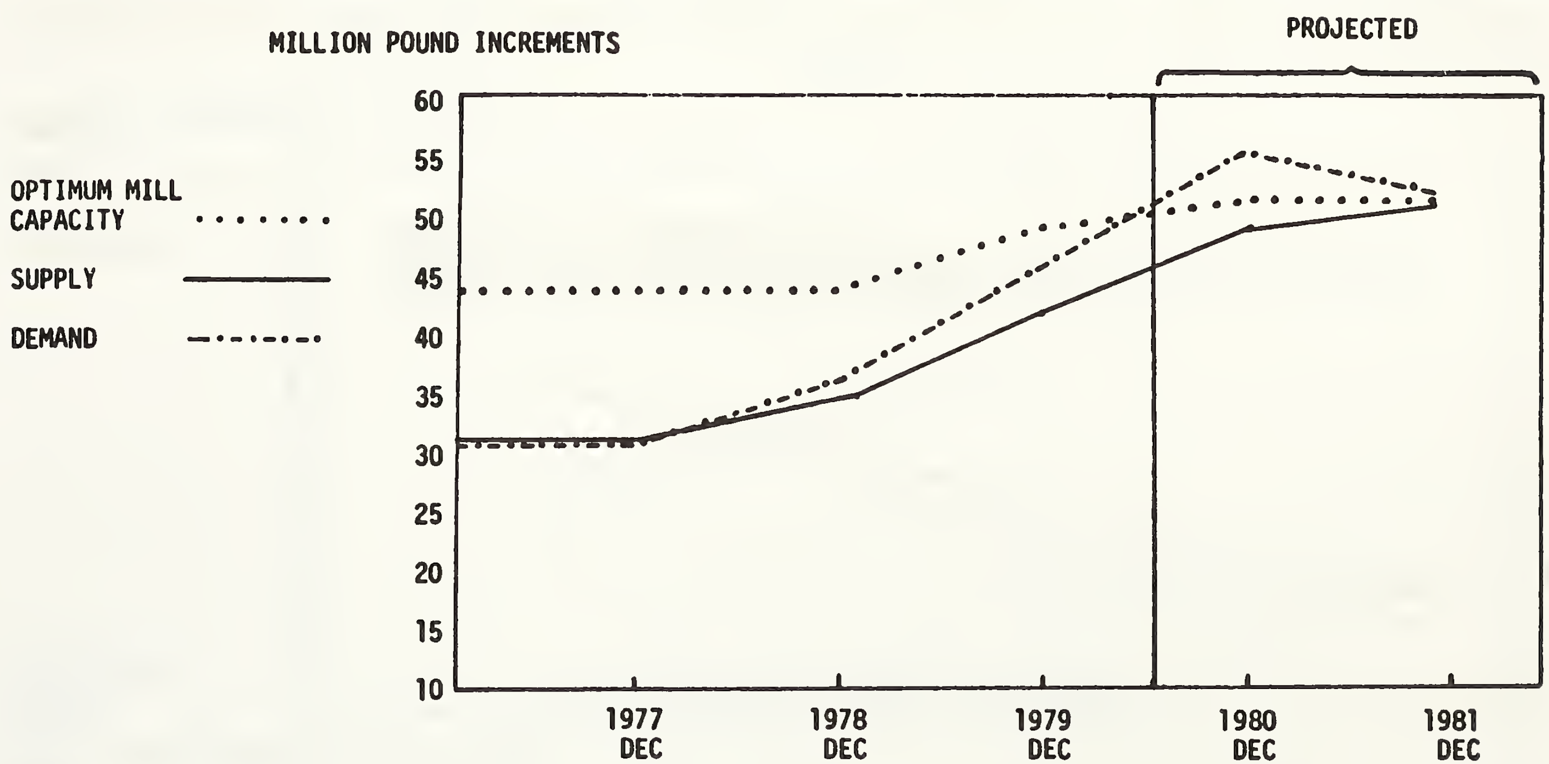


NUMBER OF SUPPLIERS:	3	3	3	2
	1977	1978	1979	1980

NUMBER OF SUPPLIERS IN 1980 SAME AS 1977 2

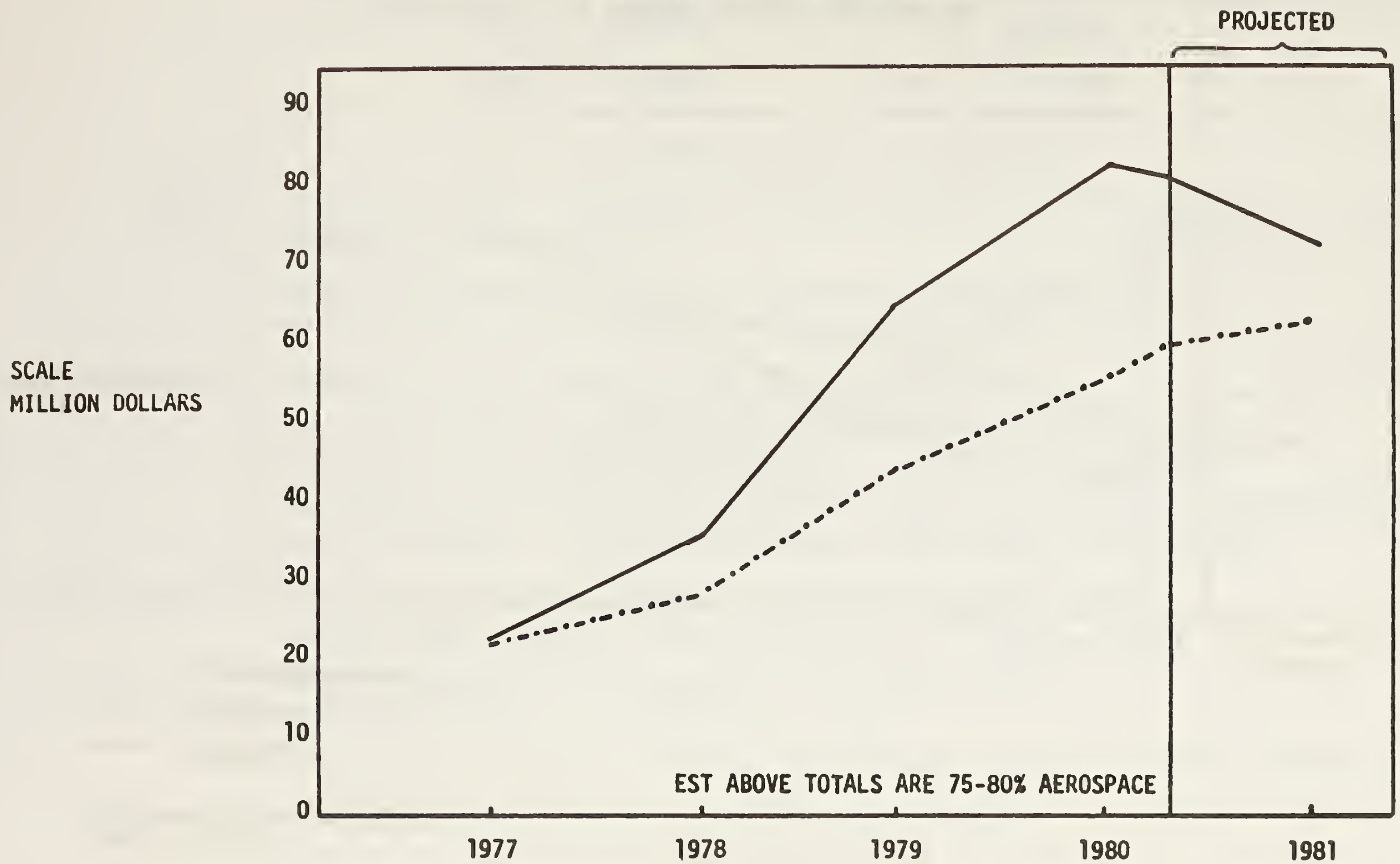
NOTE: OF TWO REMAINING SOURCES, SUPERIOR TUBE ONLY PRODUCES APPROX 5% OF MCAIR REQUIREMENTS, BALANCE (95%) MUST COME FROM CABOT.

TOTAL TITANIUM INDUSTRY



	AEROSPACE	COMMERCIAL (INDUSTRIAL)	MCAIR PARTICIPATION
1977	82%	18%	20%
1978	80%	20%	17%
1979	75%	25%	14%
1980 (EST)	70%	30%	12%
1981 (EST)	68%	32%	11%

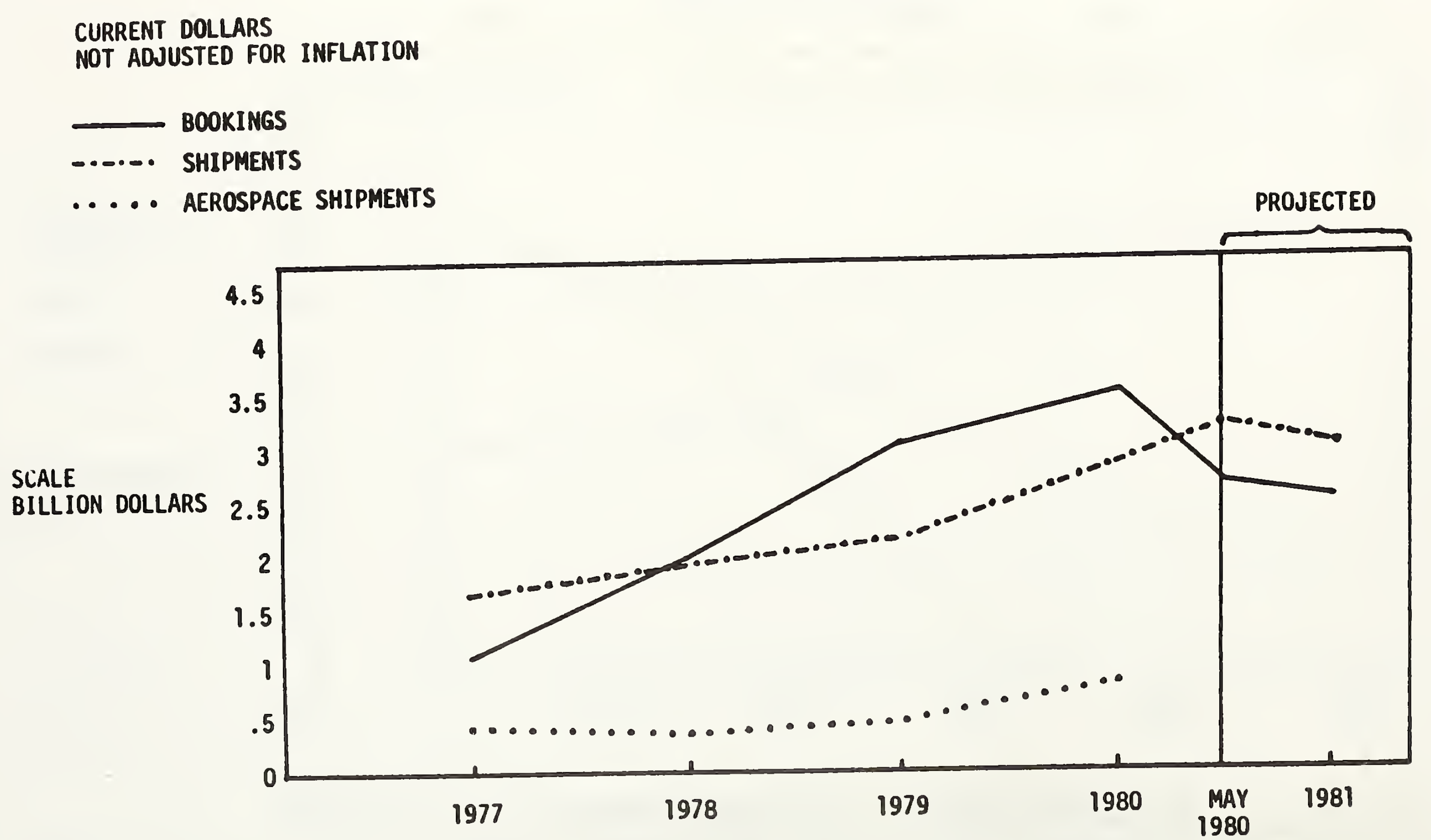
TOTAL INDUSTRY & AEROSPACE
ALUMINUM INVESTMENT CASTINGS



BOOKINGS ————
SHIPMENTS -·-·-·-

APPROX. 5% OF MCAIR CASTINGS ARE STEEL INVESTMENT
DATA FURNISHED BY INVESTMENT CASTING INSTITUTE,
APPROX. 75% OF INDUSTRY REPORTING.

FORGING INDUSTRY
BOOKINGS VS SHIPMENTS
& AEROSPACE SHIPMENTS



1. DATA FURNISHED BY FORGING INDUSTRY ASSOCIATION.
2. FORGING INDUSTRY ASSOCIATION REPRESENTS 80% OF DOMESTIC FORGING CAPACITY.
3. MAJOR FORGING PROBLEMS ARE CURRENTLY: A. LARGE PRESS ITEMS @ WYMAN GORDON
   B. PRECISION (NO DRAFT) ALUMINUM FORGINGS
4. AEROSPACE REPRESENTS APPROX. 25% OF FORGING MARKET.
5. AEROSPACE SHIPMENTS DOLLARS ONLY ACCUMULATED ANNUALLY.

AEROSPACE FASTENERS

1977	LEAD TIME	6 - 10 WEEKS
1980	LEAD TIME	40 - 60 WEEKS
	INCREASE	34 - 50 WEEKS

WHY:
- PRIMARILY A SIGNIFICANT INCREASE IN BACKLOG BASED ON NEW COMMERCIAL AND MATURING MILITARY PROGRAMS.
- INABILITY OF INDUSTRY TO INCREASE PRODUCTION TO SUFFICIENT LEVEL.
- SHORTAGE OF RAW MATERIAL SUCH AS TITANIUM AND PH13-8MO

AVAILABLE SOURCES:
- HUNDREDS OF FASTENER MANUFACTURERS OF ALL SORTS
- LESS THAN TWO DOZEN CONCENTRATE HEAVILY ON AEROSPACE FASTENERS
- MCAIR HAS AT LEAST THREE SOURCES ON MOST OF ITS FASTENER REQUIREMENTS
- NEW COMPANIES INTERESTED, DESPITE LONG AND INVOLVED QUALIFICATION TESTING AT MCAIR, WOULD SHOW MORE INTEREST IF MCAIR WOULD GUARANTEE THEIR SUPPLY OF RAW MATERIAL.

MCAIR ACTIONS:
- PROCUREMENT OF MACHINE EQUIPMENT TO FABRICATE FASTENERS IN-HOUSE
- INCREASE USAGE INVENTORY ON HAND BY BUILDING UP A PROTECTIVE STOCK
- CONSTANT CHECKING OF OTHER SOURCES TO BUY SHORTAGE ITEMS
- FIRM QUANTITY BUYING THRU CALENDAR YEAR 1982
- PROCUREMENT OF EXTRA LONG FASTENERS FOR CUT DOWN IN-HOUSE TO ELIMINATE CRITICAL SHORTAGES

THE FUTURE:
- MCAIR ACTIONS HAVE ELIMINATED LINE STOPPAGE SITUATIONS
- WITHOUT SIGNIFICANT COMMERICIAL CANCELLATIONS OR STRETCHOUTS, LEAD TIMES WILL NOT SIGNIFICANTLY CHANGE
- TREND IS BRIGHTER AS ALL MANUFACTURERS ARE CONTINUING TO INCREASE CAPACITY

24 June 1980

SUBJECT: LEAD TIMES - STANDARD PARTS - AEROSPACE FASTENERS AND VARIOUS ELECTRICAL COMPONENTS

ITEMS LISTED BELOW ARE THE ACTUAL AVERAGE LEAD TIMES, AS RECEIVED BY MCAIR, AND STATED IN WEEKS AFTER RECEIPT OF ORDER (ARO) FOR THE YEARS 1978, 1979 AND 1980 (THRU JUNE) AND ESTIMATED LEAD TIMES FOR 1981.

COMMODITIES:	YEARS '78	'79	'80	'81
BACKSHELLS (BENDIX ONLY)	16	28	36	32
BACKSHELLS (EXCEPT BENDIX)	18	22	28	26
BOLTS AN	14	32	34	32
BOLTS NAS	14	32	42	40*
BOLTS - HI-TORQ	22	46	52	46*
BOLTS - 12 POINT	21	39	49	44*
BOLTS - ROCKWELL	22	52	52	48*
BOLTS - SPEC (3M & ST3M)	24	39	47	44*
BOLTS, TIT HEX HD	16	52	56	48*
BUSHINGS	28	35	40	40*
CAPACITORS	18	25	34	32
COLLARS, HI-LOK	21	42	52	48*
CONNECTORS, ELEC-CYLINDRICAL				
AMPHENOL	18	64	55	42*
BENDIX	22	34	36	36
CANNON	20	39	37	36
DEUTSCH	24	30	30	30
MATRIX	16	46	43	42*
NULINE	16	30	35	36
OTHERS	18	30	32	32

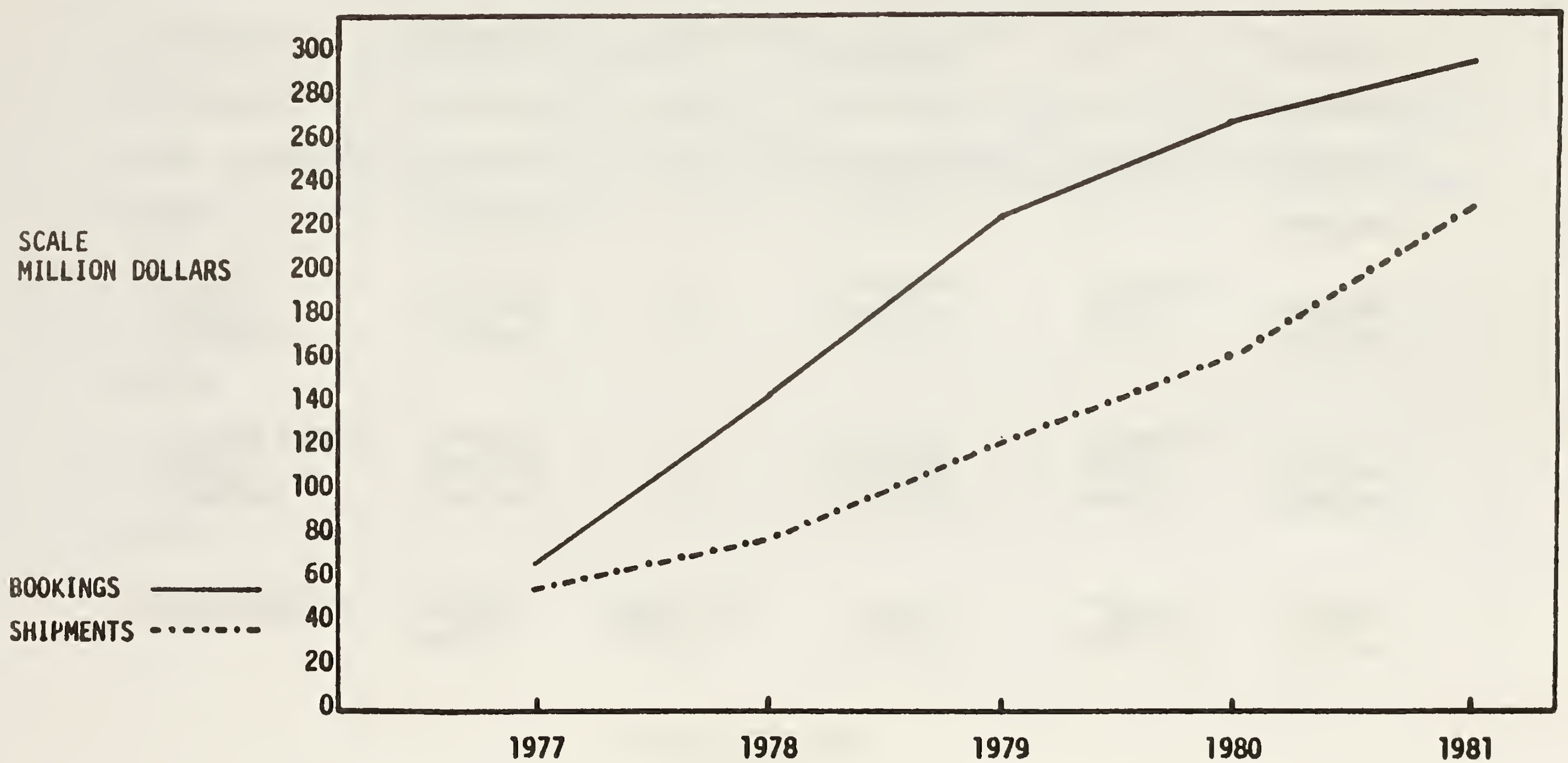
COMMODITIES:	YEARS '78	'79	'80	'81
CONNECTORS, ELEC, COAX	16	22	26	24
CONNECTORS, ELEC, MISC.	16	29	36	34
CONTACTS, ELEC	24	29	32	32
DIODES-TRANSISTORS	12	17	24	22
FASTENERS, BLIND/MILSON	15	24	28	26
FASTENERS, DZUS/MONADNOCK	12	18	24	24
FASTENERS, PANEL	14	20	40	36
FLASHER	36	52	52	52*
GROMMETS-SPEC (9M & ST9M)	8	16	24	22
HI-LOK PINS	22	42	52	48*
HI-TIGUE PINS	22	42	52	48*
JO-BOLTS	18	26	30	28
LOCK BOLTS	19	21	48	46*
MICRO CIRCUIT	24	46	46	46*
NUTS - AN	12	30	38	36
NUTS - ESNA	30	50	54	54*
NUTS - MS	14	30	38	38
NUTS - SPEC (3M & ST3M)	30	50	50	50*
NUTS - STOP	16	32	40	40*
NUTS -(NEW CALL-OUT) ANY MFG	30	52	56	56*

COMMODITIES:	YEARS '78	'79	'80	'81
PINS	12	19	24	20
RELAYS	30	36	38	38
RESISTORS	10	22	22	22
RESISTORS (RNR HERMETIC)	18	30	32	32
RETAINER - KAYNAR	22	42	42	42*
RETAINER - SPS	22	30	42	42*
RIVETS - BLIND	18	28	28	26
RIVETS - HI-SHEAR	25	30	36	34
RIVETS - OLYMPIC LOK	22	28	30	30
RIVETS - SOLID	10	15	18	18
SCREWS - NAS & FREARS RECESS	22	36	40	40*
SENSOR	30	42	42	42*
SLEEVES, METALIC	11	20	26	24
SPACER - STD	26	28	26	24
SWITCHES - PROXIMITY	48	52	52	52*
TAPER LOK SYSTEM	20	41	48	46*
TRANSDUCER	16	24	24	24
TRANSFORMERS	24	30	30	30
WASHERS (ST4M-3M-9M)	10	36	46	46*

NOTE: * ITEMS CONTRIBUTING TO INCREASED 1980 LEAD TIME

FASTENERS-AEROSPACE

CURRENT DOLLARS
NOT ADJUSTED FOR INFLATION



COMPOSITE AVERAGE OF TWO MAJOR FASTENER SUPPLIERS FOR MCAIR.
NO TOTAL INDUSTRY DATA CAN BE OBTAINED.

LEAD TIME ANALYSIS

RAW MATERIAL

AIR FRAME BEARINGS

BEARING TYPE	MCAIR USAGE	ACTIVE SUPPLIERS	SUPPLIER TREND	LEAD TIME WEEKS	LEAD TIME TRENDS
BALL					
STANDARD	CONSTANT	2	DECREASE	48-56	CONSTANT
SPECIAL	CONSTANT	1	DECREASE	48-56	CONSTANT
HI TEMP (600F+)	INCREASE	?	DECREASE	NO QUOTE	
ROLLER					
STANDARD	CONSTANT	2	CONSTANT	52-82	CONSTANT
SPECIAL	INCREASE	2	CONSTANT	52-82	CONSTANT
HI TEMP	INCREASE	2	CONSTANT	NO QUOTE	
NEEDLE	CONSTANT	2	CONSTANT	52	CONSTANT
METAL TO METAL	DECREASE	5	CONSTANT	40-58	CONSTANT
TFE SPHERICAL	INCREASE	6	INCREASE	40	CONSTANT
TFE JOURNAL	INCREASE	3	INCREASE	40	CONSTANT

AVAILABLE SOURCES:

- NUMBER OF TOP QUALITY AIR FRAME BEARING MANUFACTURERS IN THE UNITED STATES IS VERY LIMITED
- SEVEN (7) MAJOR COMPANIES THAT SUPPLY MCDONNELL DOUGLAS ARE:
  - MCGILL
  - FAFNIR
  - TORRINGTON
  - TRW BEARING DIVISION
  - NEW HAMPSHIRE BALL BEARING
  - TRANSPORT DYNAMICS DIVISION OF LEAR SIEGLER
  - KAHR BEARING DIVISION OF SARGENT INDUSTRIES
- MCAIR CONSTANTLY IN THE MARKET PLACE IN SEARCH OF NEW QUALIFIED SOURCES

LEAD TIME ANALYSIS

RAW MATERIAL

AIR FRAME BEARINGS (CONTINUED)

MAJOR CONCERNS:

- SPECIAL BALL BEARINGS I.E. HI TEMP BALL BEARINGS
- USAGE OF SPECIAL BALL BEARINGS IS LIMITED, SINGLE SUPPLIER WE NOW HAVE IS BECOMING INCREASINGLY RELUCTANT TO TOOL FOR AND SUPPLY.
- HI TEMPERATURE BALL BEARINGS USAGE WILL INCREASE AS VSTOL AIRCRAFT THAT EMPLOY THRUST VIECTORING GO INTO PRODUCTION
- MOST HIGH TEMPERATURE BEARING ALLOYS CONTAIN COBALT OR OTHER SPECIALTY METALS
- QUANTITIES INVOLVED AS WELL AS WORLD SITUATIONS AFFECTING AVAILABILITY MAKE QUOTATIONS OF PRICE AND DELIVERY EXTREMELY DIFFICULT AND MOST SUPPLIERS PREFER NOT TO PARTICIPATE.

ELECTRICAL CONNECTORS (CYLINDRICAL)

1978	LEAD TIME	18 - 24 WEEKS
1980	LEAD TIME	32 - 55 WEEKS
1981	ESTIMATED LEAD TIME	30 - 42 WEEKS

BACKGROUND:

- MCAIR IS ONE OF THE LARGEST USERS OF MIL-C-38999 ELECTRICAL CONNECTORS IN THE UNITED STATES.
- ANNUAL EXPENDITURE OF APPROXIMATELY 3 MILLION DOLLARS TO SUPPORT PRODUCTION REQUIREMENTS OF F-15, F-18 and AV-8B PROGRAMS.
- SINGLE MIL-SPEC REPRESENTS APPROXIMATELY 85% OF MCAIR USAGE ON CYLINDRICAL CONNECTORS.

AVAILABLE SOURCES:

- FIFTY (50) ELECTRICAL CONNECTOR MANUFACTURER'S IN THE UNITED STATES
- NOT MORE THAN A DOZEN HEAVILY INVOLVED IN AEROSPACE INDUSTRY
- ONLY THREE (3) SOURCES QUALIFIED TO MIL-C-38999 (BENDIX, AMPHENOL, ITT, CANNON)
- THREE (3) NEW SOURCES (DEUTSCH, MATRIX SCIENCE, PLESSEY AIRBORNE) ARE ATTEMPTING TO QUALIFY.

MCAIR ACTIONS:

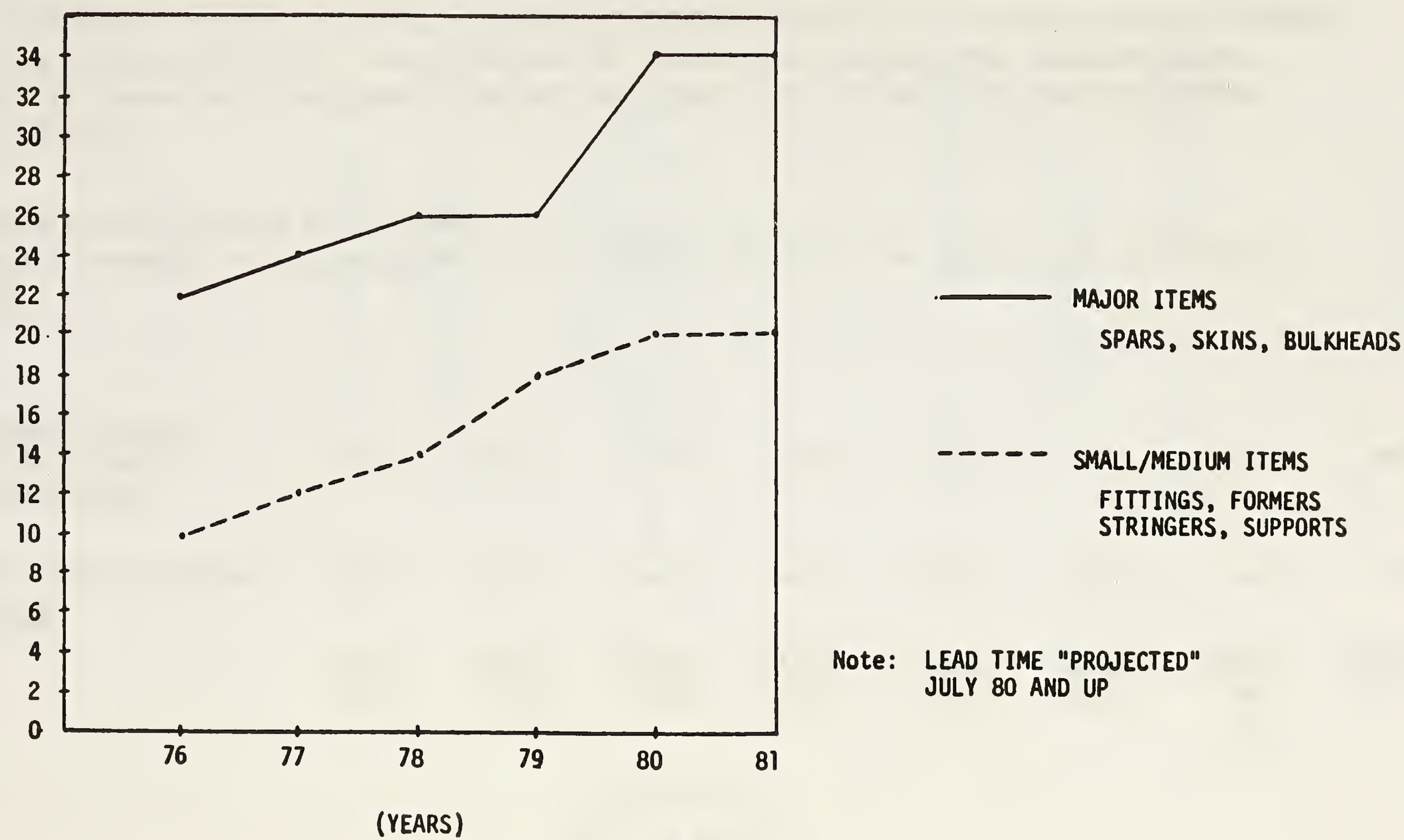
- MCAIR FOR THE PAST TWO (2) YEARS HAS MADE ITS ANNUAL PRODUCTION BUY SIX (6) MONTHS EARLY TO PROTECT PRODUCTION SCHEDULES.
- CRITICAL SHORTAGES IN PRODUCTION ITEMS HELD TO A MINIMUM

THE FUTURE:

- EXISTING SOURCES CONTINUING TO IMPROVE AND EXPAND CURRENT PRODUCTION CAPABILITIES IN ORDER TO MEET INFLUX OF NEW BUSINESS OVER PAST TWO (2) YEARS.

LEAD TIME ANALYSIS

MACHINED PARTS



Note: LEAD TIME "PROJECTED" JULY 80 AND UP

LEAD TIME ANALYSIS

MACHINED PARTS

	1976 (WEEKS)	1977 (WEEKS)	1978 (WEEKS)	1979 (WEEKS)	1980 (WEEKS)	1981 (WEEKS)	1976 TO 1981 (WEEKS)	% OF CHANGE
MAJOR ITEMS								
° SPARS, SKINS, BULKHEADS	20-22	22-24	24-26	24-26	30-34	30-34	+12	54
SMALL/MEDIUM ITEMS								
° FITTINGS, FORMERS, STRINGERS, SUPPORTS	8-10	10-12	12-14	16-18	18-20	18-20	+10	100

W29-41

LEAD TIME

EXPECTED TO REMAIN THE SAME IN FY81 AND FY82. INCREASED AVAILABILITY OF MACHINE TOOLS IS EXPECTED TO PREVENT FURTHER EXTENSION OF LEAD TIMES.

SOURCES AVAILABLE

CURRENTLY, APPROXIMATELY 250 SOURCES AVAILABLE FOR MACHINED PARTS, OF WHICH THERE ARE RESTRICTIONS BY TYPE OR SIZE OF EQUIPMENT. THIS QUANTITY IS AN INCREASE OVER PREVIOUS YEARS, PRIMARILY BECAUSE OF A SUBSTANTIAL INCREASE IN MINORITY SUPPLIERS PLUS INCREASED AVAILABILITY OF SOURCES NORMALLY SERVING THE AUTOMOBILE INDUSTRY.

LEVEL OF RESPONSIVENESS

- OVERLOAD IN THE MACHINED PARTS AREA BECAUSE OF THE HIGH LEVEL OF COMMERCIAL AIRCRAFT COUPLED WITH A SEVERE NATIONWIDE SHORTAGE OF TRAINED MACHINISTS.
- RELATIVELY SMALL QUANTITIES PURCHASED FOR FIGHTER AIRCRAFT IS NOT ATTRACTIVE TO SUPPLIERS.
- COMMERCIAL WORK IS GENERALLY EASIER TO PRODUCE AND MORE PROFITABLE. MULTI YEAR CONTRACTS ARE AVAILABLE WHICH GREATLY FACILITATES THE SUBCONTRACTORS FORWARD PLANNING FOR MACHINE TOOLS, PERSONNEL AND REAL ESTATE.

CONCEPT PROPOSAL

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WASHINGTON REPRESENTATIVE

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Submitted by

Strategic Materials Center
Metallurgy and Materials Science Division
Denver Research Institute
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Dr. Jim D. Mote, Head, Metallurgy
and Materials Science
Division

Dr. Dhanesh Chandra, Head,
Strategic Materials Center

25 November 1980

Background:

Metals such as chromium, cobalt, titanium, nickel, manganese, tungsten and vanadium are strategic to the U.S. economy and national security, yet the United States is increasingly dependent upon foreign sources. The high temperature materials used in the construction application of jet engines, aircraft and equipment for military and industry are dependent on the supplies of the above mentioned metals. Most of these critical metals and ores are imported from many of the African and Eastern Block countries, and due to the inadequacy of the supply of these materials, reasons for the development of our own resources are impelling. The reduction or periodic curtailment of the metal supply from foreign sources, in particular from politically unstable countries, will make utilization of our low grade domestic sources to extract metals and recycling scrap metal more important from a contingency point of view.

The overall objective of this proposed research program is to 1) develop methods of extraction of strategic materials from low grade non-economic domestic reserves. 2) To evaluate the reserves of the low grade ore of critical materials and compare to the material requirements. 3) Evaluate the feasibility of substitution of non-critical materials for strategic materials. 4) Develop methods for recycling scrap materials to recover key metals.

The Strategic Materials Center (SMC) was organized at the Denver Research Institute to build a sound technological base for the extraction of critical metals from low grade domestic ore reserves. SMC is involved in developing methods for processing ores or low grade reserves to extract strategic metals. For example, the extraction of chromium from the low grade Stillwater chromite reserve in Montana and the extraction of nickel and cobalt from low grade, fine grained complex lateritic ores from California and Oregon has been investigated using the hydrometallurgical approach. Development of extraction methods is dependent on understanding the association of the valuable metals with various minerals in the ores. Optimizing the extractive metallurgical parameters is performed based on data obtained from modern analytical instrumentation such as electron microscopy and X-ray analysis that can characterize the feed material and also structural changes in the intermediate and final products obtained in the various stages of a proposed extraction method.

It is proposed that practical methods, either pyrometallurgical or hydrometallurgical, be developed to extract strategic materials such as chromium, cobalt, manganese and titanium from domestic reserves in order to maintain a resource base for either contingency requirements or for future use. Another aspect will be the evaluation of reserves in this country and improvement of recycling technology. Details of import dependence are shown in the bar graph of the attached SMC brochure. The following sections concern some important strategic metals and their import dependence.

Chromium: The major use is in the production of stainless steels. Chromium imparts hardenability, creep and impact resistance to the steels. The major source of chromium or ferrochromium is from chromite($FeCr_2O_4$) mineral. The chromium ores are predominantly found in the continent of Africa. The imports are primarily from South African countries, the Soviet Union and, to a small extent, from Turkey and Japan. The domestic reserves are found in Montana, Oregon, California, Washington and Alaska. All the above ores are of a low grade variety. The extent of the reserve is not fully known; however, estimated values are 22.5 million tons of chromites.

In addition to the above chromite ores, domestic sources include laterites from Oregon and California containing up to 1% nickel, up to .8% cobalt, and up to 2 to 3% chromium. These laterites are currently being utilized to extract nickel and cobalt only. There is also an excellent possibility of extracting chromium from laterites. It is proposed that extraction of chromium from domestic chromites and laterites be investigated.

Cobalt: The major use of cobalt is in heat and corrosion resistant materials, high strength materials and permanent magnets. Major production of cobalt is in the form of sulphide ores. The sulphides are predominantly found in Zaire, Zambia, Finland and Canada and these countries are the largest exporters of cobalt to the U.S. The other source is laterites containing up to 0.8% cobalt with known deposits in the U.S. The domestic reserve is principally a low grade one in Idaho. This reserve is plagued with arsenic inclusion, which poses a problem in the extraction of the metals. Manganese nodules found on the ocean floor are an additional resource. It is proposed that methods to extract cobalt from domestic cobalt reserves, both sulphides and laterites, be further investigated.

Titanium: The major use of titanium is in structural applications in the aircraft industry. The major production of titanium is from rutile (TiO_2) supplied primarily from Australia. The domestic reserves are largely in the form of Ilmenite ($FeTiO_3$). It is proposed that a method of separating iron and titanium be investigated.

Tungsten: The major use of tungsten is in high speed cutting tools, superalloys/and non-ferrous alloys. The major production of tungsten is in Canada, Mexico, Thailand, Korea, and Bolivia. There are limited resources in the U.S., mainly in California and Colorado. It is proposed that methods to beneficiate tungsten ores be further investigated.

In addition to developing methods to extract the above mentioned metals studies are also proposed to evaluate substitution of strategic materials such as cobalt, chromium etc. with some non-critical materials in the high temperature alloy application. Evaluation of the extent of reserve; high and low grade ores of the above mentioned metals will also be performed. For example the cobalt reserves in the United States are predominantly found in Idaho in the form of a sulphide ore. Additional cobalt reserves are also found in Oregon and California in form of laterite. The overall ore reserve will be surveyed and also the possibility of new potential reserves will be evaluated.

<u>Presentation on Titanium</u>

by Ward W. Minkler

NATIONAL MATERIALS ADVISORY BOARD

SEMI-ANNUAL MEETING

September 3, 1980

<u>REVIEW OF MATERIALS AVAILABILITY ISSUES</u>

Of the metals being considered in this two day session, titanium has the advantage of being the newest engineering structural material. We have a shorter commitment to our past mistakes. Since 1950, the start of production, there are three characteristics which make titanium of interest for this assessment of major critical and strategic material availability issues:

1. The industry has exhibited a repetitive pattern of overcapacity, interrupted by short periods when supply has been temporarily insufficient to satisfy customer delivery requirements. The industry is in such a cycle today; since mid-1978 sponge and ingot capacity limitations throughout the world have been one cause for extended delivery commitments. (I presume this is the primary reason for including titanium in this availability study). There is strong evidence that the industry is now entering a more normal period where supply will exceed demand and commercial considerations, selling price rather than delivery commitment, will determine supply source(a conventional buyer's market appears at hand).
2. The commercial production of titanium metal in a competitive multi-source environment was established in the United States in 1950. Since then, the U.S. has been the world leader in the manufacture of titanium metal. Presumably, it is in our national interest to maintain a strong industry because of its importance as a structural metal in current and future commercial airplanes and military systems.
3. Finally, unlike many other strategic metals, dependence on foreign ore sources is not a consideration. The U.S. has sufficient ore and technology to support anticipated critical titanium applications for the foreseeable future. Rather, the titanium supply will be determined by the development of sound markets and the ability of the industry to attract investment for the plants necessary to maintain the most up-to-date efficient production base, compared to our foreign competitors.

In 1980, the bulk of U.S. titanium metal is being manufactured by processes conceived in the 1930's and reduced to commercial practice in the 1950's and early 1960's.

*Ward W. Minkler is Vice President - TIMET Division, Titanium Metals Corporation of America.

Titanium Flow Chart

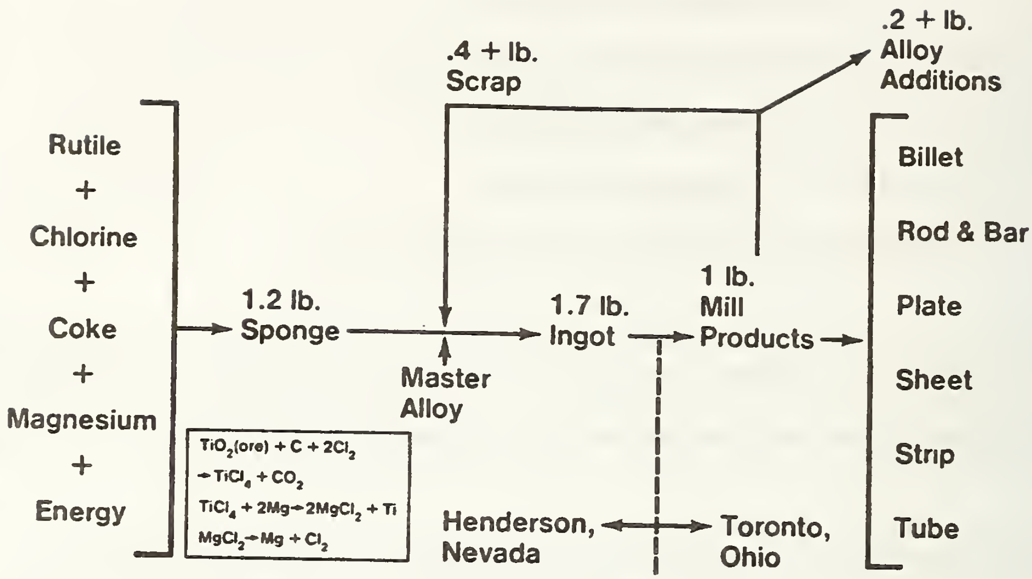

Figure 1

As shown in Figure 1, titanium ore, most generally rutile concentrates, is reacted with chlorine and carbon to form titanium tetrachloride. Alternate methods include mixtures of synthetic rutile and ilmenite, the latter extensively available in the United States. After purification, the tetrachloride is reacted with magnesium to produce titanium sponge and magnesium chloride. While the bulk of titanium sponge throughout the world is produced by reacting the tetrachloride with magnesium, sodium is being used in three plants, one in the U.S., one in the United Kingdom and one in Japan. In most instances, the magnesium or sodium chloride is recycled with only makeup quantities of magnesium or sodium, and chlorine required.

The sponge is purified, then mixed with specially prepared scrap and alloy additions, most frequently aluminum, vanadium, zirconium and molybdenum, then pressed into compacts. The compacts are vacuum-consumable arc-melted into ingots weighing from three to ten tons. Wrought products are manufactured from ingot on conventional shaping equipment such as that used to roll and form steel.

The availability of titanium metal is most frequently equated to sponge capacity. While equipment used for other metals can melt or shape the titanium, a sponge plant can only manufacture titanium and paces availability. It is also the controlling item in determining the cost of a titanium mill product.

One of the characteristics of the titanium sponge plant is the high capital investment compared to other structural metals. This is due to the complexity of the metal winning process coupled with the small plant size.

Sponge drives not only availability but also economics relative to other materials. Ore, melting, rolling and forming are not controlling so long as dramatic demand increases are not required on short notice.

Table I is a summary of 1979 world sponge capacity and includes announced expansions. By 1981, U.S. sponge capacity will have been expanded 28%, Japanese capacity 61% and non-communist world capacity 35%. Further sponge installations are planned and some under construction. These should start producing in 1982-1984. Currently, there are numerous U.S. and foreign titanium sponge ventures under study.

Table I.

World Titanium Sponge Supply For Mill Product Production
(1000 lbs)

	1979	1980	1981	1982-1984
U.S.				
TIMET	25,000	28,000	30,000	32,000+
RMI Co.	14,500	17,000	19,000	19,000
Oremet	4,000	4,500	6,500	7,500
DH Co.	-	-	-	?
Total	43,500	49,500	55,500	
UK				
ICI	5,000	4,000	3,000	-
RR Consortium	-	-	-	11,000
European Consortium	-	-	-	?
Japan				
Osaka	14,000	20,000	29,000	29,000
Toho	12,000	13,000	19,500	19,500
Total	26,000	33,000	48,000	48,500
Non-communist total	74,500	86,500	100,500	
PRC	4,000	6,000	15,000	?
USSR	77,175	92,600	92,600	?

With one exception, the current expansions are incremental additions to producing operations(thus substantially lower cost than new greenfield sponge manufacturing plants). In the U.S., these incremental expansions are the completion of sponge capacity planned for the late 1960's to support the SST, B-70 and The YF12A, but left uncompleted due to the severe downturns of the early 1970's.

This is illustrated in Figure 2. From 1970 to 1978, the U.S. titanium sponge producers operated at a capacity only in one year, 1974, during a period of intensive inventory building by the aircraft manufacturers.

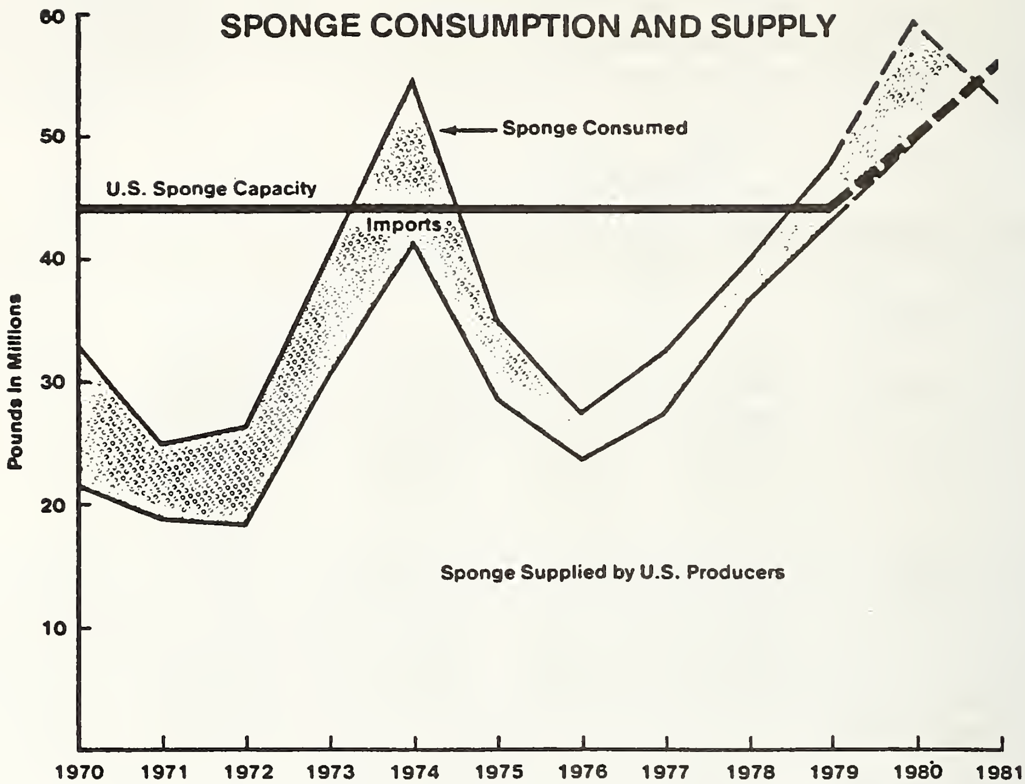

Figure 2

As shown in Table II, foreign sponge producers have historically supplied the non-integrated melters with the bulk of their sponge. In 1980, it is estimated imports may exceed 8,000,000 pounds.

Table II

Sponge Imports
1972-1980
(1000 lbs)

	Japan	USSR	UK	PRC	Total
1972	4,580	2,817	325	0	7,722
1973	5,860	3,179	1,109	0	10,148
1974	5,505	6,897	877	0	13,279
1975	4,638	1,416	359	0	6,413
1976	2,647	632	189	0	3,468

Table II (Cont'd)

Sponge Imports
1972-1980
(1000 lbs)

	Japan	USSR	UK	PRC	Tôtal
1977	3,417	1,410	489	0	5,316
1978	1,632	1,202	227	0	3,061
1979	4,116	660	2	198	4,976
Est. 1980	6,230	712	89	1,869	8,900

The genesis of the titanium industry was the gas turbine engine and its airframe. As shown in Figure 3, the 1979 military and commercial airplane applications still consumed over 75% of the mill products shipped. While industrial applications are expanding, we anticipate that, for the next several years, aerospace will continue to be the backbone of the titanium markets.

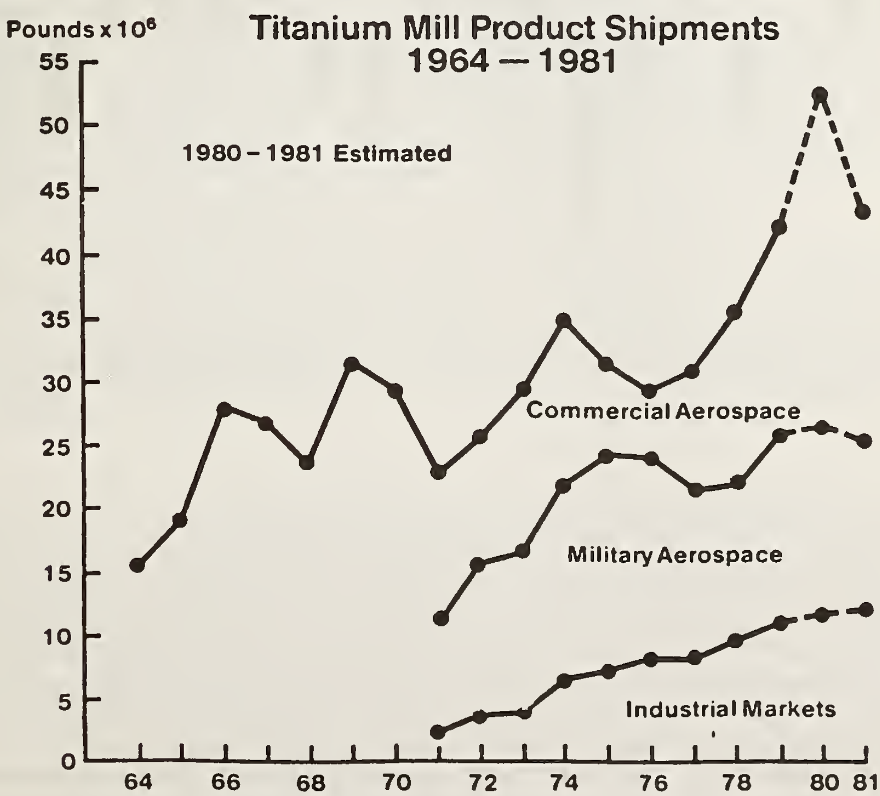

Figure 3

The swings in demand have been unusually severe for a capital intense basic metals business such as titanium. This is illustrated in Figure 4, where I have attempted to show the percentage change in titanium mill product shipments from year to year during 1964-1980. In Figures 3 and 4, I have plotted our lastest 1981 forecasts of mill product shipments. With such rapid changes, planning and operating a titanium venture becomes a challenge. If we have correctly identified and quantified market requirements, there will be an excess of sponge capacity relative to consumption in 1981.

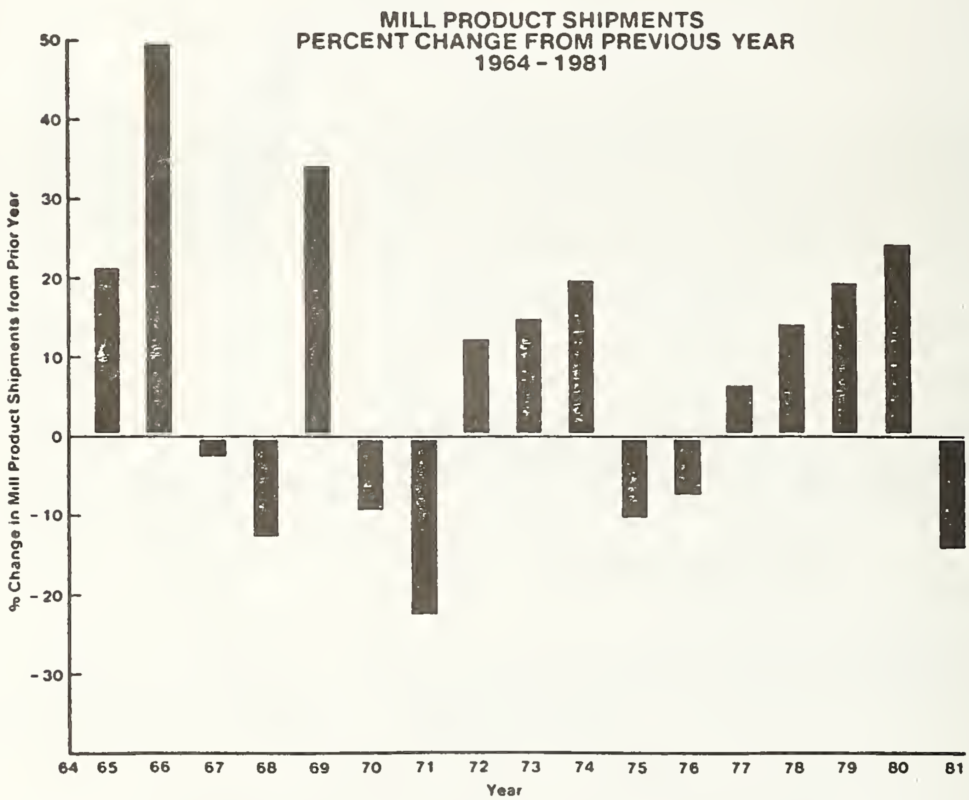

Figure 4

Since 1964, the U.S. has experienced three periods when buying demand has caused lead times in excess of consumer's desires, these were in 1966, 1974 and from mid-1978 to mid-1980. For the purposes of studying material availability issues, I believe it would be helpful to review some factors that were present in 1974 and 1979-1980 to determine their likelihood of recurrence in the foreseeable future. (In this analysis, I have found Bill Swager's excellent study "Periodic Materials Scarcity: Our National De Facto Materials Policy", presented to the Aerospace Technical Council, AIA in April, 1979, to be useful). Mr. Swager quoted the report of the National Commission on Supplies and Shortages published in December, 1976, which listed the following causes of shortages in 1973-1974:

* Sharp demand increases
* Limitations on investment in materials processing industry
* A shortage mentality
* Cutbacks by foreign suppliers and price increases

In 1974 and 1978, the titanium industry was buffeted by all these factors. Based upon grossly overly optimisitc market forecasts in 1968, excessive sponge capacity was installed. Thus, the surge capacity was available to absorb sudden demand increases until 1978. By 1978, the growth of the industrial uses of titanium, coupled with unusually high purchases of commercial airplanes, raised the market to new levels. While the current sponge expansion appears consistant with forecasted markets, the surge capacity of the 1970's no longer exists.

Limitations on investment will influence future titanium expansion. Despite uncertain profitability and high capital investment of the titanium business, incremental additional sponge capacity has been installed reasonably quickly during that shortage period. This, coupled with a following downturn in sales, has satisfied customer availability and commercial demands.

Long periods of idle capital investment have taken their toll of earnings records that would not attract knowledgeable investors. Now the U.S. industry is not faced with decisions on new greenfield capacity. The day is not far off, however, when greenfield plants will be necessary if the U.S. industry is to continue to grow. Financial risks and return potential relative to historical widely fluctuating prices and market demand will be closely assessed. The normal condition in the titanium industry has been overcapacity. This has led to product prices insufficient to justify new capacity. Prior to past incremental expansions, the titanium market demand has been strong; producers could raise prices sufficiently to justify rapid incremental expansion.

However, the lead time for new greenfield capacity is substantially longer, three to five years, and much more costly. Attracting private investment in view of historical overexpansion and the cyclical market history of titanium will be a challenge; a problem that this forum might consider, particularly if the anticipated increased demand is based upon programs considered to be in the national interest.

It appears the shortage mentality has influenced overbuying in 1974 and in the present cycle. Because of the limited number of suppliers, the small size of the industry and the engineering necessity of titanium as an aerospace structural material, buyers are obviously sensitive to availability. This leads to aggressive procurement practices and inventory accumulation in excess of that actually needed to support true consumption, when a potential tight supply is perceived. The abnormal inventory buildup in 1974 then caused severe reduction in titanium purchases in 1975 and 1976. There is mounting evidence this has occurred in 1979 and 1980 and is one of the reasons for the forecasted downturn in titanium mill product shipments in 1981.

Cutbacks and price increases by foreign sponge suppliers were, to some extent, a factor in the most recent titanium shortage. Until recently, foreign sponge was available at prices lower than domestic sponge; at times lower than domestic costs. This discouraged investment in new sponge capacity and encouraged the growth of the non-integrated domestic ingot producers with modest capital investment who were willingly dependent on the lower cost foreign sponge.

However, in 1978, the foreign sponge producer was faced with a new situation. Energy costs had increased. Demand for titanium external to the United States, particularly in the industrial markets for products more profitable than sponge, increased; 1978 and 1979 pruchase contracts were made based upon the depressed markets in 1976 and 1977. The Japanese producers diverted their production to other markets. The USSR ceased exporting, apparently for unrelated reasons. Foreign sponge exports to the U.S. fell dramatically during a period of high market demand.

In 1980, the non-integrated melter, representing approximately 25% of the U.S. ingot capacity will import a record quantity of sponge from Japanese sponge producers currently at prices double that of 1978. This expanded foreign capacity will again influence U.S. producers' sponge expansion plans, particularly if a strong buyer's market develops breeding historical price degredation.

In concluding, I would like to identify some of the issues facing the titanium industry which will affect the availability of titanium from U.S. producers, as well as the strength of our industry relative to our overseas competitors.

1. By next year, the domestic industry will have sufficient sponge capability to provide 48 million pounds of mill products. With present ingot melting capacity and expansions now underway, the integrated and non-integrated domestic melters will have the ability to ship 65 to 70 million pounds of mill products, 60% higher than last record year, 1979. With foreign sponge expansions, the titanium industry may be faced with overcapacity for the near term rather than under supply, with the attendant commercial problems.

2. As I stated previously, the world industry has been highly cyclical. Except for short periods of undercapacity, profitability of sponge producers has been poor. Despite this, the U.S. industry has responded to increased demand for overexpanding. These shortage periods resulted in short term profits used for these incremental expansion investments. Non-market related factors such as price controls, suspension of tariffs that encourage a temporary surge of foreign imports, or subsidies by the U.S. users to new foreign sponge producers, will stunt future domestic incremental expansions.

3. Despite tariff protection, the uncertain commercial priorities of foreign sponge producers in the United States market has made domestic sponge producers wary. In view of the foreign expansion now underway, or being discussed, the environment is ripe for another such cycle.

4. The bulk of the U.S. sponge plants were based upon process designs of the 1950's and 1960's. Foreign sponge plants have been more recently installed and could be expected to have operating cost advantages. The product quality of these foreign sponge manufacturers is preferable to the non-integrated ingot manufacturers. At some time in the future, assuming the demand for titanium continues to grow at the historic rate, 7% per year, new greenfield plants will be required. Do we duplicate magnesium or sodium reduction cycles or do we commit to a more promising but commercially untested method, such as electrowinning? These decisions will be required soon, particularly if we assume the three to five year period normally required to engineer and construct a new reduction plant. This choice can determine the competitiveness of the U.S. industry for the latter part of this decade and certainly well into the 90's.

5. If it is determined to be in the national interest to expand titanium production beyond that which valid demand forecasts would dictate, some form of government financial encouragement would be considered appropriate. Underlying this decision could be a temporary increase in titanium required for defense related projects or for stockpile purchases. This encouragement could involve:

   a. Multi-year material commitments for defense-related contracts that would allow for appropriate cancellation reimbursement to the titanium producer for cost of capital equipment, inventory accumulation and loss of revenue, as a result of the cancellation.

   b. An indexed stockpile procurement program which contains multi-year purchase contracts to fill stockpile objectives. Purchases would be made when domestic sponge demand fell below a pre-established percentage of domestic capacity and be suspended when demand exceeded these levels. One of the factors weighted in contract awards could be encouragement to construct new or upgraded manufacturing plants.

The future of the U.S. titanium industry will depend on the confidence of producers and investors in an acceptable return on investments, titanium's competitiveness as an engineering metal and supportive government policies. Unlike many other strategic metals, the selectivity of nature will not be a factor.

February 23, 1981

AMERICAN
INSTITUTE OF
AERONAUTICS AND
ASTRONAUTICS

Reid June
1603 121st Ave SE
Bellevue, WA 98105

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B308
Washington, D.C. 20234

Reference: Federal Register, Vol. 46, No. 61, Friday, January 9, 1981, pp 2375 - 2376.

Dear Dr. Wachtman:

The attached letter, written by a member of the Materials Technical Committee, American Institute of Aeronautics and Astronautics, is submitted relative to your study of aerospace industry materials needs.

Sincerely,

Reid R. June, Chairman
Materials Technical Committee

Attachment

Letter by Dr. Hallse

cc: Johan Benson
American Inst. of Aeronautics and Astronautics
1625 Eye Street
Washington DC 20006

GENERAL DYNAMICS
Pomona Division
P. O. Box 2507, Pomona, California 91766 • 714-629-5111

cp
6-114-00242
13 February 1981

Dr. Reid R. June
1603 121st S.E.
Bellevue, Washington 98005

Dear Reid:

The following comments are offered in response to the Department of Commerce Workshop on Materials held on February 10 & 11.

It is suggested that the impact of import disruptions of the following four metal ores be examined:

1. Cobalt
2. Chromium
3. Manganese
4. Beryllium

The supply disruptions should be postulated for the following time periods:

1. 3 months
2. 10 months
3. 30 months
4. 100 months

Next assume that the disruptions reduce our imports by the following quanities, as compared to the average level for the period 1978-1980:

1. 25% reduction
2. 50% reduction
3. 75% reduction
4. 100% reduction

It is suggested that the following two parallel approaches be studied as possible methods of minimizing the shortage impact without involving a cumbersome government allocation agency.

I

DOD would instruct the prime contractors for critical programs to stockpile sufficient ore, ingots, or slabs of designated critical metals, on their property, to satisfy 125% of their contractural commitments for the four time periods specified above. The carrying charges (interest), additional facilities and security

GENERAL DYNAMICS
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would be valid charges against the contract(s). In time of shortage the DOD primes would release their holdings, as required, on a custom toll basis to the metal producers for the required products. Any prime contractor who fails to provide himself with a sufficient stockpile would be forced to purchase the ore or metal on the open market without reimbursement from DOD.

II

Develop in the laboratory, and in pilot plant quantities, alloys and processes that are substantially free of the critical metals problem. This would be a 5 to 10 year program adequately funded by DOD. At the end of the 10 year program DOD would subsidize a metal industry base sufficient to produce, say, 25% of the required critical metal substitutes. This subsidy would be similiar in goal, but not necessarily in form, to the present agriculture maritime, and synthetic fuel programs.

The above comments are addressed to import shortages caused by political turmoil or hastily, military action where the U.S. may or may not be directly involved and foreign cartel actions. Shortages may also result from a lack of national production capacity, environmental and safety regulations and local and state ordinances. While shortages, regardless of cause, are very real in that needed hardware is delivered late and beyond budget; the case of import disruptions is of critical national import and not necessarily solvable by U.S. diplomatic, economic or military pressures. The latter shortage problems such as production capacity, etc result from domestic internal policies and therefore solvable by changing these policies and therefore should not be lumped or treated in the same manner as the import disruption problems.

Incidentally, Colonel Jim McCormack of the Air Force, who is currently stationed in Washington is studying the effect of shortages on tactical missile systems. He is planning to visit me in late March to discuss such shortages on our product lines here. Anything I can learn about his study I will convey to you in Atlanta in April.

Sincerely,

R. L. Hallse

R. L. Hallse

February 18, 1981

AMERICAN
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ASTRONAUTICS

Reid June
1603 121st Ave SE
Bellevue, WA 98105

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B308
Washington, D.C. 20234

Reference: Federal Register, vol. 46, no. 61, Friday, January 9, 1981, pp 2375 - 2376.

Dear Dr. Wachtman:

The attached letter, written by a member of the Materials Technical Committee, American Institute of Aeronautics and Astronautics, is submitted relative to your study of aerospace industry materials needs.

Sincerely,

Reid June

Reid R. June, Chairman
Materials Technical
Committee

Attachment

Letter by Dr. Crossley

Lockheed
MISSILES
& SPACE
COMPANY,
INC.

10 February 1981

Dr. Reid June, 41-37
Boeing Military Airplane Company
P. O. Box 3707
Seattle, Washington 98124

Dear Dr. June:

<u>Titanium Forgings Concerns</u>

A single act can simultaneously contribute to several goals related to the use of titanium forgings. Specifically, utilize new alloys which make it possible to go to net shape or near net shape technologies. Since current forging practices applied to the most used titanium alloy, Ti-6Al-4V are characterized by buy-to-fly weight ratios varying from 4:1 to as high as 50:1, there is the prospect of increasing the forging billet production capacity of the titanium industry (in terms of fly away weight) by at least a factor or two, and perhaps as much as a factor of four, by doing this. The net shape/near net shape technology that is being given the most attention at the present time is powder metallurgy. However, preliminary test results indicate that precision casting and net shape or near net shape isothermal forging or hot die forging offer greater promise. The latter processes married to new alloys provide under some loading conditions performance equal or superior to wrought, solution heat treated and aged Ti-6Al-4V. The new alloys are: Ti-10V-2Fe-3Al Transage 134 (Ti-2Al-12V-2Sn-6Zr) and Transage 175 (Ti-2.5Al-13V-7Sn-2Zr). Ti-10V-2Fe-3Al can be isothermally forged at temperatures as low as 1400°F (760°C) and the Transage alloys can be isothermally forged at temperatures as low as 1100°F (600°C). An isothermal forging temperature of 1400°F permits the use of relatively cheap, iron-base, hot work, tool steels for dies. Cast-to-size bars of Transage 175 alloys have demonstrated fatigue resistance superior to that of wrought, solution treated and aged Ti-6Al-4V under the following test conditions: (1) smooth bar axial, low cycle fatigue (10^5 cycles), R = 0, at 500°F (260°C); and smooth and notched bar high cycle fatigue axial (10^7 cycles), R = -1.0, at 250°F (120°C). Transage 175 was approximately equal in fatigue to wrought, solution treated and aged Ti-6Al-4V in axial, low cycle fatigue (10^5 cycles), R = 0, at 250°F. Obviously, these technologies will reduce costs of titanium components as well as conserve material and energy.

The TIMET Division of Titanium Metals Corporation of America developed the Ti-10V-2Fe-3Al alloy and is actively promoting it. The Transage alloys are a proprietary Lockheed Missile & Space Company development; therefore, they may be unknown to you. To acquaint you with their properties and characteristics, several papers are enclosed. Lockheed wishes to license the Transage alloys for general use.

1111 LOCKHEED WAY • SUNNYVALE, CALIFORNIA • 94086

Dr. Reid June 10 February 1981

Any plans on the part of the Navy to produce titanium submarines should be very carefully coordinated with the titanium industry. Such use could impact supply in a catastrophic way unless planning and scale up of capacity preceeds building by several years. Each Soviet Alfa submarine hull reportedly uses 6000 tons of titanium -- about one third of the 1978 US mill shipments of titanium.

Sincerely,

Frank

Frank A. Crossley
Consulting Engineer
Orgn. 81-04/Bldg. 154

FAC/rl

cc: FAC file

Attachments

February 26, 1981

AMERICAN
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Reid June
1603 121st Ave SE
Bellevue, WA 98105

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B308
Washington, D.C. 20234

Reference: Federal Register, Vol. 46, No. 61, Friday, January 9, 1981, pp 2375 - 2376.

Dear Dr. Wachtman:

The attached information, received from members of the Materials Technical Committee, American Institute of Aeronautics and Astronautics, is submitted relative to your study of aerospace industry materials needs.

Sincerely,

Reid R. June, Chairman
Materials Technical Committee

Attachment

NASA TM Abstract
Brazel Letter

cc: Johan Benson
American Inst. of Aeronautics and Astronautics
1625 Eye Street
Washington DC 20006

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY........................3198 CHESTNUT STREET
PHILADELPHIA, PENNSYLVANIA 19101, Phone (215) 823-1000

RE-ENTRY
SYSTEMS
DIVISION

19 February 1981

Dr. Reid R. June
Mail Station 41-37
Chairman, AIAA Materials Technical Comm.
Boeing Military Airplane Company
P.O. Box 3707
Seattle, WA 98124

Dear Reid:

In response to your letter of February 4, on shortages of aerospace strategic materials, I wish to point out the U.S.'s position in regard to supply of high purity silica fibers.

These fibers, known as "fused quartz fibers" are used in the current S.O.A. hardened antenna window composite materials AS-3DX (Ford Aeronutronic) and ADL-4D6 (GE-RSD). High purity fused silica fibers are also used in premium quality strategic missile TPS (heatshield) material components.

There only two sources of this fiber in the U.S., both of them resellers of fiber imported from France. The domestic suppliers are J.P. Stevens, Inc. ("Astroquartz") and AAI Products, Inc. ("Alphaquartz"). The silica fiber comes in the form of roving, on spools and is produced in France. The French in turn get their raw high purity quartz from Brazil (the country in South America, not Jim Braz<u>e</u>l of GE-RSD, Philadelphia).

There have been attempts to establish a U.S. source of this truly critical material. GE/RSD set up to produce about ten years ago but could not penetrate the already established market for J.P. Steven's Astroquartz (specs, previous arrangements, price, whatever).

I hope that this brief review of the situation is of interest to and use for you. I have kept it unclassified, but as the need develops, additional detail could be supplied. Please call me if you have questions.

Sincerely,

Jim Brazel

James P. Brazel, Manager
Materials Characterization Lab.
Member, AIAA Materials Technical Committee
(215) 823-2306

/am
cc: P. Gorsuch/GE-RSD
J. Dignam/AMMRC

CANNON-MUSKEGON CORPORATION
BOX 506 MUSKEGON, MICHIGAN 49443
616/755-1681 — TWX 510/394/4620

16 March 1981

Mr. Russell Babcock
Bear Creek Mining Company
7821 E. Sprague Avenue
Spokane, WA 99213

Subject: Critical Materials Needs in the Aerospace Industry Workshop

Dear Mr. Babcock:

First, my apologies at not attending the recent Critical Materials Workshop which you chaired in Washington. Unfortunately, the notice of this meeting was received rather late and I had overseas travel plans already formulated which could not be changed. I will, however, comment on the actions and recommendations which resulted from the Workshop.

Private Stockpiles

The entire idea of private stockpiling of strategic raw materials is totally unrealistic in economic concept. There are several reasons for my strong expression in this regard, and I'm particularly shocked and disappointed that you, as a representative of private industry would even consider the initiation of Federal Government involvement and audit of your firm's and others' inventories.

If you are to involve the Government into raw material inventory, this would also lead to finished goods inventory as raw material is a significant portion. As a mining company, you are perhaps only concerned with finished goods; however, a using company, such as an alloy producer, will have raw material units in both raw material and finished goods. This could result in serious government interference and involvement in the operation of a company.

The Federal bureaucracy has demonstrated time and again its ability for managing and operating enterprise. The Post Office and the Energy Departments are two examples which immediately come to mind. The administration of the strategic Stockpile is another. The Government has a proven record for buying low and selling high as well as providing great impact to the critical supply and demand balance of the marketplace. Many of the recent metal shortages can be traced directly to erratic Stockpile manipulations; specifically, cobalt, molybdenum, tantalum, columbium, tungsten, and others.

Firms which are in the business of producing critical high temperature superalloys, such as Cannon-Muskegon, are strongly raw material cost oriented, with low value added in the finished product. Approximately 70% of the product resale price is raw material value. It is not viable, economically, for such a firm to maintain any substantial raw material

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inventory under such a basis. No tax incentive program could be envisioned which would or could accommodate such a program at the alloy producer level.

So, the next step is the basic metallic element producer. In this case one must consider foreign producers such as Inco (Canada), Roan Consolidated Mines (Zambia), Le Nickel (France), Outokumpu Oy (Finland), etc. How interested do you think these major foreign-based firms will be in American tax incentives? Further, no material producer likes stockpiles, It always represents a significant weight overhanging a critically balanced market which could (and has) have a major impact at the marketplace.

The next direction is more toward the finished product. The bulk of the buyers of specialty high temperature alloys are either very large companies, such as TRW or Howmet, or very small (less than 100 employees), privately-held, owner/manager companies. Such a program would completely isolate the many small companies from participating due to lack of financial ability and working capital constraints. Also, small entrepreneurial companies are generally more possessed of personal pride than larger firms and would be expected to reject such Federal involvement and intervention even more vehemently than I am doing.

The prime OEM producers of the product are the next step in the chain: the producers of the gas turbine engine (in the case of high temperature superalloys). These are usually large companies with significant financial strength, i.e. General Motors (Allison), Signal Oil (Garrett), United Technology (Pratt & Whitney), General Electric, Avco Lycoming, etc. Such firms have the financial strength, some would claim, to maintain strategic stockpiles (although they may argue this point). The primary fault in this scheme, beyond the financial, is technological in nature. By the establishment of private raw material stockpile levels with tax incentives, the financial directors will tend to dictate alloy selection and ultimately stymie technological innovation.

<u>Role of Government</u>

There is one important aspect relative to the role and intent of government which we should not lose sight of. The primary function of any government is to provide for military defense. This is the original basis and purpose of central government. Unfortunately, government tries to be all things to all people and has become pervasive in the life of its citizens, extending itself beyond its original intent and purpose.

Strategic critical materials stockpiles are, in my view, part of the military strength of the country, and government should be required to fulfill its responsibility. However, if government sidesteps its military defense and related ancillary roles, it will then become involved in areas which are <u>not</u> governmental functions. My concern is the further

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involvement of government in private industry and the free market economic system, specifically:

inventory control of materials

finished goods audit

price controls of raw materials

profit controls

Government is necessary and important to the continued success of the Country. But, let us all remember what made the Country successful... the economic system of free enterprise and the free market.

Specific Recommendations

My comments are not meant to be negative in character, but constructive. There are several positive steps which can be taken by Government and the Federal Preparedness Agency. These suggestions can provide strong constructive influence for the Nation's preparedness and provide useful high quality raw materials for emergency wartime application. My suggestions are as follows:

1. Reaffirm the intent and purpose of the U.S. Stockpile to meet the needs of the "national defense only and is not to be used for economic or budgetary purposes."

2. Provide for a three (3) year emergency requirement. At the present time, this indicates some materials may be in surplus inventory, specifically cobalt, tungsten, and others. The stated goal of over 85 million pounds of cobalt represents about eight (8) years of total U.S. industry usage based upon current consumption.

3. Establish an on-going program which will annually upgrade 10% of the present stockpile to the highest quality level required by emergency industry critical applications. By this means at least 10% of the material would be usable "instantly" in an emergency. After ten (10) years, the oldest inventory will be of a quality standard only ten (10) years old. The quality level should be high rather than low. The product can always be downgraded in an emergency, but it is not possible to "instantly" upgrade the material,

4. Quantitatively analyze the existing stockpile materials accurately for the known deleterious trace elements which may be present. The results will determine the acceptability for refining the existing stockpile inventory or replacement with current high grade material. Specific elements of concern in cobalt, for example, include:

Pb	As	Cd	Hg
Bi	Se	Zn	Ag
Sb	Th	S	Si

. . . . .

5. Encourage domestic development of mining capacity, providing the product and process can be economically justified by the market-place without government economic guarantees.

6. Do not attempt to use the Federal Preparedness Agency or the Stockpile for economic price control and market regulation/manipulation. The free market will do this far more efficiently and effectively.

I hope these comments are helpful. Please call if further clarification is needed.

Sincerely yours,

CANNON-MUSKEGON CORPORATION

Roger E. Schwer

Roger E. Schwer
President and General Manager

RES/jm

cc: Dr. Allen Gray, American Society for Metals
Mr. James Owens, U.S. Department of Commerce
Mr. Richard P. Seelig, Meta-Tech
Honorable James D. Santini, U.S. House of Representatives
Honorable Carl Levin, U.S. Senate
Honorable Guy VanderJagt, U.S. House of Representatives
Honorable Don Fuqua, U.S. House of Representatives

H

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2d Session

THE AILING DEFENSE INDUSTRIAL BASE: UNREADY FOR CRISIS

REPORT

OF THE

DEFENSE INDUSTRIAL BASE PANEL

OF THE

COMMITTEE ON ARMED SERVICES
HOUSE OF REPRESENTATIVES
NINETY-SIXTH CONGRESS

SECOND SESSION

DECEMBER 31, 1980

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NINETY-SIXTH CONGRESS, SECOND SESSION

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LETTER OF TRANSMITTAL

DECEMBER 29, 1980.

Hon. MELVIN PRICE,
Chairman, Committee on Armed Services,
House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: I am forwarding to you a copy of the fina report of the Defense Industrial Base Panel entitled "The Ailin Defense Industrial Base: Unready for Crisis." In preparing the repor the panel held 13 days of hearings, including 4 days of field hearing and took testimony from 34 witnesses.

The panel finds that there has been a serious decline in the nation' defense industrial capability that places our national security in jeop ardy. An alarming erosion of crucial industrial elements, couple with a mushrooming dependence on foreign sources for critical mate rials, is endangering our defense posture at its very foundation.

It has been my privilege to chair this examination of one of th nation's most important national resources, our defense industri capability. On behalf of the panel, I want to acknowledge and than our staff (Tom Cooper, Don Campbell, Adam Klein, Dave Price, Ton Battista and Mary Ann Gilleece) for their excellent assistance in thi study.

I shall appreciate your early approval of the report so that it ma be printed.

With kindest personal regards,
Sincerely,

RICHARD H. ICHORD,
Chairman, Defense Industrial Base Panel.

Approved for printing:
MELVIN PRICE, *Chairman.*
December 30, 1980.

FINDINGS AND RECOMMENDATIONS

MAJOR FINDINGS

The panel finds that:

—the general condition of the defense industrial base has deteriorated and is in danger of further deterioration in the coming years;

—the Department of Defense has neither an on-going program nor an adequate plan to address the defense industrial base preparedness issue; Department of Defense inaction in enhancing industrial base preparedness, coupled with instability within the five year defense program, weapon system procurement stretchouts, inadequate budgeting and inflation, has contributed to the deterioration of the U.S. defense industrial base, and as a consequence, jeopardizes the national security;

—a shortage of critical materials, combined with a resulting dependence on uncertain foreign sources for these materials, is endangering the very foundation of our defense capabilities. These shortages are a monumental challenge to the Congress, the Department of Defense, the defense industry and the civilian economy;

—present policies and procedures for the procurement of property and services by the Department of Defense are excessively inflexible and discourage the use of contract types that would promote the best interests of the United States; as a result, many procurement contracts cannot be written that would promote stability, encourage capital formation and lead to efficiencies that would result in savings to the government;

—current tax and profit policies appear to discourage capital investment in new technology, facilities and equipment that would increase productivity and improve the condition of the defense industrial base; and

—while the condition of the defense industrial base is of vital importance to the national defense and security of the United States, responsibility for the condition of the base is dispersed among the committees for the Congress and within the executive branch; this diffusion of responsibility has contributed to a lack of effective long range planning for industrial responsiveness and has made it extremely difficult to assess the overall effects of executive and congressional action on the defense industrial base.

RECOMMENDATIONS

LEGISLATIVE RECOMMENDATIONS

The panel recommends that the Committee on Armed Services, early in the 97th Congress, favorably consider legislation to:

—repeal section 810 of the Act of October 7, 1975, Public Law 94–106 (89 Stat. 539) thereby removing the existing $5 million ceiling on cancellation costs applicable to multiyear defense procurement contracts;

—require that the Committees on Armed Services and the Committees on Appropriations of the Senate and House of Representatives be notified in advance of the award of any multiyear contract which contains a clause setting forth a cancellation ceiling in excess of $50 million;

—establish a policy for defense procurement that will promote flexibility and permit the use of contract types, including multiyear contract types, that will result in the acquisition of weapon systems and other items in the most timely, economic and efficient manner; and provide that contracting, where practicable, should provide incentives to defense contractors to make economic purchases of material and to improve productivity by investment in technology, capital facilities and equipment;

—specifically authorize multiyear contracting, including contracts for weapon systems; establish guidelines for multiyear contracting; provide that cancellation clauses may reflect recurring and nonrecurring costs; and provide that the costs of cancellation or termination may be paid from appropriations originally available for the performance of the contract concerned, from appropriations not otherwise obligated, or from funds appropriated for those payments;

—provide that advance procurement of components, parts, and materials necessary to manufacture weapon systems may be for a term of not more than five years and that advance procurement may be used to effect economic lot purchases and efficient production rates;

—direct that future authorization and appropriation requests for the acquisition of weapon systems, or portions thereof, indicate the most efficient production and acquisition rate for each system;

—amend section 2306 of title 10, United States Code, by striking out the geographical restriction, thereby permitting multiyear contracts for periods of not more than five years for certain services, and items of supply related to such services, within the 48 contiguous States and the District of Columbia, for which funds would otherwise be available for obligation only within the fiscal year for which appropriated;

—direct the Director, Office of Management and Budget and the Secretary of Defense to issue regulations to implement these legislative changes within 90 days after the enactment of the legislation.

NONLEGISLATIVE RECOMMENDATIONS

That the Committee on Armed Services take the following actions:

—recommend to the President that he establish within the Executive Office of the President a point of authority to initiate *action*, and to direct and coordinate the efforts of the several responsible departments and agencies, necessary to solve the many problems

relating to productivity, quality, manpower and critical m rials that afflict the defense industrial base;

—forward to the Secretary of Defense a copy of this report review and written comment;

—request that the Secretary of Defense address, during the f year 1982 defense posture hearings, the findings and recom dations contained in this report and the recommendations o Defense Science Board Task Force on Industrial Responsive 1980;

—in connection with the fiscal year 1982 budget submission, req the Secretaries of the Army, Navy and Air Force to identify t programs that would result in major cost savings, and enh program stability, economy and efficiency if the principle multiyear contracting, expanded advance procurement, and te ination liability funding were to be applied;

—assure that the appropriate subcommittees of the Committe Armed Services follow through on the recommendations contai in this report concerning defense acquisition policy;

—work with other congressional committees in taking action to s the many problems afflicting the defense industrial base;

—direct attention to those problems that the panel did not add in detail during its review of the capability of the defense in trial base such as manpower-shortages, profit policy and the m agement and investment practices of defense contractors.

INTRODUCTION

On September 17, 1980, the Committee on Armed Services commenced a series of hearings on the capability of the U.S. defense industrial base [1] to produce the military equipment needed to insure th national security.

These hearings were prompted by an ever growing concern that th U.S. industrial base, in general, and the defense-oriented portion o that base, in particular, are not healthy. The committee's concern aros amid revelations that U.S. industrial productivity growth has decline significantly in relation to foreign competitors, that dependence o foreign sources for critical materials is increasing, that serious manpower shortages exist today and are projected to continue in the future, and that the cost of weapon systems is rising at an alarming rat

The full committee held three days of intensive hearings in September. At the conclusion of these hearings, Committee Chairman Melvi Price appointed a 10-member panel, chaired by Representativ Richard Ichord, to continue study of the problem and to report it findings and recommendations to the full committee prior to the en of the 96th Congress. In addition to Mr. Ichord and a member-at-larg from the full committee, the panel included two members from each o the four subcommittees principally engaged in procurement-relate activities; Procurement and Military Nuclear Systems, Seapower an Strategic and Critical Materials, Investigations, and Research an Development.

In carrying out its charter, the panel held 13 days of hearings, including 4 days of field hearings, and received testimony from 34 witnesses. These witnesses included representatives of: defense prime contractors and subcontractors, associations, the military, the Genera Accounting Office (GAO), the Department of Commerce, the Federa Emergency Management Agency (FEMA), the Department of Defense (DOD), and the Congress. A listing of the witnesses that appeared before the committee and the panel is included in the Appendix.

In addressing the preparedness of the defense industrial base, the panel focused attention on those contingencies that fall short of full wartime mobilization. In so doing, the panel concentrated on the base's ability to produce the weapon systems that are included in the current five year defense program and the base's ability to respond to accelerated production rates, including peacetime "surge" production rates

As the investigation proceeded, a shocking picture emerged: the picture of an industrial base crippled by declining productivity growth, aging facilities and machinery, shortages in critical materials,

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[1] Although a precise definition does not exist, the defense industrial base is broadly viewed as encompassing those elements of American industry that contribute to defense-related work and whose production capacity and technical expertise are required to meet national security requirements.

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increasing lead times, skilled labor shortages, inflexible government contracting procedures, inadequate defense budgets and burdensome government regulations and paperwork.

Witness after witness testified before the panel that an erosion of U.S. industrial capability is occurring that, coupled with America's mushrooming dependence on foreign sources for minerals, is endangering our defense posture at its very foundations.

Gen. Alton D. Slay, Commander, Air Force Systems Command, grasped the tangle by its roots by noting:

> The problems . . . are not new and have been growing for some time. Individually, each problem chips away at our industrial base. Collectively, these problems threaten the future of our industrial sector, our national economy and our defense. And the time to correct them is now.
>
> These difficulties are national in scope, and if they are to be solved, have to be attacked on a national scale. I believe we know what has to be done to solve these problems, but the ultimate key to our success or failure is going to be the degree of commitment the Nation makes to these solutions. This commitment must exist at all levels of government, the military, business, and industry. Nothing short of an attack across a broad front will do.

Mr. O. C. Boileau, President, General Dynamics Corporation, also made the point that the problems currently plaguing the industrial base are not new. He directed the panel's attention to a Fortune magazine article that assessed the degree of industrial preparedness in the United States. The article disclosed:

> No programs to organize manpower exist;
> Wide-spread shortages of critical materials;
> Means for industrial expansion seriously constrained;
> No plan for national prioritization;
> Threat of destabilizing inflation;
> Lack of public understanding of the tasks ahead; and, finally,
> Uncertain national will.

While a good summary of many of the problems confronting the Nation today, the article is particularly intriguing because it was published in 1941, just 16 weeks before Pearl Harbor.

In the short time available to it, the panel has developed findings and recommendations that it hopes will assist the full committee as it continues its study of this critical issue. These findings and recommendations, together with a discussion of the evolution of the defense industrial base in America, are presented for the committee's consideration in the following sections.

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BACKGROUND

> Adequate preparation for war has never yet in history been made after the beginning of hostilities without unnecessary slaughter, unjustifiable expense, and national peril. It is only in the years of peace that a nation can be made ready to fight.[2]

World War I

It was not until World War I that sophisticated war-fighting m chinery appeared on and over battlefields. War waging prior to Worl War I involved men more than machines. World War I was the fir occasion that America examined its ability and will to produce larg quantities of war machines. However, even the first World War di not truly test the United States industrial capacity, and during tl early days of the war many elements of America's forces had to b equipped with weapons produced by U.S. allies.

The United States' dependence on its allies for war material illustrated by the fact that of the almost 4,400 artillery pieces fu nished to the American Expeditionary Forces (AEF), only about 50 came from U.S. production lines; of the over 6,000 planes and 29 tanks employed by the AEF, only about 1,200 planes and 40 tank were made in America. A major factor contributing to this depend ence was the long lead times associated with the domestic productio of critical war materiel. The lead time was 12 months for small arm 18 months for ammunition, and 30 months for artillery pieces.

Congress, responding to the lessons learned from World War I enacted the National Defense Act of 1920. This Act led to the estab lishment of an industrial planning organization within the Offic of the Assistant Secretary of War. This organization was to plan fo the acquisition of war materiel and for the mobilization of industria resources. Subsequently, contingency plans were developed which ad dressed the mobilization of the industrial base to meet wartime mo bilization requirements. These plans—the Industrial Mobilizatio Plans (IMP)—indicated those industrial plants which would be uti lized in the event of a national emergency to produce war materie To provide for adequate lead time to accelerate industrial productio reserves of weapons, equipment, and other materiel were stockpile The IMP was prepared every three years between 1930 and 1939 an as the U.S. entered World War II, the IMP proved to be an impo tant factor in assisting the United States in expanding its industria base to meet wartime requirements.

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[2] Huidekoper, Frederic. "The Military Unpreparedness of the United States," 1915, p. 556

World War II

Despite the emphasis given to industrial preparedness during the years immediately after World War I, the defense industrial base had deteriorated by 1939. Yet, during the next two years, increasing demands by U.S. allies for American war materiel provided the United States with a slight edge as it entered the war. Further, since the possibility of direct involvement in the war had been anticipated as early as 1939, American industry was able to produce over 67,000 aircraft, about 29,000 tanks, approximately 180 combatant ships, and other support vessels within 24 months after entering the war.

During the war, the U.S. defense industrial base responded well and produced, among other items, 310,000 aircraft, 88,000 tanks, 10 battleships, 358 destroyers, 211 submarines, 27 aircraft carriers, 411,000 artillery tubes and howitzers, 12,500,000 rifles and carbines, and approximately 900,000 trucks and motorized weapons carriers. In 1944, the United States was building Liberty ships in 50 days, and during a single month, March of 1944, 9,117 military aircraft were built. Clearly, World War II demonstrated the United States vast industrial might and its capability to surge the industrial base to meet the requirements of a protracted war.

The conclusion of World War II saw the American industrial base undergo a rapid change from producing military hardware to producing consumer products. This reallocation of industrial resources answered consumer demands for commercial products deferred during the war. Moreover, the feeling that the last great conventional war had been fought and that nuclear weapons would deter any future war, also contributed to the reallocation of industrial resources.

Korean War

Between 1945–1950 over $115 billion was invested in new plants and equipment to increase U.S. production capabilities. This investment raised the overall production capacity by 40 percent, but the vast majority of that industrial capacity was being fully utilized to produce commercial goods. Limited industrial resources were devoted to defense needs.

In 1950, prompted by the Korean conflict and the need to again reallocate industrial resources, the Congress passed the Defense Production Act of 1950. This Act, in its present form, is used:

> To establish a system of priorities and allocations for materials and facilities, authorize the requisitioning thereof, provide financial assistance for expansion of productive capacity and supply, provide for price and wage stabilization, provide for the settlement of labor disputes, strengthen controls over credit, and by these measures facilitate the production of goods and services necessary for the national security, and for other purposes.

Specifically, the Act provides for the implementation of a system—the Defense Priorities System—which permits the President to accelerate the production of critical defense items by causing the manufacturer to place these items at the front of the production line; guaranteed loans to expedite deliveries of vital national defense systems; and direct Government loans to industry to expand plants and facilities in order to develop or produce essential materiel.

As a result of the tremendous build up of the U.S. defense industrial base during World War II, a healthy industrial base existed as the United States entered the Korean War. This warm base was capable of expanding and reallocating its productive resources to support national defense requirements and, with the exception of some munitions shortages, was able to provide most of the necessary war material.

Vietnam War

During the Vietnam War, the U.S. industrial base responded relatively smoothly to demands for war-fighting machinery and supplies. Aircraft, tracked vehicles, and munitions were produced in large quantities. However, because the United States generally set the pace of the military buildup in Southeast Asia, and since war materiel production was essentially on a business-as-usual basis, the capability of the U.S. industrial base to accelerate or "surge" production to meet emergency requirements was largely untested.

Post-Vietnam War Era

The issue of the defense industrial base and its ability to respond to the demands of a crisis or war were brought into sharp focus during the post-Vietnam War era. The health of the defense industrial base and, indeed, the total industrial base, was being questioned. This heightening of interest led to a number of steps within the Federal Government and the military services to obtain a clearer picture of the problem and its implications.

This growing concern for the faltering health of the defense industrial base was highlighted in a report prepared by a Defense Science Board Task Force on Industrial Readiness in 1976. The Task Force concluded that "* * * the United States is presently deficient in the extent to which the defense industrial base is postured to provide materiel support to the forces in being in response to the full spectrum of potential conflict situations upon which our national security plans are based."

Further, the Task Force stated that "Our primary recommendation is that the Department of Defense initiate an immediate study and analysis of the requirements for creating a capability within the defense industrial base to 'surge' production rates with existing facilities and equipment in order to respond to 'limited' national emergency situations. This would provide a bridge between the conflict situation which is too lengthy to be supported by the War Reserve Materiel Stocks, but too short to last until defense production can be accelerated in response to a full national mobilization."

The extent of mobilization problems was perhaps most sharply demonstrated during the "Nifty-Nugget" mobilization exercise in the fall of 1979. It revealed major weaknesses in the machinery of the Federal Government for coordinating mobilization efforts. These weaknesses existed in the areas of logistics and transportation, stocks of munitions and supplies, and in the ability of the industrial base to respond to rapidly accelerated military demands.

In the broader aspect, the industrial base problem is symptomatic of overall trends in the economy, including declining productivity, shortages of technical and skilled personnel, increasing industrial interdependency on other developed countries, and increasing dependence on unstable or potentially unstable countries providing critical raw materials.

In the narrower aspect, this industrial base problem relates specifically to problems concerning the U.S. defense industry, including problems attributed to tax policy, capital formation, inadequate defense budgets, and on-again, off-again weapon systems procurement practices.

DISCUSSION OF FINDINGS

Defense Industrial Base is Deteriorating

Finding

The panel finds that the general condition of the defense industri base has deteriorated and is in danger of further deterioration in th coming years.

The panel specifically finds that:

—the defense industrial base is unbalanced; while excess productio capacity generally exists at the prime contractor level, there a serious deficiencies at the subcontractor levels;

—the industrial base is not capable of surging production rates i a timely fashion to meet the increased demands that could b brought on by a national emergency;

—lead times for military equipment have increased significantl during the past three years;

—skilled manpower shortages exist now and are projected to con tinue through the decade;

—the U.S. is becoming increasingly dependent on foreign source for critical raw materials as well as for some specialized compo nents needed in military equipment;

—productivity growth rates for the manufacturing sector of th U.S. economy are the lowest among all free world industrialize nations; the productivity growth rate of the defense sector i lower than the overall manufacturing sector; and

—the means for capital investment in new technology, facilities an machinery have been constrained by inflation, unfavorable ta policies, and management priorities.

Discussion

The panel's findings, as they relate to the overall health of the defense industrial base, are comprehensively documented in the public record compiled by the full committee and the panel. The panel would particularly draw attention to the presentation made by Mr. Robert Fuhrman, Chairman of the 1980 Defense Science Board (DSB) Task Force on Industrial Responsiveness, together with the Task Force's report. In addition, General Alton D. Slay, Commander, Air Force Systems Command, presented the panel with an extremely comprehensive report on defense industrial base issues. The Honorable Jim Santini, Chairman of the Subcommittee on Mines and Mining of the House Committee on Interior and Insular Affairs, thoroughly discussed U.S. minerals vulnerability. His subcommittee's report on this issue, titled "U.S. Minerals Vulnerability National Policy Implications," is included in the panel's record. The critical materials issue is treated in detail elsewhere in this report.

Production capacity and surge capability

The Honorable William J. Perry, Under Secretary of Defense for Research and Engineering, in addressing the capability of the defense industrial base, told the panel that the base is capable of producing all of the equipment which is included in the current five year defense program and has the capacity to expand production to accommodate significant increases in the defense budget. Dr. Perry indicated that the base could expand to produce "* * * 50% more A-10's, F-15's, F-16's XM-1's, UH-60's, frigates, and destroyers than we are now building." Dr. Perry added, however, that "We do not have a surge capability; that is, if we wanted to double the production rate of F-16's, in three months or six months, there is no way we can do it. I define that as a surge capability, and we don't have it."

General Slay underscored this lack of a surge capability when he noted "* * * after nearly 18 months under surge conditions, we could only expect to get an aggregate of 22 more A-10's and no additional F-15's and F-16's than already exist on the currently contracted delivery schedule. Obviously, with proper funding we could greatly increase the output of these aircraft, but we would not begin to see significantly large numbers flying for at least three years or more."

Turbulence exists within the base

Mr. Dale Church, Deputy Under Secretary for Defense Acquisition Policy, characterized the defense industrial base as "unbalanced." While the prime contractors in the base generally have sufficient or excess production capacity, Mr. Church pointed out that there are "* * * very serious deficiencies at the first, second, third, and so on and so forth, tiers of subcontractors down to the vendor levels who are vendoring components into the team."

The Defense Science Board Task Force found evidence that the defense industrial base is shrinking. In one of the programs the task force examined, there was a reduction in one year of 1,500 suppliers from the 6,000 that had participated in that program during the previous year. In another program, the Task Force found that the number of bids on a given program declined by 40 percent from one year to the next.

Mr. Harry Gray, Chairman and Chief Executive Officer, United Technologies Corp., testified that "The supplier network that forms the base of our country's defense industry is shrinking at an alarming rate. Since 1967, the number of companies involved in aerospace production has declined by more than 40 percent. In 1967, there were approximately 6,000 companies in the industry. Today there are only about 3,500." Mr. Gray noted further that of those 3,500 contractors, there has been a turn-over of some 1,500 during the last two years.

A number of other witnesses testified that the defense industrial base is decreasing in size, but the panel was not presented with solid evidence that the overall defense industrial base has significantly contracted over the past several years. Nevertheless, the panel is convinced that there has been considerable turbulence within the base.

The base is almost totally owned and operated by the private sector. There are only 83 government owned facilities within a base which is made up, at any one time, of 25,000 to 30,000 prime contractors and upwards of 50,000 subcontractors. It is, therefore, extremely difficult to draw firm conclusions about the size of the base.

Leadtimes have increased dramatically

The panel's record clearly establishes that the turbulence with the base has resulted in serious bottlenecks and choke points th adversely affect the Defense Department's ability to procure militai equipment in a timely, efficient and economical manner. This is r flected in the dramatic increases in lead times over the past three yea in military programs. The panel's record is replete with referenc to these lead time increases. Mr. Fuhrman testified that "The le times for essential equipment have been increasing rapidly, leadi to delays in the fielding of modern systems. For example, from 19 to 1980 the typical delivery span of aluminum forgings increas from 20 to 120 weeks. From 1977 to 1980 the delivery span for aircra landing gears grew from 52 to 120 weeks. In just the last 2 years t delivery span for integrated circuits more than doubled, from 25 62 weeks."

Mr. Gray noted that "In 1978, normal lead times for one of o military jet engines was 19 months. Today the Air Force has to ord that engine 41 months before delivery."

Many of the bottlenecks have resulted from the closure of forgin and casting facilities and the lack of construction of new facilitie During the 1970's, literally hundreds of founderies closed as a resu of environmental, health and safety laws and regulations impose by the Federal Government.

Bottlenecks also arise from the greatly increased demand that h recently been placed on the aerospace industry by a booming co mercial aircraft business. The base has not expanded to accommoda this additional demand, and an intense competition for limited pr duction capability has developed between commercial and defen orders. Dr. Perry told the panel that it was his view that the industr had not expanded to meet the increased demand because it believ "* * * the peak demand is going to go away in a year or two."

Smaller subcontractors hit hardest

The panel's record indicates that the lower tier subcontractors i the defense industrial base are generally hit harder by the instabiliti in defense programs, have greater capital formation problems an suffer more from the burdensome paperwork associated with doin business with the government than their larger counterparts in t base.

During a series of field hearings in California and Texas, the pan took testimony from representatives of a number of smaller firm currently involved in defense related work. Although the sample w too small to draw sweeping conclusions, several common themes ra throughout the testimony of these subcontractors, who ranged in si from 15 to 10,000 employees with sales between $800,000 an $650,000,000.

The sub-tier contractors told the panel that the main factors co tributing to the failing health of their sector of the defense industri base include excessive Government administration, on-again, off-agai procurement practices, restrictive documentation and specificatio requirements levied by many primary contractors, critical shortag of trained manpower, and lack of sufficient "flow-down" of contractin benefits from prime contractors.

The panel found a consensus among sub-tier contractors that they would prefer to do business with the commercial sector because it is more stable. In this regard, sub-tier contractors suggested that defense business could be made more attractive if multiyear contracting were used. They indicated that the use of multiyear contracting could assist in providing reasonable risk protection against erratic procurement practices. *The sub-tier contractors warned, however, that only to the extent that the benefits attributed to multiyear contracting were allowed to "flow down" to the sub-tier level, will multiyear contracting provide the investment incentives necessary to stabilize the base.*

Most of the sub-tier contractors told the panel they charged more for defense business than they charged for comparable commercial business, but the panel was not able to determine, in general, how much more. As one sub-tier contractor stated: "* * * when bidding on government contracts, we factor in the regulatory and administrative requirements, and increase the price quite substantially." There were other witnesses who stated that the price difference for performing Government contracts ranged from 25 percent to double the price charged for comparable commercial contracts.

A common complaint heard by the panel was that the prime contractors do not routinely shield their subcontractors from the administrative burdens associated with doing business with the government. One small businessman told the panel that in many cases primes add administrative burdens of their own.

The panel finds that the sub-tier contractors are perhaps less able to withstand the hardships resulting from manpower shortages than the larger prime contractors. It is clear that the shortages of machinists and other skilled laborers are contributing factors which adversely affect the ability of the sub-tier base to respond rapidly to significant increases in defense production demands.

Further, several sub-tier contractors indicated that because of the domestic manpower shortages, they have increased their dependence on foreign sources to meet their manpower needs.

In general, the panel found that negative factors affecting the health of the base disproportionately injure smaller companies.

Critical manpower shortages

The panel found that skilled manpower shortages are prevalent throughout industry. The Defense Science Board Task Force concluded that a major contributor to the increasing lead times and costs currently afflicting the defense community is a continuing shortage of skilled labor. Mr. Fuhrman painted a less than promising picture when he stated that "* * * our study indicated the nation would be short 250,000 machinists in the next five years. We did not see any overall government programs aimed at solving this problem, and the individual company training efforts were only touching the tip of the iceberg. In spite of the recession and its attendant unemployment, there remains a shortage of the skills needed by the defense industry. The shortage leads to competition for labor and an upward pressure on costs."

Mr. Church echoed Mr. Fuhrman's concerns when he stated "The skilled manpower problem is probably one of the most difficult nuts to crack of these problems, particularly when we are trying to do it from a defense perspective."

As the panel's investigation proceeded, it emerged that manpow shortages penetrate deeply into the lower-tiers of the defense indu trial base. Several of the sub-tier contractors indicated that while th have reserve equipment and capacity, their ability to surge is crippl by limited manpower.

Mr. Church told the panel "I think that we ought to be able choose from the whole base of high school graduates, or whoev would like to be a skilled machinist, because we are falling 75 perce short of those needs to merely take care of the loss that we are seei on an annual basis. So we should turn over every stone. Wherever can find a person, we have got to use them."

The panel did not examine the capability of the U.S. education system to satisfy the manpower demands of the defense industri base, particularly in the skilled trade areas. The panel suggests th the role of the U.S. educational system and its impact on the prepare ness of the defense industrial base be reviewed by the Committee Armed Services and other appropriate House Committees and t Department of Defense.

The panel believes that the solution to this national manpow problem will require a national commitment. Further, unlike Wor War II, when under full mobilization, thousands-upon-thousands people—farmers, housewives, construction laborers, clerks, an others—answered "the call to arms" and poured into our defen factories, the current economic environment and weapons system s phistication will not support any quick fix or emergency manpow reallocation to satisfy surge requirements.

Mr. Gray made this point when he stated: "Building the plant an getting the equipment are only part of the job. During the secon World War, we brought in people who never before had worked i a factory—farmers, clerks, housewives. They were trained in a matte of weeks to build aircraft engines. And they built thousands of them Today, however you can't just take someone off a farm or out of kitchen and expect him or her to build aicraft engines. The technolog is too advanced, the tolerances too tight, the equipment too sophisti cated. It takes three years for a machinist apprentice to complete hi rigorous course. It takes the better part of a year to retrain someon from producing autos, for example, to work on high technology aero space parts."

The current manpower shortages have created a "sellers market for engineers, computer professionals, and other skilled workers an competition for these scarce human resources is intense. The pane was told that "head hunters" were being paid $1,000 or more fo recruiting engineers and computer professionals for many of th firms. It is clear that in the absence of adequate supplies of engineers computer professionals, machinists, and other skilled workers, th defense industrial base will continue to exhibit symptoms of failing health.

United States losing ground in world markets

Another symptom of the decline in vitality of the industrial base is the diminishing United States share of the total manufacturing exports of the world's industrialized nations, dropping from about 25 percent in 1960 to about 17 percent in 1979. The significance of this decline in the United States economy, relative to the remainder of the world, is difficult to assess; but this import penetration into certain industrial sectors, such as machine tools, industrial fasteners and semiconductor devices, suggests an unacceptable dependency on foreign sources for key elements of defense production.

Semiconductor components and devices are vital elements of the defense posture of the United States. Most U.S. military hardware today incorporates integrated circuits and transistors. While the United States continues to play a leading role in the semiconductor industry, serious concerns exist about the long term ability of the United States to maintain its hold on this market.

Increasing dependence on foreign sources for critical components

Presently, United States based firms dominate the rapidly growing semiconductor marketplace, having captured about two-thirds of the $18 billion annual world market. The Japanese, however, pose a serious challenge to United States leadership in this field. While the United States is still a net exporter of semiconductors to Japan, imports are rising faster than exports.

The Japanese made major inroads in the United States market during 1979 when American producers failed to achieve the capacity needed to meet a surge in demand. Japanese producers recently took almost half of the United States market for the most widely used integrated circuit: a computer memory chip. Many United States semiconductor companies now rely on Japanese chips for their own line of memory units, finding it advantageous to rely on cheaper Japanese components.

During its field hearings, the panel visited Texas Instruments, Inc., Dallas, Texas and found that not only is the United States losing ground to the Japanese in the world semiconductor market, but that the majority of assembly work done on United States manufactured semiconductor devices is carried on in Malaysia, Singapore, Taiwan, the Philippines, Korea and Hong Kong. Approximately 90 percent of all assembly work on the United States manufactured devices is done offshore. The panel finds this dependence on offshore labor for assembly of critical defense related components as troublesome as our offshore dependence for critical materials.

The panel believes that if solutions are not developed to address the myriad problems that plague the defense industrial base and, indeed, the total industrial base, the United States is in danger of losing its position as the industrial leader of the world. General Slay told the panel, "* * * it is a gross contradiction to think that we can maintain our position as a first-rate military power with a second-rate industrial base. It has never been done in the history of the modern world."

Productivity growth is lagging

One of the more telling indicators of the declining vitality of American industrial might is reflected in productivity growth rates. While the United States leads the world in productivity,[8] the United States is *dead* last in productivity improvements among all industrialized nations of the world. This problem of declining productivity growth is compounded by equally troubling quality and reliability

[8] Productivity is a measure of the goods and services produced per unit of labor invested, capital invested or both.

problems. The United States no longer leads the world in manuf turing quality standards . . . the Japanese do.

In providing the panel with a net assessment of the capabilities the U.S. defense industrial base, Dr. Perry stressed the positive f tures of the base, of which there are many. Dr. Perry told the pa that in terms of technology, cost and productivity, the American fense industry is the best in the world. He went on to note, howev "* * * most of the good things I have said about our industry h resulted from investments that were made in the fifties and sixti and we are now living off the fat. If we look at the rate of investm in research and development, if we look at the rate of investm in plant modernization, we find very adverse trends, which I thi portend poorly for the eighties."

Defense industry has failed to modernize

The panel's record strongly supports Dr. Perry's observation garding investment. As an example, during the past decade, the U. aerospace industry invested approximately two percent of its sal in new capital. The average rate of investment for all U.S. indust during this same period was approximately eight percent and t average rate for all U.S. manufacturing firms was 4 percent. Th lack of investment by the defense sector of U.S. industry has result in a situation where 60 percent of the metal working equipment us on defense contracts today is over 20 years old. Further, the Defen Department's investment in the future, its technology base, has lik wise not kept pace. In real terms, the technology base budget h declined by almost a factor of two during the past two decades.

The Defense Science Board Task Force on Industrial Responsiv ness, the Joint Logistical Commanders and Dr. Perry strongly re ommended that the Department of Defense pursue a vigorous Man facturing Technology (MANTECH) program. The Defense Scien Board Task Force estimated that a 5 to 1 payback would result from properly implemented MANTECH effort with industry.

The panel found that the disincentives for investment in new facil ties, equipment and technology have resulted from a number of factor In the defense industry, in particular, the decline in the procure ment and research and development budget after the Vietnam con flict placed a serious burden on new investment in defense relate work. Put simply, profits within the defense base generally did no sustain new investments. The problem was further compounded b abnormally high, and unanticipated, inflation during the 70's. Thi high inflation, coupled with high interest rates, further discourage investment in new facilities and equipment.

In addition to inadequate budgets and soaring inflation and interest rates, the panel believes that tax policies that discourage capital investment, government over-regulation and near-term profit oriented management priorities have seriously constrained industry's ability to generate investment capital. This issue will be treated in detail in a separate section of this report.

Defense Industrial Preparedness Planning Is Nonexistent

FINDING

The panel finds that the Department of Defense has neither an on-going program nor an adequate plan to address the defense industrial base preparedness issue. Department of Defense inaction in enhancing industrial base preparedness, coupled with instability within the five year defense program, weapon system procurement stretchouts, inadequate budgeting, and inflation, has contributed to the deterioration of the U.S. defense industrial base, and as a consequence, jeopardizes the national security.

The panel specifically finds that:

—the Consolidated Guidance, the planning document of the Department of Defense that delineates U.S. military policy and establishes commensurate force structure, does not address industrial preparedness;

—the current industrial preparedness planning tool used by the Department of Defense (DD Form 1519) lacks realism in establishing the potential of the defense industrial base to expand production of major weapon systems and end items and is an ineffective planning tool;

—The Five Year Defense Plan, the document that sets forth program and weapon system acquisition objectives for a five-year period, lacks stability; weapon system procurement rates are constantly adjusted so that it is virtually impossible for defense industry to do long-range planning and to effect efficient procurement of long-lead subsystems and components; and

—war reserve materiel stocks are at a dangerously low level and can support only the shortest of "short war" scenarios.

DISCUSSION

Concerns about the capability of the defense industrial base have not surfaced overnight. The Joint Committee on Defense Production of the Congress expressed concern in 1975 that the industrial base might not be capable of responding to our military needs. The Department of Defense was also cognizant of the problem and, in 1976, initiated a Defense Science Board (DSB) study group to address defense industrial preparedness. The objectives of the DSB study were to examine the role of the U.S. industrial base in terms of projected wartime and crisis scenarios and to consider approaches for improving the responsiveness of the base to meet these needs.

The DSB final report was published in November 1976. The panel, in reviewing the report, found it to be substantive, hard-hitting and definitive in charting a course that would make the industrial base responsive to our military requirements. The report addressed the

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interrelationship of the industrial base with the requirements various conflicts, crises or wars. It considered warning time, sho to-long war transition, war reserve materiel needs and culminated a series of recommendations that would indeed have enhanced p paredness. The report delineated the steps that the Department Defense should take, beginning with policy guidance revisions include industrial preparedness planning to be responsive to curr scenarios, force structure, logistic support requirements and defe industrial base capacity.

Extended awareness of the problem and an excellent DSB rep have done little to enhance defense industrial preparedness. Wh asked about what actions DOD had taken to implement the 1976 D recommendations, Mr. Church replied, "As far as specific actio something between virtually nothing and very little."

The Department of Defense initiated another DSB industrial b preparedness study earlier this year. Many of the 1980 findings essentially those of 1976. The panel concludes that the Department Defense has done little to improve the capability of the industrial b in five years, the problem continues to worsen, and new studies initiated when, in fact, action, not analysis, is what is needed to i prove the responsiveness of the base.

Current planning approach is inadequate

The industrial preparedness planning approach used by the Depa ment of Defense lacks realism. It fails to determine the potential our industrial base to expand production of the weapon systems a end items that are being acquired. The currently used prime contract industrial planning schedule (DD Form 1519) involves the prepar tion by the prime contractors of production acceleration estimate However, the planning efforts of the various prime contracto are not coordinated with each other. Consequently, several primes m be basing their estimates of acceleration capability on the presume availability of critical materials and subcontractor support. Accor ingly, the key element in increasing production may not be the prime plant capacity but rather the plant capacity at a second or third ti supplier who may already be operating at full capacity.

It is the view of the panel that the Department of Defense needs more realistic planning device than the DD 1519. In the panel's jud ment, the DD 1519 approach in and of itself is an ineffective plannin tool and wastes both time and money.

On November 18, 1980 the following scenario was postulated to t panel:

World tensions heat up;
SALT negotiations break down;
The Russians move into the Persian Gulf;
U.S. military deficiencies are recognized; and
Congress significantly increases the defense budget but, the de fense industry cannot rapidly respond with needed increases i military equipment.

This 1980-like scenario was first postulated in 1975 by Dr. Jacque S. Gansler, then Deputy Assistant Secretary of Defense for Materie Acquisition. On November 18, Dr. Gansler advised the panel, "Tha (the postulated scenario) was five years ago, and at that time, I con cluded that corrective actions were required. The scenario is far more plausible, but no actions have been taken so the conclusion remains the same, only today the need is more urgent."

The panel is deeply concerned that the Department of Defense has failed to take corrective action on known deficiencies or even initiate policy revisions and plans that would make the industrial base responsive to our military needs. The panel finds an alarming trend in the Department of Defense approach toward current day problem solving—that of "rationalizing the problem out of existence." The Department's response to our dangerously low level of force structure is to adjust the Consolidated Guidance to accommodate only a short war. The short war syndrome, which shows the war ending before the industrial base can respond, negates the need for industrial base planning, hence, the need for funds or programs to enhance the base is "rationalized away." This is clearly evidenced by the Department's inaction on the excellent Defense Science Board (DSB) findings and recommendations in 1976. Not a single witness who appeared before the panel disputed the DSB findings. Rather than use the findings, however, the Department initiated another DSB study in 1980. The findings and recommendations of the 1980 DSB study merely echoed those of 1976. Quoting the 1980 report:

> The conclusions reached and the majority of the actions recommended are as valid today as they were in 1976. Unfortunately the 1976 report was submitted just after the Presidential election, and if there were advocates for taking action, they disappeared when the players changed. The 1980 Task Force found that very little had changed in four years, with the exception of some improvement in conventional ammunition War Reserve Materiel stocks.

The panel is extremely troubled that an issue as important as industrial preparedness could be "lost" during a Presidential transition and that the problem has not been aggressively pursued during the past four years.

Chairman Ichord summarized the panel's concern when he noted:

> * * * one of the things that troubles me most about the situation is the apparent lack of a long-range strategic plan for industrial preparedness at the Department of Defense. We have received testimony that clearly indicates that the Consolidated Guidance—the planning document used by the Department of Defense to establish its force structure—does not even address industrial preparedness. Instead, the Consolidated Guidance sizes our defense production base on the assumption that all future wars will be "short wars." That is, these wars will have to be fought with equipment that is on hand when the war starts because it is assumed that the time to activate the production base would exceed the term of the "short war." That seems to me to be a self-fulfilling prophecy. If we plan for a "short war" and make no plans for a "long war", then surely all future wars will be "short wars."
>
> I can understand how intelligent men can differ on whether we should plan for "short wars" or "long wars" but I am

greatly concerned that we are not even buying the required ammunition, equipment, and weapon systems to support a short war policy. Even a cursory look at the equipment currently in the hands of our troops, at our war reserve materiel stockpiles, and at our Five Year Defense Program is proof positive of this claim.

There are some pluses, but on the dark side of the ledger, our troops are outmanned and outgunned at every turn, our war reserve materiel stocks are woefully inadequate today to support all but the shortest of "short wars," and the current Five Year Defense Program does little to improve the situation.

Policy guidance should consider industrial preparedness

The panel believes that the appropriate action required to enhar defense industrial preparedness should begin with Department Defense policy revisions to the Consolidated Guidance. The panel cc curs in the DSB recommendation to issue guidance revisions by whi the industrial preparedness planning process is carried out to ma such planning consistent with the current scenarios, force structu logistic support requirements and defense industrial base capaci Adm. Alfred J. Whittle, Jr., Chief of Naval Material, told the pa that the Consolidated Guidance should be revised to provide for i dustrial preparedness planning. Gen. John R. Guthrie, Commandi General, U.S. Army Materiel Development and Readiness Commar likewise advised the panel that any assessment of the capability of t industrial base to support Army as well as other service requiremer must begin with the Consolidated Guidance. Dr. Perry agreed that visions are in order and told the panel he plans to incorporate indu trial base planning in the Consolidated Guidance.

Consolidated guidance must be stabilized

The revision of the Consolidated Guidance to include industr preparedness planning is only a first step in making the industrial b responsive to our military needs. In recent times, funding constrai have caused instability in the establishment of our national securi policy. This instability disrupts the Five Year Defense Plan, whi in turn, creates turmoil in the industrial base. Consequently, the b tends to atrophy, war reserve materiel replenishment is deferred f another year and weapon systems costs increase as a result of inflati and inefficient procurement practices. Since the military requireme for these systems and force structure is not diminished, the "defen mortgage" is greatly increased and extended in time. Consequentl the Department of Defense enters a revolving door from which it difficult—and becoming impossible—to escape.

The panel believes that the Consolidated Guidance must be stab lized to avoid reaching the point of no return. No one has the clai voyance to predict the requirements, characteristics or duration of th next war. However, the massive Soviet force structure and the quant tative advantage the Soviets hold over the United States—18 to 1 i surface-to-air missiles, 11.5 to 1 in armored vehicles and artiller pieces, 2 to 1 in tactical aircraft, naval surface combatant ships an submarines—makes the ability to surge production extremely important.

Further, not only is there a lack of surge capability, there is even an indication that the defense industrial base is incapable of producing some of the hardware in the Five Year Defense Plan. As an example, the panel was advised by Dr. Allen E. Puckett, Chairman and Chief Executive Officer of Hughes Aircraft, that his company, one of only a few producers of mercury cadmium telluride detectors for Forward Looking Infrared sensors, cannot produce these detectors in sufficient quantity to meet the Army's existing requirements for the XM–1 tank.

The importance of stability in the five-year defense plan

The panel believes that providing for defense industrial preparedness planning during the formation of the Consolidated Guidance, together with introducing greater stability in this phase of force structure planning, is the first step toward industrial base enhancement. Once this is achieved, the Five Year Defense Plan must be stabilized through multiyear commitments to important programs at the very least, and where desirable, through multiyear contracting. A recent report, "Review of Price Changes in Department of Defense Weapon Systems," published on December 1, 1980 by the firm of Coopers and Lybrand under a Department of Defense contract, stated that the aggregate rate of price increase (percentage until price change weighted by base year procurement amounts for all systems) was 15 percent between fiscal years 1979 and 1980. The Department of Defense estimate presented to the Congress in support of the fiscal year 1979 military budget request was 7.9 percent.

Historically, the Department of Defense is directed by the Office of Management and Budget to use inflation indices that are not in fact representative of actual economic conditions. This unrealistic budgeting is one of the root causes of confusion in the Five Year Defense Plan. Short of coming back to the Congress for additional appropriations to cover actual inflation, the Department of Defense can only select alternatives that adversely affect our military capability and the industrial base. The typical alternative chosen in previous years has been either to stretch out programs or defer replenishment of the war reserve materiel stocks. In either case, the industry simply cannot carry on realistic long-range planning. While the prime contractors suffer from this instability, it is the lower tier subcontractors, with limited capital, that are hit the hardest.

Action, not studies, well enhance industrial base preparedness

The production know-how and capacity of our industry have historically been the backbone of our military capability. However, today not only our ability to surge, but our ability to meet the requirements of the Five Year Defense Plan, is called into question.

The panel believes that the fundamental problem that the U.S. defense establishment faces is that, for a substantial time, military requirements have far exceeded the funds made available to meet these requirements. The panel concedes that greater financial resources are required. In addition, however, other steps can be taken to improve the overall industrial capability through proper planning.

The starting point for this improvement is, in the panel's judgmen a reassessment and reaffirmation of our national security policy. On our national policy objectives are established, the panel believes th the Department of Defense can better delineate military requiremen and the weapon systems that must be developed and procured to me these requirements. This, in turn, will establish the budget requir to satisfy our national security needs. At this point, requirements wi have to be matched with fiscal realities. The panel believes that th approach will minimize the turbulence that exists in the policy an planning process.

In summary, the panel believes that the Defense Science Boar findings and recommendations of 1976 and 1980 chart the prope course toward making our industrial base responsive to our curren and projected military requirements. The recommendations, if acte upon, would greatly stabilize the Department of Defense policy, plan ning and acquisition process. Action, not additional studies, is what i urgently needed if our national security objectives are to be realized

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Critical Materials Availability Threatens Defense Capabilities

Finding

The panel finds that a shortage of critical materials, combined with a resulting dependence on uncertain foreign sources for these materials, is eroding the foundation of U.S. defense capabilities. These shortages are a monumental challenge to the Congress, the Department of Defense, the defense industry and the civilian economy.

The panel specifically finds that
—the United States is heavily dependent on other nations for supply of critical materials;
—the United States does not have an effective national non-fuel minerals policy that promotes U.S. national security interests;
—the United States government still knows little about the total potential mineral resources of this country;
—trends toward excessive and unreasonable government regulations are stifling and crippling the basic mineral industries of the United States; many critical minerals exist in the United States within the 750 million acres of public lands, but because of restrictive laws and regulations, mining is either prohibited or economically unfeasible;
—the stockpile of strategic and critical materials is woefully inadequate to meet the requirements of the defense industrial base as required by the Strategic and Critical Materials Stock Piling Act, (50 U.S.C. 98);
—many of the materials now in the strategic stockpile need to be upgraded to forms that will incorporate the maximum energy conversion costs, thereby expediting their use in time of emergency; and
—the United States has not effectively utilized Title III of the Defense Production Act of 1950 (50 U.S.C. App. 2061), which authorizes the government to expand domestic supply and productive capacity of vital resources and to explore for, develop and produce those domestic materials that could relieve the dependence on many uncertain foreign sources.

Discussion

All of the witnesses appearing before the full committee and the defense industrial base panel expressed extreme concern over the United States growing dependence on foreign sources for critical materials. The panel can add little to the presentations made by Gen. Alton Slay and Representative Jim Santini on the critical materials issue.

General Slay summarized the grim situation facing the United States when he told the panel:

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There was a time when we produced more raw materials than we consumed. Since 1950, however, our raw materials situation has deteriorated drastically. We have now become dangerously vulnerable to the OPEC-type mineral cartels. The dangers of a high dependence on foreign sources for any item essential to our nation's survival can be best illustrated by the OPEC oil cartel which caused: price escalation, shortages, inflation, dollar devaluation, trade deficits, and economic stagnation. While oil is the best known and the most important single commodity subject to possible cartel-type actions, it is not the only one.

Much of the world's production and reserves of a number of our critical materials are located in two areas of the world: Siberia and southern Africa. These two areas contain 99 percent of the world's manganese ore; 97 percent of the world's vanadium; 96 percent of the world's chrome; 87 percent of the world's diamonds; 60 percent of the world's vermiculite; and 50 percent of the world's fluorspar, iron ore, asbestos, and uranium. Zaire and Zambia now provide 65 percent of the world's cobalt.

The United States is more than 50 percent dependent on foreign sources for over half of the approximately 40 minerals which have been described as most essential to our $2.3 trillion economy.

Last year, the United States had to import over $25 billion worth of non-fuel minerals. This dependence on foreign sources for raw materials vital to our industries has been increasing for many years for several reasons including: technology advancements and legislative and regulatory restrictions imposed on the U.S. mining industry.

Our strategic vulnerability is obvious. On one hand, critical materials availability is subject to the political and economic stability of several southern African nations. On the other hand our chief remaining source is also our major international rival—the Soviet Union.

Figure 1 clearly shows the degree to which the United States has become dependent on other nations for many of critical materials essential to the U.S. economy.

U.S. NET IMPORT RELIANCE OF SELECTED MINERALS AND METALS AS A PERCENT OF CONSUMPTION IN 1979

FIGURE 1

Policy impact on critical materials availability

Mr. Santini stressed that many aspects of our foreign policy have been inconsistent with our critical material needs. He pointed out that many of the countries from which the U.S. imports essential minerals are now calling for a new international economic order, the right to nationalize, expropriate or transfer ownership of foreign property and exploit market forces to their advantage. As a result, few new western-mining ventures are being undertaken in these mineral-rich underdeveloped nations.

In summarizing his subcommittee's report, entitled "U.S. Minerals Vulnerability: National Policy Implications," Mr. Santini told the panel the United States currently lacks an effective national non-fuel minerals policy. He said "Our foreign policy has not been in tune with the reality that is shaping the nature of the United States dependency or that of the free world. It is imperative that foreign policy, therefore, emphasize the legitimate economic interests of the United States as a significant element of its national security interests. We must have an economic strategy for our relations with foreign nations that will give higher priority to mineral security aspects of those relations. We cannot wait until we are irrevocably trapped. Our foreign policy must work to reestablish traditional economic concepts under international law."

The Congress, responding to this lack of policy direction, recently enacted the National Materials and Minerals Policy, Research and Development Act of 1980, Public Law 96–479. The Act provides for a national policy to promote an adequate and stable supply of materials necessary to maintain national security, economic well-being and industrial production. The Act requires the President to report to Congress by October 21, 1981 his program plan to implement and carry out the national materials policy. While a step in the right direction, much remains to be done if an effective non-fuel minerals policy is to be implemented.

Excessive stifling and unreasonable governmental regulations

Approximately one-third of the nation's lands, some 750 million acres, are publicly owned. While these publicly owned lands have a huge mineral potential, little has been done to exploit it. Mining uses less than 6 million acres of U.S. lands. In contrast, farm lands use 1.3 *billion* acres, highways cover 24 million acres and airports and railroads cover 6.5 million acres.

In addressing the failure of the United States to tap the nation's mineral resources, Mr. Santini told the panel:

> Our Government, over the past 10 years, has made fundamental errors with respect to use or nonuse of public lands for mineral development. Instead, Government policies have proven to be counterproductive and discouraging to the discovery and development of mineral deposits. We have put every conceivable roadblock in the way.
>
> The most deplorable aspect of this shortsightedness about public land use is that it is being done without knowledge of the losses involved. There has been no attempt to understand

the long-term impacts. There is no government accountability to weigh the consequences. There have been numerous instances where public lands have been withdrawn when they were known to have mineral potential.

In 1974, one study estimated that we had prohibited or restricted mineral development under the mining law on two-thirds of our public lands.

We hear a lot of "regulatory reform", but all I have seen to date are cosmetic references to that phrase. The most difficult thing for me to grasp is that our dedicated but tunnel-vision regulators will be satisfied with nothing short of perfection. They refuse to even consider the alternatives. Perfection becomes a safe refuge in the bureaucratic process. It has created the expectations in the public mind that the only safe standard is "zero risk".

General Slay echoed Mr. Santini's concern over the growing restrictions on the U.S. mining industry by noting:

> The list of federal restrictions on mineral exploration is extensive. They include land management and land use restrictions, such as the Clean Air Act, Federal Water Pollution Control Act, Wilderness Act, Federal Land Policy and Management Act, and the Surface Mining Control and Reclamation Act.
>
> Currently, there are 80 different laws administered by 20 different federal agencies which directly or indirectly affect the domestic non-fuel minerals industry. The complex regulatory processes, the Government demand for data, and the environmental, safety and health requirements often prevent companies from starting new operations or expanding existing capacity.

Strategic and critical materials stockpile inadequate

The Strategic and Critical Materials Stock Piling Act, originally enacted in 1946, provides that strategic and critical materials will be stockpiled in sufficient quantities to sustain the United States for a period of not less than three years in the event of a national emergency. During the period 1946–1960, materials were actively procured for the stockpiles. However, in 1962, the size of the stockpile was considered excessive and in the following years large amounts of the accumulated commodities considered to be in excess of revised goals, were sold.

From 1946 to 1979, stockpile policies have changed direction many times with many changes in the established goals for individual commodities. During the period 1964 to 1975, stockpile holdings of some commodities, such as copper, aluminum, and nickel, were liquidated.

Today, the stockpile holdings of many materials that are vital to our national security needs are far below stated requirements; 60 percent of the 62 family groups and individual metals called for do not meet their goals. Mr. Paul Krueger, representing the Federal Emergency

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Management Agency (FEMA), the agency with responsibility f the stockpiles, told the panel that the raw materials currently in th stockpile are valued at $13 billion, compared to a desired invento valued at $18 billion. However, of this $13 billion worth of materia on hand, only $7 billion worth represents needed materials, the r maining $6 billion is considered excess to national security needs.

The declining posture of the stockpile has resulted not only fro a failure of successive Administrations to request, or the Congress appropriate, funds to make purchases for the stockpile, but also fro a failure to replenish the stockpile from the revenues generated fro the sale of commodities from the stockpile. During the 1960's an 1970's, large sales were made from the stockpile. Frequently, the sales were made for the purpose of helping to balance the feder budget. Instead of being used to buy badly needed materials such cobalt, titanium, platinum and tantalum, the revenues derived fro these sales were transferred to the general fund of the U.S. Treasu for other uses. With the exception of minor additions of chrysoti asbestos, jewel bearings and small diamond dies, no major additio has been made to the stockpile since 1960. The panel believes that, wit the support of the Executive Branch, the recently enacted Strateg and Critical Materials Stock Piling Revision Act of 1979, Public La 96–41, will help improve the strategic stockpile posture.

Stockpile in need of upgrade

Many of the materials currently in the stockpile should be upgrade or reprocessed to be usable. As a matter of prudence, the panel believe many materials need to be converted from the ore state to the primar metal or alloy. The best examples are the conversion of bauxite t aluminum, chromium to ferro-chrome and manganese to ferro-manganese. Through these conversions, energy is stored and the material are then readily available for use without further processing.

The purpose of the critical materials stockpile is to protect agains critical material shortages in times of national emergency. Furthe the stockpile is intended to reduce lead times and demands on man power, energy, production capacity, scarce machinery, and transportation incident to mining and processing that would otherwise creat additional demands in a war time environment.

The panel believes that current stockpile goals are much too low. In view of the complexity of international relations and political alignments over which the United States has no control, and of the genera trend toward resource nationalism, the panel believes the Unite States should reevaluate its stockpile goals, placing more emphasis o having the bulk of its three-year emergency requirement for critical materials available within the United States, either from domesti capacity or in its stockpiles.

At the current import rate of non-fuel minerals, some $25 billion worth a year, three years of imports would be valued at $75 billion. In contrast, the current stockpile goal for three years of material is only $18 billion. In a time of national emergency, the panel concludes, the nation's mineral needs would not be satisfied if imports were seriously curtailed * * * not an unlikely occurrence in a protracted conflict.

Title III Defense Production Act

The Joint Logistics Commanders,[4] Dr. Perry, and representatives from the Department of Commerce and FEMA recommended that the broad authority provided under the Defense Production Act should be used to address many of the critical materials problems facing the nation. The Act provides the authority to expand "* * * productive capacity and supply beyond the levels needed to meet the civilian demand, in order to reduce the time required for full mobilization * * *." Title III of that Act authorizes the use of Government loans, loan guarantees, purchase commitments, guaranteed production levels, and guaranteed prices to achieve these goals.

During the 1950s and 1960s, extensive use was made of the Defense Production Act. However, during the past decade little use has been made of the Act. The panel believes that the Act needs to be utilized to assist in the development of new materials and in the exploration and production of domestic sources of minerals that can relieve the U.S. dependence on many uncertain foreign sources for these minerals.

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[4] The Joint Logistics Commanders are: Commander, U.S. Army Materiel Development and Readiness Command; Commander, U.S. Air Force Logistics Command; Chief of Naval Material; and Commander, U.S. Air Force Systems Command.

Contracting Procedures are Excessively Restrictive

Finding

The panel finds that present policies and procedures for the procurement of property and services by the Department of Defense are excessively inflexible and discourage the use of contract types that would promote the best interests of the United States. As a result, many procurement contracts cannot be written that would promote stability encourage capital formation, and lead to efficiencies that would result in savings to the government.

The panel specifically finds that

—existing restrictions on advance procurement, multiyear contracting, including restrictions on the extent and content of cancellation ceilings, and funding of defense contracts, are unrealistic in view of the economic realities that now prevail in the defense industrial base;

—subject to the controls inherent in the authorization and appropriation process, multiyear contracting for advance procurement for the purpose of obtaining economic lot purchases will reduce costs, encourage program stability and enhance the defense industrial base; and

—the use of multiyear contracts to procure property and services (other than construction, alterations or major repair of real property) for periods normally not exceeding five years would offer maximum economies to the government at little additional risk.

Discussion

The panel was impressed by the recommendations of the witnesses representing the Department of Defense (DOD), industry, the Joint Logistics Commanders, the General Accounting Office, the Defense Science Board and the Department of Commerce that current procedures and policies relating to defense procurement should be made more flexible. Specific recommendations are as follows:

—Expanded application of the multiyear contracting procedure including the authorization of such contracts funded by single year appropriations;

—Repeal of section 810 of Public Law 94–106, which places a $5 million ceiling on cancellation costs in multiyear contracts; or increase the cancellation costs ceiling by severalfold;

—Relief from the so-called "full funding policy" which now effectively confines procurement contracts to those usable end items that can be placed under single year contracts supported by annual appropriations;

—Expanded application of the advance procurement concept through multiyear contracting for long lead items and for the purpose of obtaining economic lot quantities;
—Permit the recovery of recurring costs (labor and material) in the cancellation ceiling included within multiyear contracts;
—Require the Department of Defense to identify candidate programs for multiyear procurement, and to indicate the most efficient and economical production and acquisition rates for weapon systems or components contained in the Five Year Defense Plan;
—Establish criteria for multi-year contracting.

The basic policy which underlies the Armed Services Procurement
Act (10 USC 2301 et. seq.) is that purchases of and contracts for serv-
ices and property for the military departments will be subject to com-
petition where practicable. Except where one of 17 exceptions set
forth in section 2304 of title 10 applies, procurement must be by formal
advertising. Where permitted by law, procurement contracts may be
negotiated and, with the exception of the cost-plus-a-percentage-of-
cost system of contracting, " * * * the head of an agency * * *
may make any kind of contract that he considers will promote the best
interests of the United States." There is no general prohibition within
the law against the making of multiyear contracts through formal ad-
vertising or through negotiation.

Multiyear contracting

Multiyear contracting was authorized by Armed Services Procure-
ment Regulation (ASPR) in 1963, and is now authorized by para-
graph 1–322 of the Defense Acquisition Regulation (DAR). The le-
gality and propriety of this contracting method have been confirmed
by the Comptroller General on several occasions.[6] The concept has
been successfully applied in past DOD procurements and is generally
applied in the case of federal public works projects.

At this point, it is appropriate to define the panel's understanding
of what multiyear contracting entails. The panel understands that
this device involves the making of contracts, under competitive con-
ditions if practicable, for the procurement of quantities not in excess
of known requirements, for up to five years in support of programs
set forth in the Department of Defense Five Year Defense
Plan. Multiyear contracts may be entered into even though
the total funds ultimately expected to be obligated under the contract
are not available to the contracting officer at the time that the contract
is made. Contract quantities are budgeted, authorized and appropri-
ated for in the amounts required during each program year. Further,
a multiyear contract may authorize a defense contractor to expend
funds for materials, tooling, parts and the application of labor that
apply to the total quantities of end items planned for acquisition,
rather than limiting the contractor's expenditures to those items re-
lating only to quantities ordered and funded in a single year. Multiyear
contracts would normally contain a provision whereby the contractor
would be paid a cancellation charge representing preproduction, start-
up and other (material and labor) costs that would normally be amor-
tized in the price of all items to be furnished under the multiyear

[6] 43 Comp. Gen. 216, 43 Comp. Gen. 657, 46 Comp. Gen. 749, 48 Comp. Gen. 103.

contract. The cancellation provision would become operable if tl
requirement for the contractor's performance in the follow-on yea
disappears or if the Congress fails to provide additional funding f
the contract. The cancellation charge can be paid from existing appr
priations or from funds appropriated for such payments.

Benefits of multiyear contracting

During the panel's hearings, a broad range of witnesses unanimous
agreed that multiyear contracting for defense requirements can resu
in substantial benefits for both the government and industry, inclu
ing small business. The chief benefit to the government cited by tl
witnesses is the potential for reducing short-term costs, while impro
ing the industrial base to avoid higher costs in the future.

If the government is able to offer a long-term production contra
the competitive base is broadened, economies of scale are possible,
higher learning curve can be established, the work force is more stabl
and the contractor has an incentive to invest in labor-saving machine
and innovative production techniques. In summary, productivity
increased. In addition, costs can be reduced through the ordering
materials, parts and components in economic lots. Further, the inef
ciencies of program starts and stops are avoided.

Ancillary benefits to the government involve enhanced standardiz
tion, particularly in parts and components which under current pr
cedures may be obtained from a different contractor each year; reduc
administrative costs by avoiding multiple one-year contracts; ar
more consistent production quality. Moreover, where the contract
responds to the incentive to modernize his facilities, improved indu
trial capacity will be available for future defense orders.

As noted elsewhere in this report, United States industry is opera
ing in an environment of scarcity in many critical and strategic ra
materials. Domestic and international competition for these material
and for manufacturing capacity, has resulted in high rates of inflatic
and lengthening lead times which add to the cost of weapon systen
and delay production. The evidence before the panel clearly show
that current methods and policies for procurement and budgetir
within the Department of Defense are inadequate to deal with tl
problems at hand. Dealing with a multiyear problem on the basis
a single year's procurement slice defers any solution and aggravat
the problem's ill effects on costs and production.

Previous recommendations for multiyear contracting

Recommendations for expanded use of multiyear contracting di
not originate in the testimony before this panel. The Commission o
Government Procurement was established by Congress in 1969 to stud
and report its recommendations on methods to achieve "economy, eff
ciency and effectiveness" in procurement by the Executive Branch o
the government. In its December 31, 1972 report to the Congress, th
Commission recommended that the Congress enact legislation autho
izing all executive agencies to enter into multiyear contracts for sup
plies and services *with annual appropriations*. The General Accountin
Office (GAO), following a 1977 study of multiyear contracting, mad
almost identical recommendations to the Congress and the Executiv
Branch. The GAO, in its November 8, 1979 report, Impediments t

Reducing the Costs of Weapon Systems (PSAD-80-6), again recommended expanded multiyear procurement. The DOD Investment Policy Group report, approved by the Deputy Secretary of Defense on February 10, 1978, identified multiyear contracting as a technique to encourage capital investment by defense contractors. In addition, the Defense Science Board, in its 1976 and 1980 findings, recommended multiyear contracting in appropriate cases and the removal of several existing impediments to this contracting device. The panel also notes that in the Department of Defense Annual Report, Fiscal Year 1981 (page 252), Secretary Brown stated:

> * * * We are considering implementation of several recommendations for reducing unit cost made by the Defense Science Board. These include enhancing program stability through long term funding commitments, increasing use of competition, and greater attention ot product improvements in lieu of developing new systems.

The Joint Logistics Commanders have estimated that an expanded and more flexible multiyear procurement approach can provide savings of 10 to 15 percent. In one program alone, the TR-1 aircraft, the use of a multiyear approach can, according to the Commander, Air Force Logistics Command, avoid an 86 percent increase in costs compared to the currently-approved annual procurement plan.

The panel finds that, while there are legal and administrative provisions for multiyear contracting, certain impediments prevent the full use of the principle in cases where potential cost reductions would be the greatest—i.e. major weapon systems acquisitions and advance procurement of critical materials.

Limitation on cancellation costs provisions

Section 810 of Public Law 94-106 (The Department of Defense Appropriation Authorization Act, 1976) is as follows:

> "No funds authorized for appropriation to the Department of Defense shall be *obligated* under a contract for any multiyear procurement as defined in section 1-322 of the Armed Services Procurement Regulations as in effect on September 26, 1972, where the cancellation ceiling for such procurement is in excess of $5,000,000 *unless the Congress in advance approves such cancellation ceiling by statute.*" (emphasis added)

The net effect of the $5 million ceiling imposed by section 810 has been to restrict the use of multiyear contracting to a small number of low value contracts. Since program planning, budgeting, and contracting processes within the Department of Defense are not synchronized with the authorization and appropriation process within the Congress, it is a practical impossibility to identify a program, establish a level of funding, obtain bids or negotiate a contract, and then obtain a statutory exception for a particular contract. Section 810 has not been incorporated in the United States Code but is considered to be permanent law by the Department of Defense. Its restrictive provisions have been included in Office of Management and Budget (OMB) Circular A-11 and in Defense Acquisition Regulation (DAR) 1-322.

As previously stated, a multiyear contract is used for the purpose procuring planned requirements for more than one year without nec sarily having the total funds available at the time the contract is ma Contract quantities are budgeted for and financed for each progra year. Certain costs are amortized over the entire number of end ite to be produced, and unescalated unit costs are the same for items d livered in each contract year. Since contractors must incur certain co that pertain to the production of all items during the life of the mult year contract, a mechanism is required to protect them from loss in t event of contract cancellation after the first year. These costs are e pected to be recovered as the end items are produced. This protecti is provided through contract provisions that allow reimbursement f costs that would have been recovered in the prices of items that ha been cancelled—a "cancellation clause."

"Cancellation" of a multiyear contract means the cancellation of t *total* requirements of *all remaining years* covered by the contrac Cancellation occurs when the contracting officer notifies the contract that funds are not available to pay for contract performance for an subsequent contract year, or if the contracting officer fails to noti the contractor that funds are available to pay for performance in succeeding year.

Cancellation ceilings are reasonable estimates of the cost of pla and equipment rearrangements; special tooling and test equipmen preproduction engineering; initial rework; initial spoilage; pil runs; cost of facilities; costs for assembly, training and transportatio of a special work force; and unrealized labor learning. The cancella tion clause in a contract establishes the government's *maximum* liabil ity in the event of cancellation. Since these costs are amortized as con tract performance progresses, the government's exposure to liabilit for cancellation costs decreases with each year of performance.

The panel agrees with the collective opinion of the many experts i defense procurement that the ceiling of $5 million on cancellation cost should be eliminated because it serves to prohibit contracting officer from making contracts in the best interest of the United States. As now constrained, the multiyear contracting technique can be applied t only a small number of relatively low-value contracts where the potential for savings is low.

The legislative history of section 810 reveals that the provision wa an outgrowth of concern by the House Committee on Armed Service about two total-package, multiyear shipbuilding contracts—the LHA and DD-963. The contracts, for the design, development and construction of 9 LHA and 30 DD-963 vessels, were awarded on the basi of competition to a contractor with limited shipbuilding experience The vessels were to be built in a new shipyard utilizing series production techniques for the first time. These were high-to-medium risk programs with respect to both ship design and production techniques. A series of problems caused delays in the LHA program. These problems were intensified by the reduction of sealift requirements by the Secretary of Defense and the directed cancellation of four of the nine LHA ships. This cancellation required that the unamortized costs of the entire program be applied to only five ships instead of nine, substantially increasing units costs.

While the LHA and DD-963 programs were special and unusual cases, which occurred in a different economic environment, it is unlikely that a total package multiyear contract would be used for similar purposes today because of the requirement that the design must be stabilized before such a contract is made.

In view of the discouraging effect that the $5 million cancellation ceiling has had upon multiyear contracting, the panel believes that the ceiling should be removed or adjusted.

Recurring and nonrecurring costs

A second impediment to a more realistic application of multiyear contracting is the content of a contractor's (subcontractor's) protection against cancellation. As noted above, the cancellation ceiling may provide for payment of the contractor's costs for preproduction or start-up, labor learning and other *nonrecurring* costs applicable to all items and services to be furnished under a multiyear contract. However, DAR 1-322 provides that the contractor may not recover: "*any costs of labor or materials, or other expenses, which might be incurred for performance of subsequent program year requirements.*" (emphasis added) The contractor cannot recover *recurring* costs.

As the expert witnesses testified, this prohibition against the recovery of recurring costs would prevent the achievement of maximum savings through multiyear contracting even if the Congress increased or removed the $5 million cancellation ceiling. The panel finds that the inclusion of recurring labor and material costs in the cancellation ceiling can encourage longer-term contracting and avoid significant costs to the government. Under current regulations, a defense contractor is not authorized or obligated to incur costs for labor, materials or components that apply to work to be done subsequent to the current program year. If the contractor would take advantage of market conditions by ordering scarce materials earlier to assure their availability or to escape the effects of inflation, to take advantage of economic order quantities, invest in labor-saving equipment, or maintain a stable work force, thus lowering the government's costs, he must do so at his own risk. Understandably, contractors are becoming more and more unwilling to assume this risk.

Unfunded advance procurement

The business realities of the real world, where major defense acquisition programs are involved, are characterized by a seller's market, an ailing industrial base, competition from civilian procurement, a rising cost of money, competition for skilled workers, high inflation rates, and uncertain defense budgets. To maintain delivery schedules and program continuity, defense contractors are forced to buy a place in line years ahead of the fiscal year in which end items are actually purchased. Examples of items requiring advance obligations by contractors are components, forgings, castings, aluminum, titanium, and support equipment. Since current policies inhibit the ability of the Department of Defense to protect production schedules through adequate advance funding, defense contractors are either exposed to longer periods of unfunded financial risk or forced to delay deliveries. Because of increasing costs of materials and components, the increasing cost of money, program instability, and, in some instances,

cash flow problems, defense contractors are becoming more hesitan to assume financial risks for which they believe they are uncompen sated.

The panel believes that if the government is to take advantage o the considerable potential benefits of a more stable base of suppl and opportunities to avoid additional inflationary costs, it must b prepared to share the additional risks that now rest with the contrac tor and for which the contractor is not compensated. The panel wa unable to find any logical reason for the exclusion of recurring cost from multiyear contracts and can only conclude that the DAR pro vision in that instance is an overcautious approach to the matter an should be eliminated.

The "full funding" principle and advance procurement funding

"Full funding" is a principle agreed to by DOD and the appropri ations committees in budgeting for and providing funds for item covered by the procurement title of annual DOD appropriations acts Under this principle, each annual appropriation request must contair *all* of the funds *estimated* to be required for the *total costs* to be in curred in completing the delivery of a *given quantity* of *usable en items*. While the principle has never been incorporated into law, it ha nevertheless been incorporated into OMB Circular A-11 and DOD Instruction 7200.4, dated October 30, 1969.

"Advance procurement" funding for the purchase of long lead time components in advance of the fiscal year in which the related end items are to be funded is a recognized exception to the full funding principle, and is incorporated in DOD Instruction 7200.4.

While the full funding principle has not been universally applied to other areas of the federal government, it has been justified for several reasons in the case of defense procurement, as follows:

—A demonstrated joint commitment by the Congress and Executive Branch to a specific procurement;
—Visibility of the total costs of specified end items;
—No commitment to future procurement by the Executive Branch or future Congresses;
—Maximum flexibility to increase or decrease programs;
—All funds are in the hands of the Executive Branch, including estimated costs, cost growth and inflation; and
—Reduced requirements for program reviews.

The full funding principle is said to have many benefits which make its continued use desirable for most programs. Shipbuilding programs, for example, which span a number of years, particularly benefit from the availability of an appropriation of all estimated necessary funds prior to the commencement of construction. Full funding is also desirable where program schedules are not stable and where programmatic changes are highly probable.

While no witness before the panel advocated that full funding be abandoned as a general principle, all of those who addressed the issue strongly recommended that the Congress and the Executive Branch apply the principle with greater flexibility. The panel agrees with this recommendation based upon evidence that a strict adherence to full funding can be much more costly than the expected benefits. For example, full funding does not permit a stable procedure for the advance procurement of materials, piece parts, subassemblies and components that will be used in the production of end items in subsequent years. In the absence of some relief from full funding requirements, neither the benefits from multiyear contracting nor the economies of advance procurement can be fully realized by the government. Specific recommendations for *exceptions* to full funding received by the panel included: procurement of materials and other items two or more years in advance; permitting multiyear contracting for property and services from one year appropriations in selected cases; relaxing restrictions on the content and extent of contract cancellation clauses; and, permitting funding to "termination liability" limits in selected cases.

It has been argued that in the absence of full funding for procurement programs the government risks being left with no usable end items (aircraft, spare parts, engines, etc.) in case a contract is cancelled. The panel accepts the possibility of this risk but believes that the degree of risk can be minimized by restricting the application of multiyear contracting to programs which are stable and unlikely to be cancelled. Even in those cases where a contract may be cancelled the panel believes that the costs of cancellation can be greatly reduced by the diversion of unused materials to other uses, the sale of other assets, and the use of components where possible as spares. The panel believes that the actual experience of the Department of Defense has shown that the probable savings from a relaxation of the full funding principle are sufficient to overshadow the risks and that the risks are small.

The panel does not believe that multiyear contracting, liberalizing advance procurement procedures, or exceptions to the full funding principle are, within themselves, a panacea for the ills now afflicting the industrial base or the procurement of property and services for the Department of Defense. The panel does believe, however, that the removal or amendment of overly restrictive laws and regulations would result in substantial savings to the government, the value of which outweighs the benefits of those laws and regulations. The panel's recommendations are designed to achieve this objective.

Restrictions on advance procurement

To accomplish the possible savings incident to more prudent and businesslike advance procurement for major weapons systems, the military services must have relief from regulations that now apply. First, advance procurement has effectively been limited to a single year in advance of the year in which procurement funds are requested. Second, advance procurement has been limited to fully funding a given quantity of usable end items. Consequently, materials and parts cannot be bought in advance to avoid higher costs. Third, advance procurement policy now restricts advance procurement funding to a small percentage of total long lead requirements.

As currently structured, advance procurement regulations do not permit the most efficient use of appropriated funds. The regulations reflect the condition of the defense marketplace of several years ago when the numbers of long lead items were relatively small and

the costs represented a smaller ratio with respect to the costs of th completed weapon system. During the past decade, the procuremer environment has changed, but the regulations have not. As has bee mentioned elsewhere in this report, lead times on many items hav increased dramatically. Increased lead times for more and more item require more advance procurement funding earlier in the procure ment program. The alternatives to advance procurement—progra extension or production breaks—are unnecessary additional financi burdens on the taxpayers that can and should be avoided.

Termination liability funding

An alternative to fully funding advance procurement requiremen is "termination liability" funding. Under this method of contrac ing for long lead items, the government is obligated to pay the co tractor's *actual* expenditures plus termination liability for the ad vance procurement contract. The government initially pays the in tial costs to begin manufacturing of components. When the end item are subsequently purchased, the long lead items are fully funded.

The advantage of termination liability funding is that the amour required to be appropriated and obligated for advance procuremer is minimized, while the contractor's manufacturing effort is full funded at all times. Examples of four programs provided to the pan showed that full funding the advance procurement for those program would require 163 percent *more* funds to be appropriated for this pu pose than if termination liability funding were to be applied. The pan believes that termination liability funding for advance procuremen should be adopted as *a policy* since this alternative approach permit a more efficient use of available funds.

The utility of termination liability funding was recognized in th Joint Statement of the Committee of Conference on the Departmen of Defense Authorization Act, Fiscal Year 1980 (H. Rept. No. 96–546) In that report, the conference committee provided $130.1 million fo advance procurement of long lead items for 72 F/A–18 aircraft an directed the Secretary of Defense to contract for items and services fo that purpose on a termination liability basis. The conference committe said:

> This method of contracting and budgeting reduces the funding needed prior to the procurement authorization of full funding of the aircraft, and more accurately represents the manufacturing effort actually incurred during the advance procurement period.

Multiyear contracting using single year funds

Dr. William J. Perry, Under Secretary of Defense for Research an Engineering, the General Accounting Office, and the Joint Logistic Commanders have recommended that the Department of Defense b authorized to procure supplies and services by multiyear contractin from funds available only for a single year within the contiguous 4 States. This recommendation was also made by the Commission o Government Procurement which also recommended that such contract should be based on clearly specified requirements and not exceed a five-year duration unless otherwise authorized by statute.

The panel found that there are statutes that now prohibit the Department of Defense from entering into contracts for needs that extend beyond the current fiscal year when the funds to be used for such contracts are one-year appropriations. The Comptroller General has held that the obligation of funds under such circumstances would violate the Anti-Deficiency Act, the Surplus-Fund-Certified Claims Act of 1949, and the Adequacy of Appropriations Act. The witness representing the Comptroller General expressed the view that single year funds, such as funds for operation and maintenance, cannot be used to finance mulityear contracts for supplies or services inside the 48 contiguous states without specific statutory authorization. The panel notes that Public Law 90–378 (10 U.S.C. 2306(g)) permits the Department of Defense to enter into contracts for supplies and services outside of the contiguous 48 States for which funds would otherwise be available for obligation only within the fiscal year for which the funds are appropriated. Such contracts are subject to the following criteria:

—that there is a continuing requirement for the supplies and services;
—that the furnishing of such supplies or services will require a substantial investment in plant or equipment, or the incurrence of substantial contingent liabilities for the assembly, training, or the transportation of a specified workforce; and,
—that the use of such a contract will promote the best interests of the United States by encouraging effective competition and promoting economies in operation.

The "annual" form of funding is the most prevalent form found within Department of Defense appropriations acts. These funds are available for obligation only for the year in which appropriated unless otherwise specified by law. The Department of Defense must obligate annual funds during the appropriation year for bona fide needs of that year and is precluded from entering into contracts that obligate the government in excess of those needs.

The panel believes that opportunities exist to make substantial savings through multiyear contracting for supplies and services within the 48 contiguous states as well as in overseas areas within the criteria set forth in section 2306 of title 10 of the United States Code. This is especially true in view of the increased use of Office and Management and Budget Circular A–76 that is requiring more and more operation, maintenance, training, and base service functions to be placed under contract. The committee believes that the additional competition that would be engendered through multiyear contracting would result in greater efficiency and considerable savings if applied without geographic limitations.

Criteria for multiyear contracts

The panel emphasizes that multiyear contracting should be effectively managed to the end that property and services, including weapon systems, are acquired in the most timely, economic, and efficient manner. It should be the policy of Congress and the Department of Defense that, except for cost-plus-a-percentage-of-cost contracts, property and services shall be acquired by any kind of contract, including multiyear contracts, that will promote the best interests of the United States. Further, it should be the policy of Congress and the Department of Defense that such contracts, where practicable, shall provid for the acquisition of property and services, including weapon sys tems, at times and in quantities that will result in reduced costs an provide incentives to contractors to improve productivity through in vestment in capital facilities, equipment, and advanced technology.

The Department of Defense should be authorized to enter int multiyear contract whenever the following conditions exist:

—there will be a continuing requirement for the items to be ac quired in quantities consonant with current plans for the pro posed contract period, and the risks of contract cancellation ar low;
—the furnishing of such property will require a substantial invest ment in plant or equipment, the incurrence of substantial contin gent liabilities, or substantial investment for the assembly, train ing, or transportation of a specialized work force;
—the use of such a contract will promote the best interests of th United States by encouraging competition, promoting economie in production, and reducing total costs, thereby resulting in a mor timely delivery and deployment of the items tō be produced an contributing to improved prouctivity; and
—there is a stable design and the technical risks are not excessive

It should also be noted that under DAR 15.207.17 neither interes paid by the contractor nor imputed interest on equity working capita is an allowable cost that can be recovered by the contractor. Progres payments are discussed later on in this report in more detail but i should be noted at this point that since interest is not an allowabl cost, the incentive for the contractor to take advantage of market con ditions in material buys is thereby reduced; therefore, contracting of ficers should be given more flexibility in making progress payments i full advantage of multiyear contracting is to be taken.

Executive flexibility and congressional control

The panel recognizes the desire of the Executive Branch for maxi mum flexibility; that is, the ability to reduce or increase budget level for defense items from year to year, for fiscal or other reasons. Th panel also recognizes the desire of the Congress to retain control of th Federal budget through the authorization and appropriations proc esses. The panel believes that expanded multiyear contracting and th relaxation of full funding regulations do not conflict with thos principles.

The panel recognizes that almost all government procurement ac tions involve some degree of risk to both the government and the con tractor. The challenge to defense procurement management is t minimize risks while minimizing expenditures. The challenge to busi ness management is to minimize risks while maximizing profits. Th panel believes that management on behalf of both the Department o Defense and defense contractors have placed too much emphasis o risk avoidance and too little emphasis on cost avoidance.

The panel's record shows that there is a need to change some of th ways that the Department of Defense does business and has submitted recommendations for improvements. If these improvements are t work, however, there must be better business management, innovatior and fortitude in defense contracting.

Tax and Profit Policies Need Review

Finding

The panel finds that current tax and profit policies appear to discourage capital investment in new facilities and equipment that would increase productivity and improve the condition of the defense industrial base.

The panel finds that the Executive Branch and the appropriate committees of the Congress should consider

—revision of tax laws to allow more rapid depreciation;

—the amendment or repeal of Cost Accounting Standard 409, "Depreciation of Tangible Capital Assets";

—adjustment of progress payments to reduce contractor borrowing at high interest rates, and payment of interest as an allowable cost in defense contracts;

—amendment of Cost Accounting Standard 414, "Cost of Money as an Element of the Cost of Facilities Capital"; and

—examination of the cost versus benefits of safety, environmental, health, energy, equal employment, and other regulations.

Discussion

According to the Rules of the House of Representatives, the Committee on Armed Services has jurisdiction generally over matters relating to the common defense and also has the oversight responsibility, as do all House committees, of "* * * reviewing and studying on a continuing basis the impact or probable impact of tax policies affecting subjects within its jurisdiction * * *" (clause 2(b)(d), Rule X). The panel has identified possible modifications to the tax system that might improve the defense industrial base. Witnesses from both government and industry who appeared before the committee and the panel identified certain changes that could lead to improved productivity. The panel did not have sufficient time to explore these subjects to the extent the panel believes necessary. Each subject is complicated and warrants a separate review. The panel strongly urges that the appropriate committees of the Congress and the Department of Defense carefully examine each of these possible changes and such other measures that they find would stimulate and encourage capital investment.

Declining productivity

The record of hearings and the several studies completed by the Department of Defense and the General Accounting Office clearly document a decline in the United States' industrial productivity growth rate. According to the November 1979 report of the Comptroller General, *Impediments to Reducing the Costs of Weapons Systems* (PSAD 80-6), the average "annual rate of productivity growth in the past 10

years in the United States has been only one-half of that of the preceding 20 years, and the present rate of productivity improvement is considerably less than that of other industrial nations. The industrial decline of Great Britain has generally been viewed as the world's worst case; however, the United States' manufacturing productivity growth during the period from 1967 to 1977 has shrunk below Great Britain's. *The United States has achieved the alarming distinction of maintaining the lowest average annual manufacturing productivity growth rate among six major industrialized countries.* The range is from Japan's high of 6.8 percent to the United States' low of 2.3 percent, and both West Germany and France have more than doubled our rate." (italics added)

Productivity increases have historically followed capital investments in new plants, equipment, and manufacturing technology. Since such investments are made by management decisions that balance capital investment against long-range profits and the profitability of alternative investments, the United States needs a policy or strategy based upon the relationship between productivity and investment and the impact of tax policies on those two factors. The panel found no evidence of such a policy. The panel found indications that the management and investment practices of industry appear to be more oriented toward short term profit rather than long term growth. Although this is an important issue that needs to be developed, the panel did not specifically address management priorities in detail during its hearings.

While the panel recognized that many considerations are involved in investment decisions, the panel believes that the following issues should be immediately addressed by the Congress and by the Executive Branch.

Depreciation

The panel believes that the current tax system does not encourage industry to invest its profits in modern buildings and equipment. The tax lives of assets are set by the Treasury Department and are intended to reflect the useful life of each asset. Thus, industrial buildings are depreciated over a period of 30 to 45 years and industrial equipment is depreciated over periods of 6 to 12 years. The depreciation system is complex, cumbersome, and in burdened by many rules and regulations. Furthermore, the depreciation of an asset allowable for tax purposes is based on the original *acquisition cost* and not on the *replacement cost*, which, during this era of high inflation rates, is substantially greater. High inflation rates appear to have had a notably negative effect on investment under this current method of depreciation. For example, if the compounded inflation rate is 15 percent, the replacement cost of a piece of equipment quadruples in 10 years. If that equipment is depreciated over 10 years, only 25 percent of the replacement cost is recovered. The very reason for depreciation—replacement of equipment and productive assets—is defeated.

As a hedge against inflation, other industrial countries have adopted various methods of accelerated depreciation for their industries. For example, Switzerland allows a 50 to 80 percent depreciation in the first year for new machinery, 100 percent is allowed in the United

Kingdom in the first year, 95 percent in Japan in the first year, and 100 percent in Canada in the first 2 years. The panel, therefore, was not surprised to learn that the United States is running last in the rate of productivity growth.

The panel was informed that the Department of Defense recently has taken certain initiatives to improve the capability of the industrial base. Mr. Dale Church, Deputy Under Secretary of Defense for Acquisition Policy, stated that the success of the Department's initiatives is not yet known. For example, the Department, earlier this year, attemped to provide incentives to allow a contractor making a capital investment to recover an after-tax return of 15 percent. However, immediately after the Department of Defense instituted the change, the prime interest rate soared to nearly 20 percent, thereby diminishing the intended return.

The panel believes that, as a matter of high priority, the government should consider modification of current depreciation schedules to create an incentive for defense industry to invest in new facilities and equipment.

Cost Accounting Standards Board

The Cost Accounting Standards Board, created by law (50 U.S.C. Appendix 2168) as an agent of the Congress, is responsible for making, promulgating, amending, and rescinding rules and regulations for the implementation of cost accounting standards, that apply to all defense contractors and subcontractors, where procurement contracts exceed a value of $100,000. The panel received testimony to the effect that the Board is now defunct and that its functions may be transferred to the Office of Federal Procurement Policy within the Office of Management and Budget. The panel was told that currently there is no mechanism for amending or rescinding those cost accounting standards that have been promulgated. The panel received recommendations from several witnesses that two cost accounting standards should be modified—CAS 409 and CAS 414.

Cost Accounting Standard 409

Cost Accounting Standard (CAS) 409, concerning the depreciation of tangible capital assets, states at 409.50(f)(1) that:

> The method of depreciation used for financial accounting purposes (or other accounting purposes where depreciation is not recorded for financial accounting purposes) *shall be used for contract costing* unless (i) such method does not reasonably reflect the expected consumption of services for the tangible capital asset (or group of assets) to which applied, or (ii) the method is unacceptable for Federal income tax purposes. (emphasis added)

CAS 409 was incorporated into the Armed Services Procurement Regulation (now Defense Acquisition Regulation (DAR) at 15-205.9 that states, "allowable depreciation shall not exceed the amounts used for book and statement purposes * * *"

The effect of CAS 409 is to require depreciation, used for contract cost purposes, to be based on the historical useful life of capital assets or on their economical useful life. The Department of Defense has

implemented this standard by accepting the depreciation cost used contractors for financial accounting purposes to their stockholde which can be at a much slower rate of depreciation than the contrac uses for income tax purposes.

Some of those supporting a change in CAS 409 argue that even other devices, such as tax incentives, were provided to encourage c tractor investment in plants and machinery, CAS 409 would thw those efforts because contractors would have to depreciate their ass using one method for tax purposes and another method to reco depreciation of those same assets on Department of Defense contra Therefore, it is argued, capital recovery programs such as that c tained in the Capital Cost Recovery Act of 1979 (H.R. 4646 a S. 1435) being considered by the Congress, would be negated by C 409. It was suggested that this cost accounting standard be revised require that Department of Defense depreciation accounting rules compatible with tax incentives and with any national investm policy.

Some industry witnesses suggested that CAS 409 should be repeal particularly because it necessitates recordkeeping to develop the h torical basis for the tax lives of the assets.

The Department of Defense position on CAS 409 is that it is keeping with the concept used in the contractors' financial accounti for capital assets and generally reflects the actual useful lives of t assets. The Department also takes the position that CAS 409 would n negate the potential tax benefits of any accelerated depreciation mea ure and if CAS 409 were revised to require the use of a celerated depreciation for contract cost purposes, then contracto doing business with the government would receive benefits far excee ing those available to businesses selling to the public market. T defense contractor would, therefore, receive both a tax benefit and increase in cost chargeable to the government under government co tracts. On the commercial market only the tax benefit would be ava able, because commercial contractors could not increase their prices a remain competitive with foreign suppliers. The Department believ that the repeal of CAS 409 would significantly and, perhaps, pr hibitively increase the cost of weapons systems.

While the Department of Defense does not recommend that CAS 4 should be changed to comply with tax laws, the Department does su port revision of CAS 409 to permit the use of alternative depreciati methods where their use would increase capital investment and there decrease the total cost of the weapon systems.

The panel believes that the organizations responsible for the fu tions of the Cost Accounting Standards Board and the Department Defense should review CAS 409 with the objective of creating great incentive for contractors to invest in capital equipment.

Cost Accounting Standard 414

Cost Accounting Standard 414, entitled, *Cost of Money as an El ment of the Cost of Facilities Capital*, became effective on October 1976, and was implemented in DAR 15-205.50.

The purpose of CAS 414 was to give relief to contractors for t cost of money for facilities by establishing criteria for the measureme and allocation of the cost of capital committed to facilities as an el ment of contract cost, and to offset that cost in developing the contract profit objective. Under CAS 414, the capital cost of money for facilities is removed as an unidentified contract profit amount and is treated separately as an identified contract cost. The Cost Accounting Standard Board's intent was, apparently, that a contractor, with substantial investment in facilities, should receive increased compensation. This intent, in part, has been subsequently frustrated since the government has now removed this cost from the contract profit and now determines a rate of return on the cost of capital based on the Treasury rate, which today is substantially less than the actual cost of money to industry.

The Cost Accounting Standards Board selected the Treasury rate for determining the return on imputed capital for equipment because, in its opinion, the rate approximated the real cost of money for long-term investments. The Department of Defense informed the panel that it would support a revision to CAS 414, and suggested that consideration of the use of alternate long-term market money rates would be equally appropriate. The panel believes the use of short-term money rates, however, would be inappropriate for return on investments in capital equipment. The panel urges an examination of CAS 414 in order to provide flexibility such as using alternate rates that reflect a rate of capital cost closer to the actual rate.

Progress payments

Defense Acquisition Regulation (DAR) E–503.1 establishes the uniform standard percentages of progress payments to defense contractors. Progress payments compensate the contractor for labor, materials, and other costs incurred as the work on the contract progresses toward completion. These costs are billed to the contracting officer periodically, after they have been paid by the contractor as established by the contract. Prudent management requires that the government withhold a portion of progress payments as a protection against the contractor's nonperformance of the contract. The usual progress payment is 80 percent of total costs for contractors other than small businesses. For contracts awarded to small businesses, the rate is 85 percent. To the extent that the contractor's costs are not compensated, the contractor is required to carry the cost of working capital.

Dr. Allen Puckett, Chairman and Chief Executive Officer, Hughes Aircraft Co., provided the panel with an insight into the cost to the contractor of working capital not covered by progress payments. He stated: "In fact, the situation is much more complex because of time lags in recording cost, submitting billings, and receiving payment. Data gathered in a recent industry survey indicate that at an 80 percent rate, progress payments actually provide only about 60 percent of the working capital investment and the contractor must provide the balance of 40 percent."

In addition, interest paid by the contractor on his share that is financed by borrowing, or imputed interest on any working capital financed from equity, is not an allowable cost recoverable from the government under the existing regulation (DAR 15.207.17). Therefore, assuming a 15 percent interest rate, as opposed to what is considered a normal interest rate, the cost of the contractor's share of the working capital to the contractor will result in a substantial decrease in realized profits. The panel believes that this decrease in profits directly impacts

industry's cash flow and ability to reinvest in capital equipment an new technology.

If contracting officers were given more flexibility in making progres payments, and were allowed to compute the amount to be paid by th individual contractor and individual contract up to 100 percent of th contractor's cost, the contractor would not have to use large amounts o his own capital. Consequently, the problem caused by high interes rates paid by a contractor would substantially diminish.

The panel realizes that progress payments provide a degree of pro tection to the government against the failure of a contractor to per form under the contract. However, in view of high inflation and in terest rates, current progress payment rates may be placing an in ordinate burden on defense industry. Changes in progress payment can be addressed by the Secretary of Defense through changes t regulations and the panel believes appropriate action should be taken It appears to the panel that the government's interests in the contrac could be protected by a formula that would consider the risk of non performance, interest rates, the cost of capital and contract profit ability. While progress payments at the 80 percent rate may provid a higher degree of protection to the government, other aspects ma well work against the governments' interest in improving produc tivity.

Other contractor costs

The defense contractor is bound by procurement regulations and practices which determine both profit rates and contract financing terms. In addition, in the last decade, government regulations in other areas have increased dramatically. The recent requirements of safety, environmental, health, energy, equal employment, and other regulations have diverted large amounts of business capital from investment in new equipment and facilities. The cost of compliance particularly hampers the subcontractor who finds his profits eroded by the number of regulatory burdens the system places on his business.

Deputy Under Secretary Church commented to the panel that one major problem he believes influences the capability of the industrial base is "overburdening the defense contracting system with social, economic, and other types of special legislation. It is at least ten times worse than the second worse system of government contracting in the world."

While the panel is unaware of any previously expressed strong Department of Defense position regarding the ill effects of the above legislation, the panel recommends that, in the future, DOD express to the Congress the Department's position before burdensome legislation is passed. Legislation during the past decade has required huge expenditures from industry in attempting to meet unrealistic guidelines and deadlines. Many of these expenditures have had to be given first priority over plant and equipment improvements. In sum, the government has forced industry to invest its profits in nonproductive improvements. The panel agrees that the number of government regulations should be minimized and that defense contracting should not be used to solve social problems. Further, the panel believes the regulations should be examined to assess the cost of compliance compared to the social benefits derived.

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Need for Leadership in Defense Industrial Planning

Finding

The panel finds that while the condition of the defense industrial base is of vital importance to the national defense and security of the United States, responsibility for the condition of the base is dispersed among the committees of Congress and within the Executive Branch. This diffusion of responsibility has contributed to a lack of effective long range planning for industrial responsiveness. It has also made it extremely difficult to assess the overall effects of executive and congressional action on the defense industrial base.

The panel specifically finds

—no focal point for leadership with respect to the defense industrial base within the Congress; jurisdiction of interstate and foreign commerce, public lands, mining, minerals, procurement laws, defense production, procurement, research and development and taxation is divided among several committees;

—no focal point for leadership within the Executive Branch, where responsibility for the defense industrial base is divided among the Departments of Defense, Commerce, Interior, Treasury, Energy, State, and various other agencies; and

—a need for central leadership and coordination in defense industrial base preparedness (defense industrial base preparedness plannings) at least as great as similar needs in the energy and environmental areas. The lack of concentrated leadership within the Congress and in the Executive Branch has served to mask from public view the acute problems afflicting the defense industrial base.

Discussion

Clause 1(c) of Rule X of the Rules of the House of Representatives assigns a very broad area of legislative jurisdiction to the Committee on Armed Services. Jurisdictional areas involved in the panel's report are: the common defense generally; the Department of Defense, the Departments of the Army, Navy and Air Force generally; research and development in support of the Armed Services; strategic and critical materials necessary for the common defense; and military applications of nuclear energy.

In addition to its specific legislative jurisdiction under clause 2 of rule X, the Committee on Armed Services has the responsibility to assist the House in its analysis, appraisal and evaluation of the application, administration, execution and effectiveness of the laws. Also, the committee is responsible, where conditions or circumstances exist, for recommending necessary changes in the law or the enactment of new laws when required.

The committee is charged with a continuing review of the laws applicable to the Department of Defense and the Departments of the

Army, Navy and Air Force in order to determine whether those la
and defense programs are being implemented in accordance with t
intent of Congress.

As mentioned elsewhere in this report, the Committee on Arm
Services also has the function of reviewing and studying on a co
tinuing basis the impact or probable impact of tax policies affecti
the matters within its jurisdiction.

The panel has approached the complex subject assigned to it w
both the letter and spirit of rule X in mind. The panel realizes th
several of the problems existing in the industrial base can be alle
ated by legislative action within the jurisdiction of the Committee
Armed Services. Recommendations for this action are included in t
report. However, the ills that now beset the industrial base perva
not only various segments of the Executive Branch but also the jur
diction of several other standing committees of the House. In the
cases, the panel hopes that this report will serve as a catalyst for add
tional congressional and administrative action.

The panel believes that the assignment of a strong central respo
sibility and leadership role within the executive branch—not to stud
but to act—will be necessary to prevent a further deterioration in o
defense industrial responsiveness. On the other hand, the panel b
lieves that a spirit of urgency and cooperation among the sever
committees of jurisdiction within the House will be necessary. Wi
anything less, both the Congress and the Executive Branch will l
attempting the impossible—the reestablishment of a first-rate milita
force through a second-rate industrial base.

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APPENDIX

Witness List

List of witnesses appearing before the Full Committee and the Defense Industrial Base Panel on the matter of the preparedness of the defense industrial base.

Full Committee Hearings

SEPTEMBER 17, 1980

Dr. Eugene Fubini, Chairman, Defense Science Board.
Mr. Robert Fuhrman, Chairman, Defense Science Board Summer Study Task Force on Industrial Responsiveness.
Mr. Harry Gray, Chairman and Chief Executive Officer, United Technologies Corp.

SEPTEMBER 18, 1980

Dr. Allen Puckett, Chairman and Chief Executive Officer, Hughes Aircraft Co.

SEPTEMBER 25, 1980

Mr. T. A. Wilson, Chairman of the Board, The Boeing Co.
Mr. Dale Church, Deputy Under Secretary of Defense for Acquisition Policy, Department of Defense.

Panel Hearings

OCTOBER 21, 1980

Mr. Oliver Boileau, President, General Dynamics Corp.

OCTOBER 22, 1980

Mr. Donald Maag, President, Norris Industry.
Mr. Donald White, Consultant to the President, Norris Industry.
Mr. Frank Taylor, President, Tectron, Inc.
Mr. Samuel Garcia, President, Hydraulic Research.
Mr. James Brannan, President, Waltco Engineering Co.
Mr. Walter Brannan, President (ret.), Waltco Engineering Co.
Ms. Maria Belanger, President, Precision Dip Brase, Inc.
Mr. Dick Valdes, General Manager, Precision Dip Brase, Inc.
Mrs. Helen Sherman, President, Sherman Corp.
Ms. Darlene Sherman, Vice President, Sherman Corp.
Mr. Edward Gowen, Vice President, Huck Manufacturing Co.

OCTOBER 23, 1980

Mr. James Weldon, Vice President and General Manager, Electrodynamics Division, The Bendix Corporation (record not published).

OCTOBER 24, 1980

Mr. Jerry Junkins, Vice President, Texas Instruments, Inc.
Mr. Donald Walker, Manager of the Military Products Department, Texas Instruments, Inc.
Mr. Pat Weber, Vice President, Manager of the Electro-optics Division, Texas Instruments, Inc.

NOVEMBER 12, 1980

Gen. Henry Miley, Jr. (ret.), President, American Defense Preparedness Association.
Maj. Gen. Frank Ragano (ret.), Director, Technical Operations, American Defense Preparedness Association.

NOVEMBER 13, 1980

Gen. Alton Slay, Commander, Air Force Systems Command.
Adm. Alfred Whittle, Chief of Naval Material.

NOVEMBER 14, 1980

Gen. John Guthrie, Commanding General, U.S. Army Material Development and Readiness Command.

NOVEMBER 17, 1980

Mr. Walton Sheley, Jr., Acting Director, Procurement and Systems Acquisition Division, General Accounting Office.

NOVEMBER 18, 1980

Gen. Alton Slay, Commander, Air Force Systems Command.
Dr. Jacques Gansler, Vice President, Analytical Science Corp.

NOVEMBER 19, 1980

Gen. Bryce Poe II, Commander, Air Force Logistics Command.
Mr. Thomas Bahan, TR-1 Program Manager, Air Force Logistics Command.
Mr. Peter McCloskey, President, Electronic Industries Association (EIA).
Mr. Robert Maneship, Chairman, EIA Multiyear Procurement Task Force.
Mr. Jim Drake, Staff Member, 1980 Defense Science Board, Summer Study Task Force on Industrial Responsiveness.
Mr. Wallace Brown, Director, Office of Industrial Mobilization, International Trade Administration, Department of Commerce.
Mr. Iain Baird, Director, Priorities and Allocations Division of the Office of Industrial Mobilization, Department of Commerce.

NOVEMBER 20, 1980

The Honorable Jim Santini, Chairman, Subcommittee on Mines and Mining, Committee on Interior and Insular Affairs, U.S. House of Representatives.
Mr. Paul Krueger, Assistant Associate Director for Research Preparedness, Federal Emergency Management Agency.

DECEMBER 3, 1980

The Honorable William Perry, Under Secretary of Defense for Research and Engineering.
Mr. Robert Trimble, Director, Contract and Systems Acquisition, Department of Defense.

SELECTED POLICY ASYMMETRIES RELEVANT TO THE U.S. MINING AND MINERAL PROCESSING INDUSTRY: TAXATION

U.S. POLICY OR CONDITIONS	FOREIGN GOVERNMENTS POLICY OR CONDITIONS
Uncertainty about future tax laws can also detract from the investment climate. An official of the zinc industry stated that frequent changes and calls to overhaul U.S. tax laws creates a climate of uncertainty that affects long-term planning. For instance, the percentage depletion allowance has come under frequent attack as a subsidy to mineral enterprises which deprives the Federal Government of large amounts of revenue. Largely on the basis of such arguments, the Tax Reform Act of 1969 reduced percentage depletion rates for a number of minerals.	As a way to attract desired investment, some countries are guaranteeing tax rates for a period of years. -- Chile allows foreign-owned companies to pay either the prevailing tax rate, which might fluctuate, or a rate guaranteed to remain the same for 10 years. -- Peru negotiates reduced tax rates during a project's investment recover period. -- The state governments of Australia (which have primary authority over mineral development) negotiate the terms for new ventures, including the tax rate, which may be less than the statutory rate. Foreign governments have allowed firms to recover a higher percentage of capital outlays in the early years of new projects. This is particularly important since the earlier the tax benefits, the sooner cash is freed for such pruposes as further capital investment.

Source: Report to the Congress of the United States, by the Comptroller General of the United States, entitled: "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications," Oct. 31, 19 ID-80-04, p. 48.

U.S. MINING AND MINERAL PROCESSING INDUSTRY:

TAX POLICY

U.S. POLICY OR CONDITIONS	FOREIGN GOVERNMENTS POLICY OR CONDITIONS
[U.S. Investment Tax Credit of 10% of the cost of eligible property.]	-- Swedish companies are allowed to set aside 40% of their profits from any one year as tax-free income. These funds may be used later, under certain conditions, for new investments. -- Norwegian firms may set aside and exempt from taxable income up to 25% of their profits for investment in certain developing areas of Norway. Companies must reduce the depreciable amount of assets purchased with these reserves, but the reduction may be as little as 55% of the reserves used. -- Spanish companies may place up to 50% of their undistributed earnings in a tax-free investment reserve which may be used to acquire fixed assets. Some countries also offer other exemptions or reductions in the amount of taxes paid by companies located there. -- Ireland offers a tax exemption on all export profits until 1990. -- The Philippines allows certain enterprises a diminishing tax exemption over a 15-year period from all national taxes except income taxes. -- The Republic of Korea allows foreign enterprises exemptions or reductions for up to 8 years for income and corporation taxes, property and acquisition taxes, and taxes on dividends.

Source: Report to the Congress of the United States, by the Comptroller General of the United States, entitled: "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications," Oct. 31, 1979 ID-80-04, p. 47-48.

ACCESS TO PUBLIC LANDS & ASSISTANCE IN EXPLORATION

<table>
<tr><th>U.S. POLICY OR CONDITIONS</th><th>FOREIGN GOVERNMENTS POLICY OR CONDITIONS</th></tr>
<tr><td>[Access to public lands for mineral development is very much in question and the U.S. Government limits the use of Federal lands for mineral exploration.]

Even when authority to explore Federal lands for minerals is granted, operating conditions must be followed which industry officials believe are overly restrictive and impede exploration and development. The conditions imposed include:

-- restrictions on the types of equipment that can be used, i.e., size limitations on helicopters;
-- parameters for construction of roads and drill sites; and
-- provisions for restroation.

Mineral exploration and development has also been hampered by administrative delays. To process lease applications for exploration and development on Federal lands, coordination is needed between Interior's U.S. Geological Survey and Bureau of Land Management and Agriculture's Forest Service. A Forest Service official estimated, based upon actual examples, that the minimum processing time for approval of a prospecting lease was 17 months and for a mineral lease and mining plan 3 years. For example, in August 1976, a U.S. firm applied for two hardrock Federal prospecting permits covering tracts in Idaho. It took about 24 months of processing time for the permits to reach the Secretary of the Interior's office, where they were presented for signature by July 1978. As of April 1979, the applicant had not been advised of the final disposition of these permits.</td><td>In contrast to U.S. restrictions, several countries, in line with their own national priorities, successfully encourage exploration and mine development through government programs. For example:

— The Republic of South Africa funds and actively participates in exploration for certain minerals in areas selected for development.
— Ontario, Canada, funds one-third of approved exploration in selected areas.
— Argentina provides financial support and risk-sharing programs to assist in identifying and developing resources.
— The Republic of Korea directly funds a substantial mineral exploration program in support of its metal-processing industry.
— The Philippines and Spain provide development loans and loan guarantees to private companies to finance exploration and development of mineral deposits.
— Brazil has programs to finance of subsidize up to 80 percent of exploration costs.

Additionally, a number of countries, such as Japan, The Republic of Korea, France, and The Federal Republic of Germany provide substantial incentives and subsidies to their minerals industries for exploration in foreign countries, usually with the understanding that their own processing industries will be acsured access to the ores and concentrates from any deposits found.</td></tr>
</table>

Source: Report to the Congress of the United States, by the Comptroller General of the United States, entitled: "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications," Oct. 31, 197 ID-80-04, p.23, 24.

AVAILABILITY OF RISK OR CAPITAL SUBSIDIES

U.S. POLICY OR CONDITIONS	FOREIGN GOVERNMENTS POLICY OR CONDITIONS
[Capital availability is a significant problem as cost of new facilities significantly outpaces capital reserves. Earnings are insufficient to provide capital and some firms have reached debt limits.] Representatives of several major commercial banks commented that in recent years banks have increasingly attempted to assess "regulatory risks" in considering mineral project proposals and that as perceptions of such risks grew, access to loan capital diminishes. One bank representative indicated that any loan made to finance a new domestic copper smelter would be loaded with protective conditions which would give a borrower difficulty but which would be necessary to protect the bank against "regulatory risks," specifically emissions regulations compliance problems.	While the financial condition of U.S. mineral firms is hindering their ability to accumulate capital for domestic projects, foreign governments are often subsidizing or sharing the risks of projects within their borders as a way of stimulating development perceived to be in their national interest. One increasingly common technique is for governments to guarantee loans for projects. For example: — Guyana guaranteed repayment to three banks for a $30 million loan to finance the development of bauxite/alumina facilities. — The Government of Qatar guaranteed repayment to 23 banks for $100 million loan to finance development of steel production facilities. — New Zealand guaranteed repayment to a consortium of banks for a $100 million loan to finance mining activities. — The Philippines guaranteed the loan for a recently completed copper mine which would not have been financed without the guarantee. Foreign governments also have provided direct subsidies to finance new developments. For example, the Government of Ireland provided direct subsidies totaling more than $33 million for an aluminum company to construct and equip alumina production facilities. In 1974, the Canadian Government contributed $717 million in direct cash grants to the firm sponsoring a $63 million ferrosilicon production facility. Canada also recently contributed $18 million in cash grants and easy term loans as part of its participation with two European companies in a joint venture to develop a zinc mine. Some governments have formed national development banks to foster growth in the minerals sector as part of economic development plans. The Development Bank of the Philippines has been effective in Philippine mining ventures through (1) loan guarantees to third parties, (2) direct funding of loans, and (3) direct investment in the project, if necessary, to get it started. Brazil's National Development Bank has aggressively loaned funds for steel and nonferrous metals projects as part of a national effort to reduce imports of these commodities. During 1976-79, the Bank estimated its participation in nonferrous metals projects at $111 million and in the steel industry at $318 million.

Source: Report to the Congress of the United States, by the Comptroller General of the United States, entitled: "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications," Oct. 31, 197 ID-80-04, p.28, 32.

U.S. MINING AND MINERAL PROCESSING INDUSTRY:

JUSTICE DEPARTMENT ANTI-TRUST POLICY

U.S. POLICY OR CONDITIONS	FOREIGN GOVERNMENTS POLICY OR CONDITIONS
According to domestic mineral industry officials, the preconceived threat of investigation has inhibited a number of firms from considering joint ventures. For instance, in the early 1970s, when U.S. copper smelters were pressed into producing sulfuric acid from waste gases as the most practical means of complying with the Clean Air Act, some companies in the southwest considered the possibility of a joint disposal effort. Because of their distance from the main sulfuric acid market (the industrial midwest) and because of the high cost of producing sulfuric acid, the companies believed that a joint venture would ease some of the difficulties involved in the disposal of the acid. However, they decided that even though they could make a strong case for the legality of the venture, it would still be viewed with great suspicion by the Justice Department and lead to increased surveillance of the copper industry.	In contrast, Canadian copper producers formed just such a joint venture for selling sulfuric acid in the United States, and as a result, will have a lower disposal cost than they would have had otherwise.

Source: Report to the Congress of the United States, by the Comptroller General of the United States, entitled: "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications," Oct. 31, 197 ID-80-04, p. 36.

U.S. MINING AND MINERAL PROCESSING INDUSTRY:

OCCUPATIONAL HEALTH AND SAFETY

U.S. POLICY OR CONDITIONS	FOREIGN GOVERNMENTS POLICY OR CONDITIONS
Measuring the differences between worker health and safety standards of the United States and other countries is difficult because the strictness and methods of enforcement vary from country to country. However, a significant difference in the approach to such standards does seem apparent from our observations. U.S. worker health and safety standards are enforced at all locations generally without regard to circumstances, and, although OSHA allows some variances, its latitude in permitting these variances is limited. In contrast, other countries apply their standards case by case, obtaining the level of compliance feasible for each particular facility, and seemingly giving priority to the continued operation of the facility. OSHA also prefers engineering controls (design of processing machinery and facilities to contain emissions) for achieving compliance, while less expensive control methods, such as protective clothing, respirators, and work practices, are acceptable in some foreign countries.	In the Philippines, Australia, Chile, Mexico, and Spain, enforcement of worker health and safety standards does not appear to be as strict as in the United States; priority companies are often allowed great latitude in enforcing the standards. A copper smelter in Chile, for example, uses a process that occasionally emits large concentrations of sulfur dioxide gas into some work areas, a more efficient and energy-saving process is being developed which will also reduce and facilitate treatment of these emissions, but efforts directed specifically at reducing sulfur dioxide emissions will not be made until this process is implemented. For example, Swedish health and safety standards are generally strict; however, a copper smelter in Ronnskar that processes copper ore with a high arsenic content, similar to a smelter in the United States, has been permitted to use protective clothing and respirators to protect its workers from arsenic exposure and has been given considerable time in which to comply with Sweden's arsenic emission standards. In 1975, the Swedish Government also authorized a $13 million grant to the firm for processing equipment that reduce arsenic emissions.

Source: Report to the Congress of the United States, by the Comptroller General of the United States, entitled: "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications," Oct. 31, 197' ID-80-04, p. 41-42.

U.S. MINING AND MINERAL PROCESSING INDUSTRY:

AVAILABILITY & PRICE OF ENERGY

U.S. POLICY OR CONDITIONS	FOREIGN GOVERNMENTS POLICY OR CONDITIONS
<u>Availability & Price of U.S. Energy Are Both Significant Questions</u> Industry officials believe the uncertainties regarding electric power availability in the United States will hinder future expansion of mineral processing capacity and will encourage expansion overseas where power availability will be most assured by host governments.	<u>Foreign Governments Attempt to Minimize Uncertainty About Energy Availability</u> Some countries have a natural advantage over the United States in providing energy because they have underutilized energy resources; others are giving high priorities to securing energy for industrial expansion. For example: — Chile, although it does not have abundant energy resources, has taken steps to assure the minerals industry of long-term energy availability. — The Republic of South Africa provides long-term energy supply commitments to industrial customers. — Australia, South Korea, Norway, and Sweden negotiate special energy rates of fixed (often long-term) duration. These approaches reduce the uncertainty regarding energy availability that is important to an investment decision. This is in apparent contrast to the climate of increased uncertainty in the United States.

Source: Report to the Congress of the United States, by the Comptroller General of the United States, entitled: "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications," Oct. 31, 1979 ID-80-04, p. 44-45.

U.S. POLICY OR CONDITIONS	FOREIGN GOVERNMENTS POLICY OR CONDITIONS
For example, in the United States companies are allowed accelerated depreciation that enables assets used in mining and beneficiation to be depreciated on a diminishing-value basis over 8 years.* (The minimum depreciation period for manufacturers of primary ferrous and nonferrous metals is 14.5 and 11 years, respectively.) The companies also may deduct 20% of the cost of qualifying property (subject to dollar limitation) as additional first year depreciation. Net operating losses may be carried back 3 years and forward 5 years. *This is the lower limit of IRS' Class Life Asset Depreciation Range System of computing the reasonable depreciation allowance for all eligible property (IRS publication 534, 1979 ed.) Under the system, useful life is generally shorter than under normal methods of depreciation.	-- In Ireland, mining firms may claim at any time depreciation up to 100% of the cost of fixed plant and machinery. In the underdeveloped areas, a 20% investment allowance is available for new plant and machinery in addition to 100% depreciation (total 120%). Unlimited loss carryforward and a one-year loss carryback is also permitted. -- In Australia, mining firms enjoy an accelerated depreciation allowance that enables capital expenditures on the mine to be deducted on a diminishing-value basis over 5 years. They may also take a 20% investment allowance for new plant and equipment costs. Net operating loss carryovers may be carried forward 7 years, but not carried back. -- In South Africa, mining firms may deduct 100% of mining capital expenditures as incurred. While there is no loss carryback, there is no limit on loss carryforward. -- In Canada, mining firms may deduct up to 100% of the costs of depreciable assets acquired for new mines or major expansions of existing mines in any one year, limited to the amount of income before depreciation. Net operating losses may be carried back one year and carried forward 5 years.

Source: Report to the Congress of the United States, by the Comptroller General of the United States, entitled: "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications," Oct. 31, 1979 ID-80-04, p. 46-47.

ENVIRONMENTAL COSTS & THEIR INCIDENCE

U.S. POLICY OR CONDITIONS	FOREIGN GOVERNMENTS POLICY OR CONDITIONS
One of the most significant ways the U.S. Government influences mineral development costs is through mandated environmental protection requirements. For instance, a study performed under contract for the Department of Commerce estimates that if compliance with Federal air and water pollution control standards and land-use requirements are fully enforced, it will cost the U.S. copper industry over $1.4 billion (1974 dollars) in capital expenditures during 1978-87. (Operating costs during this period are estimated to be an additional $1 billion.) In a 1970 report to Congress, titled "The Cost of Clean Air," the Secretary of Health, Education, and Welfare asserted that 98.8% of sulfur dioxide emissions could be feasibly removed from copper, zinc, and lead plants (49% removal was average at the time) and that this could be accomplished at all primary nonferrous metallurgical plants in 100 selected areas over a 5-year period for a probable capital cost of $67.6 million. However, domestic copper producers spent an estimated $695 million from 1974 to 1978 for sulfur dioxide emission controls. According to a report by Arthur D. Little, Inc., for EPA in 1978, producers could have to spend as much as an additional $953.5 million through 1987 (1974 dollars).	Shifts in mineral sector investment due to regulatory constraints could benefit countries whose approaches to regulations are more flexible or willingness to support the additional costs may give projects cost advantages. For example, several countries, including Australia, the Philippines, Brazil, Venezuela, Sweden, West Germany, and Ireland give high priorities to the costs and practical consequences of environmental standards in determining the extent to which they will be enforced. Norway, Sweden, and West Germany also provide financial support for new equipment needed by firms, including equipment needed for environmental protection.

Source: Report to the Congress of the United States, by the Comptroller General of the United States, entitled: "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications," Oct. 31, 197 ID-80-04, 26-28.

Columbia University in the City of New York | *New York, N.Y. 10027*

HENRY KRUMB SCHOOL OF MINES

Seeley W. Mudd Building

26 February 1981

Dr. John B. Wachtman, Jr., Director
Center for Materials Science
National Bureau of Standards
Washington, DC 20234

Dear Dr. Wachtman:

We appreciate the invitation to attend and participate in the Workshop on "Critical Materials Needs in the Aerospace Industry." My presentation pivoted about the enclosed paper on "Cobalt Availability and Superalloys" and our very recent progress report to NASA on research on "Understanding the Role of Cobalt in Nickel-Base Superalloys." These documents are attached. Please use the information as you see fit. However, the data in the progress report are, of course, of a preliminary nature and should be treated accordingly. I also take the liberty of enclosing a copy of the "NASA's Activity in the Conservation of Strategic Aerospace Materials" paper by Mr. Joe Stevens, which discusses the NASA-contemplated COSAM (Conservation of Strategic Aerospace Materials) program. In what follows Robert Jarrett, my graduate student, and I wish to convey to you our thoughts on the issues that were raised in the Workshop.

We agree with the Workshop conclusions that Ni, Fe, Al and Mo are basically available for strategic applications. Ti, although available, can be in periodic short supply due to capacity problems. W is overstockpiled, its availability enhanced by recent domestic discoveries. Certainly Co, Cr, Ta and Nb can be considered to be strategic elements with critical supply problems.

We classify Ta a rare element, since data show that its proven reserves, including old tin slags, are similar in magnitude to those of Ag. In addition, the current plans of the major engine manufacturers for the use of high Ta containing nickel-base superalloys may further aggravate the supply situation in the near future. Therefore, the Ta supply, demand and pricing situation should be critically studied as soon as possible as a first step toward assessing the types of technical R&D programs necessary for alleviating U.S. dependence for Ta.

We, like you, find the Co supply to be non-diverse, non-secure and non-elastic. The inelasticity arises from Co's by-product status vis-a-vis Ni or Cu. Superalloys are the major (plurality) host for Co use in this country. We strongly believe that the need for the amounts of Co used in superalloys has never been proven. Accordingly, we support all actions that strive to understand the role of Co in order to determine the necessary levels of Co needed for specific applications in hot sections of engines. Further, we urge that the Co remaining in the U.S. Stockpile be assessed with respect to its suitability for use in the purity-demanding superalloys.

Like Co, Cr has geopolitical problems. We do not believe that Cr and its role can be substituted for in the engine alloys. Please be aware that the Cr amounts in most superalloys are already at minimum levels. Also, engine alloys are not major consumers of Cr. In times of national emergency, Cr could be diverted for strategic uses. The form of the Cr in the U.S. Stockpile should also be assessed with respect to usability in superalloys. High strength (high performance) superalloys generally cannot use Ferrochromium, for example.

We have no comments on Nb, except that it may have to serve as a substitute for Ta in the current Ta-bearing alloys.

Finally, we urge your Committee to consider the following general issues in your deliberations on designing the guidelines for a National Mineral Policy:

1. What role should the Federal Government and its various appropriate agencies play? For example, we know that President Reagan favors non-involvement by the Federal Government. However, it must be noted that substantial conservation of, say, a critical element through substitution can occur only if the science and technology for said substitution is shared by the manufacturers. Government can encourage this sharing by funding key elements of the necessary programs and by enjoining and coordinating the participation of different segments of industry, Government research institutions and universities. In contrast, Government non-involvement could result in a proprietary stance toward the technology by a small segment of the industry. Another example is scrap tracking, reclamation and recycling. If the Government does not impose some regulations, we believe that the industries will practice this segment of conservation only when the prices of the elements involved are on the peak side of the price cycles. In other words the industries will follow conservation practices with respect to scrap when the metal costs are high and will be lax about them when the prices are temporarily in decline.

2. What role stockpiles? We believe that the stockpile issue should be re-examined not only with respect to how much would be necessary to weather a crisis, but also to its role in stabilizing prices in periods of fluctuating supply and demand and to its role in encouraging long-term conservation and substitution. For example, a large purchase of Ta by the U.S. at this time could be most unsettling for Ta availability. The sudden large sale of W from the stockpile could result in much lower W prices in the short term and could, in turn, result in the reapplication of W in alloys that had already substituted Mo for W.

3. What role industries? Unfortunately we have to believe that industrial ethics are motivated by the yearly "bottom line." We do not expect industries to fund long-term research on a sustained basis. Nor do we foresee industries consistently practicing conservation measures without Government insistence through appropriate regulations.

4. We urge you to study the results of the Air Force and NASA Assessments on Strategic Elements which took place during the past two years.

Sincerely,

John K. Tien
Professor
COLUMBIA UNIVERSITY

JKT/s

Enclosures

Cc: Dr. Bruce Steiner

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March 9, 1981

Copy to Dr. Wachtman
Candy Stevens
Parsons
Bailey -

Mr. James Owens
Director
Office of Basic Industries
U. S. Department of Commerce
Room 4845
Washington, D. C. 20230

Dear Jim:

Enclosed for the record is a final edited copy of the remarks David Swan, Vice President of the Kennecott Corporation, made on behalf of the American Mining Congress before the workshop sponsored by the Commerce Department on "Critical Materials Needs of the Aerospace Industry," on February 9 at the National Bureau of Standards, Gaithersburg, Maryland.

The American Mining Congress is grateful that we had an opportunity to participate in the Workshop. Please let us know how we can be of further assistance at any time.

Sincerely,

Jim Beizer

James Beizer
Assistant to the President

cc: David Swan

DEPARTMENT OF COMMERCE WORKSHOP

ON

CRITICAL MATERIAL NEEDS OF THE AEROSPACE INDUSTRY

February 9 - 10, 1981
Gaithersburg, Maryland

COMMENTS

My comments are on behalf of the American Mining Congress, a trade association representing more than 200 American companies involved in the minerals industries.

In dealing with questions of supply of critical materials, I would like to propose a methodology for identifying and characterising critical materials issues, particularly those involving interaction of the public and private sectors and which views those issues in an international framework.

In developing this, I would suggest we visualize supplying raw materials as a four (4) step process, consisting of:

- discovery of mineral resources;
- development of ore bodies into mines;
- mining and beneficiation; and finally
- extraction of desired material in sufficiently pure form to permit subsequent fabrication into useful articles.

For those mineral resources which the United States has adequate competitive grade reserves, the entire process can and is carried out domestically. Imports and exports at any stage of the process become almost purely economic decisions based on such considerations as freight costs, location of facilities and short-run market conditions. Even for such minerals, however,

/imposition....

imposition of unilateral U.S. policies can significantly and adversely alter the competitiveness of the U.S. mining industry in the international marketplace.

Unfortunately, this desirable state of affairs does not exist with many minerals, therefore, the interface between the U.S. industry consumer and offshore supplier is moved towards the fabrication/end use part of the process. From a policy point of view, the consuming country has a strong incentive to purchase supplies of the material as early in the cycle as possible, i.e., as ores and concentrates rather than alloys or metals. Conversely, the raw material owner has an equally strong incentive towards integration toward end uses as far as possible. At this stage, various government policies come into play, designed to maximize the self-interests of the producing and consuming countries. Generally speaking, such arrangements are considered to be a part of trade policy development and are aimed at directly supporting the mineral policy goals of sovereign nations.

Inevitably, however, other national policies also impinge on the location of the interface, but less directly. These include tax policies, environmental health and safety policies, employment and labor policies, energy policies, etc.

/In the.......

In the more advanced countries, very often application of these types of policies have a larger impact on mineral availability than do trade policies and it is this area which I propose that we concentrate on. In order to analyze the economic impact of these policies, it is necessary to identify the policy asymmetries between the U.S. and producing countries and to determine whether these inhibit or enhance the availability of a specific mineral resource.

I have extracted a number of these examples from the excellent GAO report, "The U.S. Mining and Mineral-Processing Industry: An Analysis of Trends and Implications:" to illustrate how they impact the availability of resources in the real world.

In its testimony in support of the National Materials and Minerals R&D Act to Congress, the American Mining Congress recommended that specific responsibility for identifying these policy asymmetries be assigned in the President's Office with the requirement that policy changes be proposed which would support the national objectives of assuring adequate supplies of critical raw materials.

I would suggest that our examination of critical resource needs for the aerospace industry follow this method of analysis. This conference can provide an important input by contributing useful data to carry out the charges of the Congress in enacting the National Materials & Minerals Policy Research & Development Act.

*****

RMI Company

D.M. STROLLO
VICE PRESIDENT – MARKETING

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March 3, 1981

Dr. John B. Wachtman, Jr.
National Bureau of Standards
Materials Building B308
Washington, D.C. 20234

Dear Dr. Wachtman:

Attached is essentially the transcript of my comments presented during the Department of Commerce Workshop. We trust these comments will be incorporated into the Workshop's recommendations.

Should you have any questions concerning any of the information contained therein, please feel free to contact me.

Very truly yours,

attachment

RMI COMPANY COMMENTS

U.S. DEPARTMENT OF COMMERCE WORKSHOP

February 9, 1981

RMI Company is an integrated producer of titanium mill products, with sponge facilities in Ashtabula, Ohio, ingot and mill product facilities in Niles, Ohio, and finishing facilities in Washington, Missouri.

In this paper, we would like to review several of the key topics of concern to us in the titanium industry:

(1) The critical nature of the industry
(2) The uses of the metal
(3) A brief history of the industry
(4) The strategic importance of titanium to America's future
(5) The advantages in the applied use of titanium

We will close by suggesting some questions that might be addressed in any study that may be made.

At RMI Company, we reaffirm the belief that the current and future status of titanium mill products production and demand should be the subject of such a study on critical materials needs. History has shown that end products are essential to many facets of American life, not the least of which is our nation's defense preparedness.

General Alton Slay, formerly head of Air Force Systems Command, had identified the titanium industry as one where domestic productive sponge capacity is, and may continue to be, insufficient to meet domestic industrial and defense market demands.[1]

Titanium sponge is the necessary feedstock for the production of titanium metal. The metal is low in density, light in weight, exceptionally strong, and resistant to many forms of corrosion.

[1]The Air Force Systems Command Statement on Defense Industrial Base Issues, Gen. Alton D. Slay, November 13, 1980.

Alloys have been developed that have the strength of steel, at 60% the density. These alloys can be used at temperatures far exceeding 1000°F. Because of this special property, titanium alloys are the most engineeringly efficient materials of construction for critical parts of both defense and commercial airframes, and the power plants used to propel them. Currently, about two-thirds of all titanium mill product shipments are allocated to the aerospace industry.

Of the aerospace purchases, approximately 50% go to America's defense contractors for such programs as the F-14, F-15, F-16, F-18, various types of offensive and defense missiles, and helicopters. These programs utilize titanium to reduce weight and increase operational integrity.

The titanium mill products shipped to commercial aircraft manufacturers are primarily for use in the Boeing family of airliners, Lockheed's L-1011, and the McDonnell Douglas DC-10 (KC-10) and DC-9 series. Principally Pratt and Whitney and General Electric, through their subcontractors, consume millions of pounds annually for both defense and commercial aircraft jet engines.

In the evolution of jet engines, the addition of a two-stage titanium fan to a basic straight jet helped produce 42% more takeoff thrust, while reducing fuel consumption by 13% and specific weight by 18%. The current generation of large, high-bypass-ratio engines have substantial amounts of titanium alloys in the fans and compressor sections, as well as other structures. These engines, and the aircraft they propel, could not have been built without titanium alloys.

Despite the obvious engineering advantages of the metal, there has often been a reluctance on the part of industry executives to fund expansions. We believe it valuable to briefly review the history of the industry. This will help us to better understand the position we are in now.

In the 30-year history of the titanium industry, market demand has been extremely erratic. Because of large anticipated government contracts, and private enterprise expectations, a number of companies have, in the past, entered into the supply market. Unfortunately, many of those programs were abruptly terminated, due primarily to the lack of political and economic support (e.g., the B-1, B-70, and SST programs). Thus, several companies withdrew from sponge production. Included are such industry giants as Union Carbide, DuPont, Crane Company, Crucible Steel, and Dow Chemical. (Although Dow has recently reentered in a joint venture with Howmet.)

In the 1960s, with increased defense spending, and a new generation of commercial aircraft coming on stream, capacity was once again developed to meet anticipated demand. But, because of program terminations, and despite exceedingly low domestic sponge prices, the non-integrated producers bought their sponge product from Russian and Japanese sponge producers. These countries were dumping their sponge on American markets, with subsidies from their governments.

Domestic sponge consumption and production fared no better throughout most of the 1970s. But, a recent surge in demand finds the industry producing at capacity levels.

A combination of reasons have led to this surge in demand and resultant capacity constraints. Among them are: (1) the almost complete withdrawal of the Soviets from supplying Western markets, (2) other offshore supply channels being redirected to fulfill internal and other markets, and (3) a spike in demand from both industrial and aerospace users.

When we talk about the first two items just mentioned, it is important to reemphasize the "dumping" practiced by the Russians and Japanese. A suit was won against the Soviets in 1968 for dumping practices, yet the penalties were not enforced. If they had been, it is quite likely that production capacity would have been in place domestically.

The importance of titanium in the defense establishment and in commercial markets, and the susceptibility to disruptive foreign product penetration, make it clear that a strong domestic industry for this strategic metal is advantageous to the United States.

An examination of expanded uses of alternative ore sources may be a valuable addition to any proposed study. America has vast resources -- ilmenite -- which can be process upgraded to a form comparable to rutile, which is then compatible with existing process facilities. With the keen interest being shown in rutile producing countries about developing their own metal reduction plants, domestic integration would assure this important industry of plentiful and totally self-sufficient resources.

Titanium is a cost-effective material of construction, especially when one considers elements beyond initial cost; elements like: lifespan, cost of construction, cost of maintenance, etc. This can be most accurately measured by comparing titanium to other materials of construction, like zirconium, inconels, hastelloys, and nickel alloys. In 1980, the following relative prices have been demonstrated[2] (where titanium = 1.00).

Zirconium	2.8
Hastelloy C276	2.8
Inconel 625	2.1
Hastelloy G	1.5
Nickel 200	1.3
Inconel 600	1.2
Incoloy 825	1.1
Monel	1.1
Carpenter 20	1.0
Titanium	1.0
Alloy Steel	0.1

Compared to other metals, the discrepancy can be seen even further:

Tantalum	53.5
Columbium	26.7
Titanium	1.0

[2] Relative costs of plate product

RMI TITANIUM

There are a number of reasons why a strong domestic industry is extremely important to the United States. We have previously discussed the strategic importance of the industry, and, the United States could be in the enviable position of self-sufficiency in at least one strategic metal.

It is our hope that any proposed study would consider this crucial fact. There are a number of avenues that might be examined when we consider this potential. Included are: (1) improvements in productive capabilities, (2) additional R&D into the potentials for material conservation and wise application, and (3) fulfillment of the stated goals of the national stockpile.

Taking the last item first, there are currently only 32,331 tons of titanium in the stockpile. Of this, 10,836 tons are considered not to be of stockpile grade.[3] The objective is 195,000 tons. Thus we really have only 11% of our goal attained.

The strategic importance of the metal is acknowledged by being placed on the list of materials in the Strategic and Critical Materials Stockpiling Act. This act requires the acquisition of materials determined to be "deficient or insufficiently developed to supply industrial, military, and naval needs of the country for common defense," and necessary to "prevent wherever possible a dangerous and costly dependence of the United States upon foreign nations for supplies of these materials in times of national emergency." U.S. Code, Section 98 (1951)

In this sense, titanium is comparable to cobalt. Both metals are vital to the country. Both are especially important in the development of cost-effective and fuel efficient jet engines.

With any surge in defense preparedness requirements, the United States would not have enough titanium stockpiled to last the aerospace industry one year. This is true -- even assuming we devote all current production capabilities to aerospace. New and current aerospace systems production would be slowed severely, especially in essential engine production.

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[3] Mineral Commodity Summaries 1980, U.S. Bureau of Mines, U.S. Department of Interior.

RMI TITANIUM

Long-term contracts for replenishment and rebuilding of the stockpile would be one means to give domestic industry the incentive to go even further in current expansion plans and programs. It would insure both a complete stockpile, and the productive capacity to respond to critical or surge requirements. The United States would indeed be capable of self-sufficiency in one strategic metal. As this indicates, we would then have developed a significant improvement in our materials production base.

The rebuilding of American industrial strength should not rely solely on defensive weapons procurement. The strength of the United States depends on a totally strong industrial economic base. And, part of a strong economic base in America is energy development and energy conservation. Titanium is the preferred application material in many energy-related applications, including: auxiliary heat exchangers, condensers for liquefied natural gas, steam turbine blades, geothermal power, and instrumentation and piping for oil exploration.

One of our common objectives in this meeting today is to illustrate the crucial issues facing our country. We believe our discussions, to this point, have demonstrated the importance of the titanium industry, and its critical applications.

Securing a strong economic and defense capable industrial base is imperative in the United States today!! To do this, we must adopt intelligent, rational policies with which to act most propitiously. To develop these policies, we need to initiate aggressive and insightful studies which will lay the foundation for policy formulation.

We are hopeful that this discussion will assist you in defining our nation's needs. And, we would respectfully suggest that titanium be included in the initial studies, so that a comprehensive titanium policy can be developed to the benefit of everyone.

In a proposed study of titanium production capacity and demand requirements, there are a number of questions that might be asked. These may provide the basis for policy initiatives. Though the following list is certainly not all-inclusive, it may be representative of other issues that might be covered in a study of this nature.

(1) Would it not be advantageous to U.S. policy-makers to be made totally aware that the defense concerns of the United States today imply that critically needed materials be examined completely? As previously suggested, America would easily become self-sufficient in titanium metals production if the incentives to do so were present.

(2) Might it not be of concern to U.S. policy-makers to understand how our balance of payments can be affected by the redevelopment of a strong domestic industry? Rather than a reliance on imports which may be suddenly cut off, for economic or defensive reasons, it may be better to be in a position where value added production can be sent out of the United States instead of into the United States. One way for America to fight the awesome effect of payments out of the United States, due to the huge deficit from OPEC accounts, is to increase exports. Many aerospace contractors are running surplus accounts now (most notably Boeing), and strong domestic subcontractors could help maintain or build, this payment flow into America.

(3) Might we not look at the current U.S. policy initiatives concerning redeveloping America through applied R&D? Research and development on improved alloys has been a way of life at RMI Company. As new areas of application grow, R&D becomes an even more essential element in the total equation. As demand for the metal grows, industry

feels an obligation to put its first priority on facility expansion. Inasmuch as the titanium industry is extremely capital intensive, this does not always allow for congruent growth in R&D for the future. It is suggested then that careful thought be given to the possible benefits of legislation to encourage R&D funding -- be it through grants or tax benefits.

(4) One element of policy in government today is to understand the problems of strategically important industries. Government can be very beneficial by encouraging communications that enhance predictability. Thus, study of the titanium industry may include a comprehensive analysis of long-term market demand. The recent, and temporary, shortfall in capacity versus demand requirements was partially due to the lack of communication of true demand. Would industry have added capacity to prevent this problem if we had an accurate picture? The answer is yes. In fact, RMI Company recently did add to capacity -- an increment of over 25%. Past history has made the industry shy about expansion. Long-term contracting might be examined as potential methods of building a sense of economic security in this strategically important industry.

(5) It might be worthwhile to examine the federal emergency allocation policies and procedures. Included in these laws are the potential for assisting American industry in capacity expansions, economic production practices, and other incentives for domestic industry to produce at levels not only to support defense requirements, but also allow commercial development not to be restricted or impinged upon.

In 1950, the Congress passed the Defense Production Act. This act, in its present form, is used:

> To establish a system of priorities and allocations for materials and facilities, authorize the requisitioning thereof, provide financial assistance for expansion of productive capacity and supply, provide for price and wage stabilization, provide for the settlement of labor disputes, strengthen control over credit, and by these means facilitate the production of goods and services necessary for the national security and for other purposes.

Specifically, the act provides for the implementation of a system -- the Defense Priorities System -- which permits the President to accelerate the production of critical defense items by causing the manufacturer to place these items at the front of the production line; guaranteed loans to expedite deliveries of national defense systems; and direct government loans to industry to expand plants and facilities in order to develop or produce essential material.

(6) The Department of Commerce could act as a synthesizer of the needs of the titanium industry. With the two previous topics in mind, is it not worthwhile to have the assistance of a central body who can recognize both commercial and defense requirements, and recognize both classified and unclassified demands?

Might we not also look into the question of materials substitution capabilities as an element of U.S. policy? For example, titanium is an excellent candidate for substitution among many nickel-based alloys.

RMI TITANIUM

To carry this one step further, might not U.S. policy place even greater emphasis on more extensive applications in energy and environmental areas? These are areas where titanium metal is constantly being demonstrated to be the most engineeringly efficient and cost-effective material of construction.

In conclusion, we would like to suggest that it may be beneficial to use titanium as a vehicle of policy analysis. Though it is an atypical metal, it is one where there is a definite domestic solution.

The life of the titanium industry has been very short, only three decades; yet, the potential for critical applications which will be immensely beneficial to the United States is tremendous. And, the developed technologies put titanium on the threshold of fantastic growth.

With an integrated effort on the part of the producers, users and other members of private industry, hand-in-hand with our military and other government agencies, solutions may be readily obtained.

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here*)

On February 9 and 10, 1981, the Department of Commerce held a Public Workshop to obtain the views of the American Public on three questions directly pertinent to the Department's responsibilities under the Materials and Minerals Policy, Research and Development Act of 1980, Public Law 96-479. These questions were:

1) What are the materials issues of primary concern to the American aerospace industry and its suppliers?
2) What recommendations do the American aerospace industry and its suppliers have for Federal action to address these issues?
3) Which specific materials should the Department of Commerce review in detail over the next few months in order to recommend the most urgently needed programs for Federal action?

The Workshop addressed these questions within three distinct areas:

I. Critical raw materials
II. Critical engineering materials
III. Substitution, conservation, specialized recycling, and higher performance.

This report includes the formal views presented to the plenary workshop sessions, the reports of the Workshop Task Forces in each of the three above areas, and the written submissions invited in the Federal Register notice of the Workshop.

12. KEY WORDS (*Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons*)

Critical materials; aerospace; chromium; cobalt; titanium; tantalum.

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