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PUBLICATION

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

REPORT TO THE CONGRESS

A METRIC AMERICA

A decision whose time has come

U.S. METRIC STUDY

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National
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Public Law 90-472

An Act

To authorize the Secretary of Commerce to make a study to determine advantages and disadvantages of increased use of the metric system in the United States.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of Commerce is hereby authorized to conduct a program of investigation, research, and survey to determine the impact of increasing worldwide use of the metric system on the United States; to appraise the desirability and practicability of increasing the use of metric weights and measures in the United States; to study the feasibility of retaining and promoting by international use of dimensional and other engineering standards based on the customary measurement units of the United States; and to evaluate the costs and benefits of alternative courses of action which may be feasible for the United States.

Metric system. Study.

SEC. 2. In carrying out the program described in the first section of this Act, the Secretary, among other things, shall—

Investigation and appraisal requirements.

(1) investigate and appraise the advantages and disadvantages to the United States in international trade and commerce, and in military and other areas of international relations, of the increased use of an internationally standardized system of weights and measures;

(2) appraise economic and military advantages and disadvantages of the increased use of the metric system in the United States or of the increased use of such system in specific fields and the impact of such increased use upon those affected;

(3) conduct extensive comparative studies of the systems of weights and measures used in educational, engineering, manufacturing, commercial, public, and scientific areas, and the relative advantages and disadvantages, and degree of standardization of each in its respective field;

(4) investigate and appraise the possible practical difficulties which might be encountered in accomplishing the increased use of the metric system of weights and measures generally or in specific fields or areas in the United States;

(5) permit appropriate participation by representatives of United States industry, science, engineering, and labor, and their associations, in the planning and conduct of the program authorized by the first section of this Act, and in the evaluation of the information secured under such program; and

(6) consult and cooperate with other government agencies, Federal, State, and local, and, to the extent practicable, with foreign governments and international organizations.

SEC. 3. In conducting the studies and developing the recommendations required in this Act, the Secretary shall give full consideration to the advantages, disadvantages, and problems associated with possible changes in either the system of measurement units or the related dimensional and engineering standards currently used in the United States, and specifically shall—

Results of changes in measurement system.

(1) investigate the extent to which substantial changes in the size, shape, and design of important industrial products would be necessary to realize the benefits which might result from general use of metric units of measurement in the United States;

(2) investigate the extent to which uniform and accepted engineering standards based on the metric system of measurement units are in use in each of the fields under study and compare the extent to such use and the utility and degree of sophistication of such metric standards with those in use in the United States; and

(3) recommend specific means of meeting the practical difficulties and costs in those areas of the economy where any recommended change in the system of measurement units and related dimensional and engineering standards would raise significant practical difficulties or entail significant costs of conversion.

SEC. 4. The Secretary shall submit to the Congress such interim reports as he deems desirable, and within three years after the date of the enactment of this Act, a full and complete report of the findings made under the program authorized by this Act, together with such recommendations as he considers to be appropriate and in the best interests of the United States.

Report to Congress.

SEC. 5. From funds previously appropriated to the Department of Commerce, the Secretary is authorized to utilize such appropriated sums as are necessary, but not to exceed $500,000, to carry out the purposes of this Act for the first year of the program.

Funds.

SEC. 6. This Act shall expire thirty days after the submission of the final report pursuant to section 3.

Expiration date.

Approved August 9, 1968.

A METRIC AMERICA
A decision whose time has come

Daniel V. De Simone, Director
U.S. Metric Study

National Bureau of Standards,
Special Publication 345

U.S. DEPARTMENT OF COMMERCE
Maurice H. Stans, Secretary
NATIONAL BUREAU OF STANDARDS
Lewis M. Branscomb, Director

Issued July 1971

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U.S. DEPARTMENT OF COMMERCE
Office of the Secretary
Washington, D.C. 20230

THE HONORABLE PRESIDENT OF THE SENATE
THE HONORABLE SPEAKER OF THE HOUSE OF REPRESENTATIVES

SIRS:

I have the honor to transmit to you the Report on the U.S. Metric Study, which was conducted by the National Bureau of Standards of the Department of Commerce.

Thousands of individuals, firms and organized groups, representative of our society, participated in the Study. After weighing the extensive evidence presented by these participants, this report concludes that the United States should change to the metric system through a coordinated national program.

I agree with this conclusion, and therefore recommend

—That the United States change to the International Metric System deliberately and carefully;
—That this be done through a coordinated national program;
—That the Congress assign the responsibility for guiding the change, and anticipating the kinds of special problems described in the report, to a central coordinating body responsive to all sectors of our society;
—That within this guiding framework, detailed plans and timetables be worked out by these sectors themselves;
—That early priority be given to educating every American schoolchild and the public at large to think in metric terms;
—That immediate steps be taken by the Congress to foster U.S. participation in international standards activities;
—That in order to encourage efficiency and minimize the overall costs to society, the general rule should be that any changeover costs shall "lie where they fall";
—That the Congress, after deciding on a plan for the nation, establish a target date ten years ahead, by which time the U.S. will have become predominantly, though not exclusively, metric;
—That there be a firm government commitment to this goal.

The Department of Commerce stands ready to provide whatever further assistance the Congress may require in working out a national plan and putting it into effect.

Respectfully submitted,

Maurice H. Stans

Maurice H. Stans
Secretary of Commerce

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

OFFICE OF THE DIRECTOR

The Honorable Maurice H. Stans
Secretary of Commerce

Dear Mr. Secretary:

I have the honor to transmit to you the report on the U.S. Metric Study, undertaken by the National Bureau of Standards at your request, pursuant to Public Law 90-472. This report embodies our analysis of the alternatives realistically open to the United States and the choice we recommend on the basis of the evidence marshalled during the Study. I am convinced that after nearly two hundred years of national debate on this issue, the time has come for a national decision on a positive course of action.

The questions posed by the Congress do not lend themselves to a clear-cut analysis in terms of dollars and cents, although we have discussed the question of costs and benefits as objectively as we could. Neither are the questions to be answered by evaluating the scientific merits of different measurement systems in the abstract, even though American scientists, like those of other nations, commonly prefer the metric system for their work. Accordingly, our Metric Study Group based their work primarily on the informed views of citizens in every walk of life, considering not only their experiences but their apprehensions, their hopes for the future and the realities of current problems. We have done our best to give everyone an opportunity to express his or her views.

Just as numbers are the language of mathematics, measurement language permits people to communicate with one another in quantitative terms. The nation's measurement system must be not only accurate and precise; it must be useful. This perspective is reflected in the Department's goal for the National Bureau of Standards: to strengthen the nation's science and technology and to foster their useful application in the public interest.

From this vantage point—how the measurement system can best serve the future needs of America as we enter our third century of progress—we have examined the matter of metric conversion.

Sincerely,

Lewis M. Branscomb, *Director*
National Bureau of Standards

FROM THE FIRST METRIC STUDY

Weights and Measures may be ranked among the necessaries of life to every individual of human society. They enter into the economical arrangements and daily concerns of every family. They are necessary to every occupation of human industry; to the distribution and security of every species of property; to every transaction of trade and commerce; to the labors of the husbandman; to the ingenuity of the artificer; to the studies of the philosopher; to the researches of the antiquarian; to the navigation of the mariner, and the marches of the soldier; to all the exchanges of peace, and all the operations of war. The knowledge of them, as in established use, is among the first elements of education, and is often learned by those who learn nothing else, not even to read and write. This knowledge is riveted in the memory by the habitual application of it to the employments of men throughout life.

John Quincy Adams
Report to the Congress, 1821

PREFACE

One hundred and fifty years ago John Quincy Adams wrote an eloquent and comprehensive report for the Congress. Based on a four year investigation, his report dealt with the metric question and the modernization of our measurement system. It was the first U.S. Metric Study. Although three decades earlier, Thomas Jefferson also had written a report for the Congress on the need for modernization of weights and measures, the metric system was no more than a conception in his time and his report did not consider it as an alternative seriously to be entertained by the newly founded United States of America. Inventive genius that he was, he proposed his own measurement system.

In 1821 Adams did give serious attention to the metric system as an alternative for adoption. Yet, although he believed it approached "the ideal perfection of uniformity applied to weights and measures," he rejected it because he felt that the time was not right for it. Most of our trade was with inch-pound England, and the metric system was not even firmly established in France, let alone the rest of the world. Better to wait, he pointed out, until a uniform international measurement system could be worked out.

Adams' conditions have now been met: the world has committed itself to the metric system, and even in the United States its use is increasing. For America, it is a decision whose time has come.

Three years ago the Congress asked for a sweeping investigation of the metric question (see inside front cover), because it sensed that the world trend toward metric called for a new assessment. The investigation progressed over a dozen different avenues involving public hearings, supplemented by surveys on international trade, business and industry, education, national security—almost every activity in our society.

This volume evaluates and distills all of that, and also covers what has been learned from the British, who are just past the midpoint of their metric changeover period; the Australians, who are beginning theirs; the Canadians, who have decided to go metric, too; the Japanese, who finished conversion ten years ago; and the thousands of individuals who spoke and corresponded with us during the course of the U.S. Metric Study.

Most of us are not acquainted with the technical details and subtleties of international trade, technology, and the many other factors that were considered in the Study. We need not be, to understand the issues that the Study tackled. Twelve volumes of detailed special reports on the hearings and supplemental surveys are listed in Appendix Two. Those who need to dig deeper for elaborative detail will find the keys to it there.

My colleagues on the Study Group at the National Bureau of Standards and elsewhere provided me with the indispensable basis for this concluding volume. The investigations they conducted and the 12 special reports they authored, as part of the record of the U.S. Metric Study, are described in Appendix One. I am particularly grateful for the wide-ranging contributions of Mr. Alvin G. McNish, a guiding spirit from the inception of the Study; Mr. George A. W. Boehm, my close collaborator in the preparation of this volume; Dr. Robert D. Huntoon, whose fertile mind contributed many insights and helpful suggestions; and Mr. Louis E. Barbrow, whose perception and patient understanding helped us to skirt many pitfalls.

We owe a great debt to the hundreds of organizations, committees, and other groups that participated in the U.S. Metric Study. It is not possible to name them all here, but those that were most involved—particularly the Study's Advisory Panel, ably chaired by Mr. Louis F. Polk—are identified in Appendix One. Dr. Francis L. LaQue served as vice chairman of the panel; Mr. Leonard S. Hardland was its executive secretary.

Mr. Polk, Dr. LaQue and their colleagues were a source of enlightenment and encouragement throughout the planning and conduct of the Study. The 44 members of the Panel represented a wide variety of opinion. It follows that their individual views are not necessarily reflected by this report, nor are those of the diverse organizations with which they are affiliated. This is also true of the other committees that were consulted and are identified in Appendix One: The President's Science Advisory Committee, the Commerce Technical Advisory Board, and the National Inventors Council. I deeply appreciate the constructive advice they gave on how the first draft of this report could be improved.

During the Study a great deal was learned in consultations with experienced individuals from other countries. I am indebted for the discerning and practical advice given our Study by Lord Ritchie-Calder, Chairman of the British Metrication Board, Mr. Gordon Bowen, its Director, and other members of the Board; Mr. John D. Norgard, Chairman of the Australia's Metric Conversion Board, and Dr. Alan Harper, its Executive Member; Dr. Sydney Wagner, General Director of the Office of Science and Technology in Canada's Department of Industry, Trade and Commerce, and his Director of Policy, Mr. Hugh C. Douglas; Dr. José M. Alcalá, Director of Standards in Mexico's Department of Industry and Commerce; Dr. M. C. Probine, Director of the Physics and Engineering Laboratory in New Zealand's Department of Scientific and Industrial Research; Dr. Lal C. Verman, Industrial Consultant, and Dr. S. K. Sen, Director General, Indian Standards Institution, both of New Delhi, India; and Mr. Lian Peck Baey, Chairman of the Metrication Board of Singapore. My thanks to all of them.

In addition to the groups consulted both here and abroad, there were several individuals whom I asked to comment on the first draft of the manuscript. They helped greatly to rescue it from error and oversight. Since they are not identified elsewhere in this report, I gratefully acknowledge them here: Dr. Allen V. Astin, Director Emeritus of the National Bureau of Standards; Mr. Carl A. Beck, Chairman of the National Small Business Association; Mr. William K. Burton, Manager of Metric Systems Development, Ford Motor Company; Dr. John H. Dessauer, Vice Chairman of the Xerox Corporation; Dr. James Hillier, Executive Vice President for Research and Engineering, RCA; Dr. Harold K. Hughes, Vice President for Academic Affairs, State University of New York at Potsdam; Mr. John L. Maddux of the World Bank; and Mr. Mark S. Massel, international consultant.

Those who were consulted in the preparation of this report are not responsible for any imperfections that remain, only for reducing their number. I am grateful to all of them for their help.

In the almost 200 years that the metric question has been considered in this country, it has never been clear to most Americans what the question entailed. This time, as many of us as possible should be given the basis for understanding what is really involved and what the alternatives are. That is the purpose of this report.

Daniel V. De Simone, *Director*
U.S. Metric Study

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SUMMARY

Many times in the last two centuries, the Congress considered the merits of adopting the metric system as America's primary language of measurement. Each time, action was postponed, often because the metric system was not then in use by our major trading partners abroad. Now, with every other major nation converted to metric or committed to conversion, this obstacle has been removed.

In the light of these and other changing circumstances, the Congress directed the Secretary of Commerce to undertake the U.S. Metric Study. Its purpose was to evaluate the impact on America of the metric trend and to consider alternatives for national policy.

The U.S. Metric Study concludes that eventually the United States will join the rest of the world in the use of the metric system as the predominant common language of measurement. Rather than drifting to metric with no national plan to help the sectors of our society and guide our relationships abroad, a carefully planned transition in which all sectors participate voluntarily is preferable. The change will not come quickly, nor will it be without difficulty; but Americans working cooperatively can resolve this question once and for all.

The basis for the conclusion that the U.S. will eventually be metric lies in the findings of the Study that America is already metric in some respects; that we are becoming more so; and that the great majority of businessmen, educators and other informed participants in the Study reported that increased use of the metric system is in the best interests of America. They also believe that it is better for the nation to move to metric by plan rather than by no plan at all.

They go beyond the question of whether or not the United States should progressively replace its present measurement language with metric. The question they ask is how and when America will choose to make the change. It is primarily a question of timing and preparation. Shall the nation do so by plan over a comparatively brief period of ten to fifteen years? Or shall it drift toward a metric status, over a much longer period of time, with some parts of the society inadequately prepared for the increasing prevalence of metric usage?

Consequently, the costs and benefits to be considered are not so much those of changing to metric versus not changing at all. The key comparison is between changing *by plan* versus changing with *no plan*—with no framework to guide the nation.

There will be real costs and difficulties in the change, whether or not it is done by plan. The Study indicates that such difficulties will in any event have to be faced as metric usage reaches substantial proportions in America. Thus, without a plan the United States would experience all the difficulties of dual inventories, dual education, dual thinking, dual sets of tools and dual production—perhaps not so soon but over a much longer period of time.

On the basis of all the factors that were considered, the Study concludes that it would be best for the nation to change to metric under a coordinated program that provides for flexibility and encourages the various sectors of society to deal with their particular problems voluntarily. Within this framework, these sectors would work out their own timetables and programs, dovetailing them with those of other sectors.

Developing a national program for change would require a great deal of forethought and discussion. But the Study finds that two major activities should be begun immediately, because they would be pivotal in preparing the nation for increased use of the metric system.

The first is education. Every schoolchild should have the opportunity to become as conversant with the metric system as he is with our present measurement system.

The second concerns international standards. High quality American industrial practices should be much more vigorously promoted in international negotiations that are beginning to establish "engineering standards" (see *Special Terms*, below) on a worldwide basis and will increasingly affect world trade.

While the majority of the American people are not well versed in the metric system, the Study shows that those who are informed about it tend to favor it. This demonstrates a need for public education to help all citizens to cope with the trend to metric and poses a challenge to the Congress to point the way for all Americans.

Special Terms

Metric System: Developed in France at the time of the French Revolution, this measurement system was based primarily on the meter, a length defined as a small fraction of the earth's circumference. Since then the system has been refined in many ways. The up-to-date version, on which the nations of the world have agreed, is called *Système International d'Unités*. When this report refers specifically to this version of the metric system, it will be called the International Metric System.

International Metric System: At this time, the whole system is founded on six base units. The unit of length is the meter. The unit of mass (commonly called "weight") is the kilogram. The unit of time is the second. The unit of electric current is the ampere. The unit of temperature is the kelvin (which in common use is translated into the degree Celsius, formerly called centigrade). The unit of luminous intensity is the candela. All other units, such as those for speed and volume, are derived from the base units. Standard prefixes are added to give names for quantities of a particular unit that differ by multiples of 10—e.g., meter (m), kilometer (1000 m), millimeter (0.001 m).

Customary System: The predominant measurement system in the U.S. It includes such commonly used units as inch, foot, yard, mile, pint, quart, gallon, bushel, ounce (fluid and avoirdupois), pound, degree Fahrenheit—and, like metric, the ampere, the candela and the second.

Going Metric, Metric Conversion, Metric Changeover: As used in this report, these terms are synonymous. They mean a national changeover that would result in acceptance of metric as the preferred system of measurement and, ultimately, thinking primarily in metric terms instead of primarily in Customary terms. *Metrication* is the term the British apply to their own conversion program.

Transition Period: The length of time needed for a nation to become predominantly, though not exclusively, metric.

Engineering Standards: Broadly speaking, they are agreements that specify characteristics of things or ways to do things—almost anything that can be measured or described. They cover an enormous range: e.g., the diameter of wire; the length and width of typewriter paper; the purity of aspirin; the fire resistance of clothing; the meat content of frankfurters; the symbols on highway signs; the way to test for sulphur in fuel oil; the technical basis for local building codes; the strength of a safety belt; the wattage of light bulbs; the weight of a nickel. Taken together, engineering standards serve as both a dictionary and a recipe book for a technical society.

CHAPTER I

Perspective

In the last 20 years the metric system has become the dominant language of measurement in the world. Only a few nations have not yet adopted the metric system or decided to do so. Of these, the most notable is the United States. This is illustrated by the world map on the preceding pages.


"What does it mean to our . . . balance of trade?"

What is the effect on the U.S. of the worldwide swing to metric? What does it mean to our international relations and balance of trade? How does it affect Americans in every walk of life?

Would it be desirable for the U.S. to use the metric system more widely than it does? Should this be done deliberately in some coordinated way? Or should the nation take no action to promote the use of metric weights and measures?

Or, as another possibility, should the U.S. try to persuade the rest of the world to make more use of the Customary system? What can be said about the benefits and costs of deliberately changing to metric in comparison with doing nothing at all?

The Metric Study Act

These are the kinds of questions that Congress wanted answered when it passed the Metric Study Act in August of 1968. The Act was spawned after a decade of effort by Congressman George P. Miller and Senator Claiborne Pell, joined in the final phase by Senator Robert P. Griffin. The text of this Act is reproduced on the inside front cover of this volume.

Congress directed the Secretary of Commerce to arrange for a broad inquiry and evaluation: the U.S. Metric Study. He assigned the task to the National Bureau of Standards. On the basis of the findings and conclusions of the Study, the Secretary was asked to make "such recommendations as he considers to be appropriate and in the best interests of the United States."

A "Technology Assessment"

The questions, at first, seemed fairly straightforward.

Actually, the quest for answers proved extremely complex and challenging. Technology, economics, sociology, international relations, and many other factors are involved. So are emotions and prejudices.

The choice of a measurement system affects people in so many different ways that the questions posed by Congress cannot be reduced to a simple issue and settled to everybody's satisfaction. As with most major assessments, the answers depend largely on subjective thinking and personal preference, on balancing possible future gain against current inconvenience. There is yet no way for drawing up a reliable national balance sheet, in dollars and cents, for deciding complex social issues. Going metric is one of these.

Scope of the Study

During the course of the Study, representatives of business, labor, trade associations, consumers, educators, and the professions answered thousands of questionnaires, engaged in thousands of personal interviews, and participated in a series of hearings that were widely publicized

"How does it affect Americans in every walk of life?"

in advance. In addition, interviews with a representative sample of American households sought to determine the general public's knowledge of the metric system. Appendix One (p. 138) describes in detail how the U.S. Metric Study was carried out and who the major participating groups were.

The primary goal in the planning of the Study was to give every sector of society an opportunity to express its views with respect to the questions raised by the Metric Study Act. The plan provided for a series of seven public hearings, called National Metric Study Conferences, supplemented by eleven special investigations.

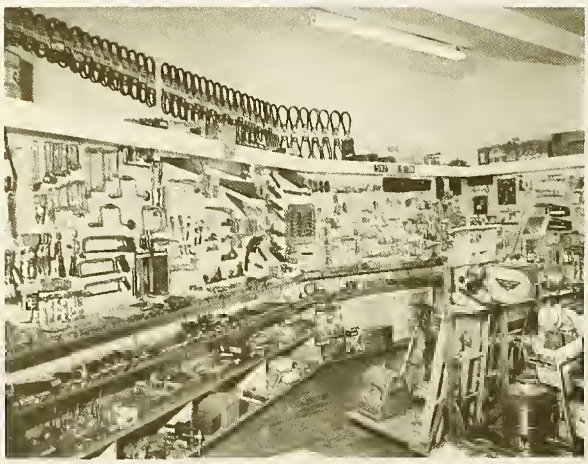
The public hearings alone included representatives associated with: manufacturing and nonmanufacturing industries, organized labor, small businesses, engineering and scientific disciplines, education at all levels, advertising, publishing, law, medicine, public health, agriculture, forestry, fisheries, agencies of Federal, state, county, and local government, real estate, college athletics, finance, insurance, warehousing, transportation, construction, communications, retailers, wholesalers, chiefs of police, fraternal organizations, exporters and importers, home economists, consumers, and other groups that could be affected by a change in the nation's system of measurement.

This list suggests the breadth and depth of the U.S. Metric Study.

The investigations that supplemented the hearings covered the following subjects:

(1) Manufacturing Industry
(2) Nonmanufacturing Businesses
(3) Education
(4) Consumers
(5) International Trade
(6) Engineering Standards
(7) International Standards
(8) Department of Defense
(9) Federal Civilian Agencies
(10) Commercial Weights and Measures

"... to give every sector of society an opportunity to express its views ..."



(11) History of the Metric System Controversy in the U.S.

Each of these investigations is the subject of a volume, published as part of the record of the U.S. Metric Study. The public hearings are summarized and analyzed in an additional volume. All twelve volumes are cited in Appendix Two (p. 164), the bibliography of this report.

Courses of Action

In the Metric Study Act, Congress specifically requested an evaluation of "the costs and benefits of alternative courses of action which may be feasible for the United States." As the Study progressed, it became clear that the U.S. is already increasing its use of the metric system, albeit slowly now, and that sooner or later the U.S. will probably become predominantly metric.

Many courses of action are conceivable, including an abrupt and mandatory conversion to metric and a program to promote more use of the Customary system in the world. However, the feasible courses of action are narrowed to two main alternatives:

Course One: The United States follows no overall plan. Each firm or other entity pursues its own measurement policy. A target date for the nation to become predominantly metric is not set. The government does nothing to impede or foster the change.

Course Two: The nation goes metric according to plan, under an overall national program with a target date for becoming predominantly metric. Within this framework, segments of the society work out their own specific timetables and programs, dovetailing them with the programs of other segments.

The analysis of this report focuses on these alternative courses of action. The expanded table of contents (p. x) of this volume is meant to serve as a detailed "roadmap." It outlines what is covered in each of the chapters that follow.

Two Centuries of Debate

One of the powers specifically given the Congress by the men who framed the Constitution was to fix the standard of weights and measures. It comes as one of the very first of the responsibilities assigned to the federal legislature.

From the early days of the Republic, the United States has repeatedly considered the question of going metric. Yet today, on the eve of the nation's second centennial, the question remains unsettled.

Many of the facts and opinions that have been gathered during the U.S. Metric Study are new in the context of their times. But others have changed so little in a century or two that a reader of history might feel as if he were walking through a revolving door. The following historical account casts light on why, up to now, the metric question has not been settled.

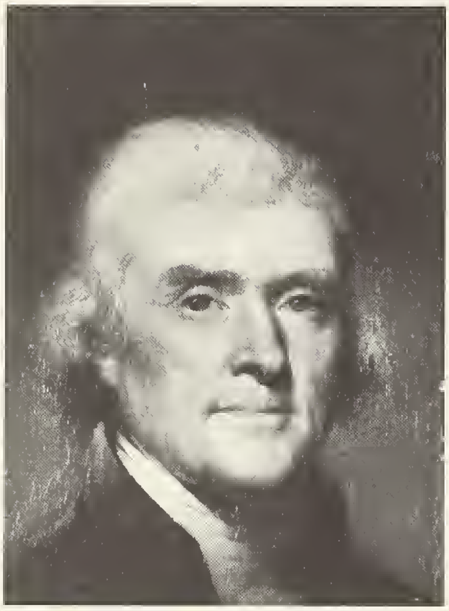
From Barleycorns to Inches

Our Customary system of measurement is part of our cultural heritage from the days when the thirteen Colonies were under British rule. It started as a hodge-podge of Anglo-Saxon, Roman and Norman-French weights and measures. Since medieval times, commissions appointed by various English monarchs had reduced the chaos of measurement by setting specific standards for some of the most important units. Early records, for instance, indicate that an inch was defined as the length of "three barleycorns, round and dry" when laid together; a pennyweight, or one-twentieth of a Tower ounce, was equal to 32 wheatcorns from "the midst of the ear."

The U.S. gallon is the Queen Anne wine gallon

The U.S. gallon is the British wine gallon, standardized at the beginning of the 18th century (and about 20 percent smaller than the Imperial gallon that the British adopted in 1824 and have since used to measure most liquids).

In short, as some of the founders of this country realized, the Customary system was a makeshift based largely on folkways.



Thomas Jefferson: America's Universal Man

Jefferson's Foot

In his first message in 1790 President Washington reminded Congress that it was time to set our own standards of weights and measures. The matter was referred to Secretary of State Thomas Jefferson, an inventive genius, who soon proposed two plans. Both involved adoption of a standard of length based on a natural phenomenon that was more nearly reproducible than a barleycorn or a wheatcorn. His own preference was for a simple pendulum: a cylindrical iron rod of such length that a swing from one end of its arc to the other and back again would take two seconds.

Jefferson's first plan was to use this pendulum as a standard to "define and render uniform and stable" the weights and measures of the English Customary system. With length firmly established, units of area, volume, weight, force, and other measurements could be consistently derived.

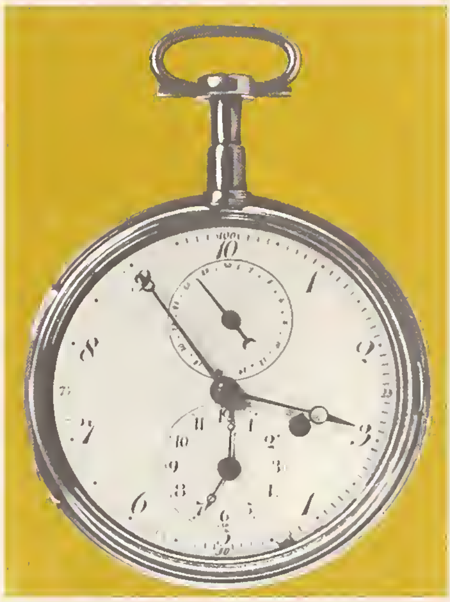
His second plan was more far-reaching. He wanted to establish a new system of weights and measures based on decimal ratios, which the U.S. had recently adopted for its coins. He suggested retaining some of the old names for frequently used units, and he felt also that the sizes of the new units should be as close as possible to the sizes of the old ones. His new "foot," based on the pendulum, would be nearly as long as an old foot, but it would be divided into ten new "inches."

Jefferson's report was accepted by Congress and discussed by select committees on several occasions over the next six years. But despite prodding from President Washington in two subsequent messages, neither plan was adopted.

Inventing the Meter

Meanwhile, a brand new measurement system, strictly based on natural phenomena, had been born in the intellectual ferment of the French Revolution. In 1790 Talleyrand, Bishop of Autun, got approval to proceed with formulating a new system of weights and measures. The Paris Academy of Sciences constructed a system based on the most scientific principles of the time and radically different from commonly used measurement systems in that it was wholly rational, quite simple, and internally consistent. Its keystone was the "meter," a unit of length defined as a specific fraction of the earth's circumference.

The meter was used in the derivation of all other elements of the metric system. Larger and smaller measures of a given unit, such as the meter, were related by decimal ratios. Originally time and angles were divided decimally, and for a while during the Revolution, Frenchmen lived on a ten-day week.



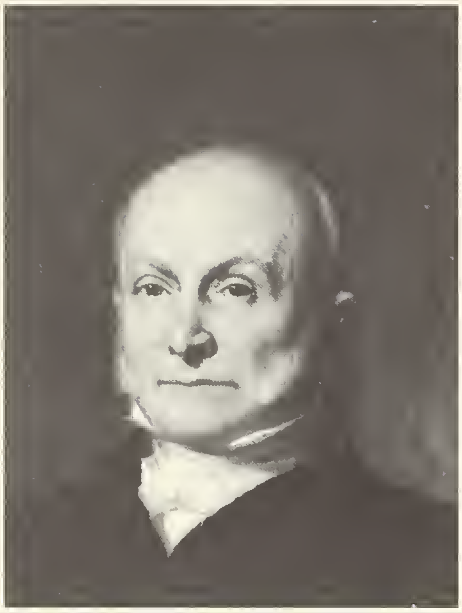
The decimal watch never took hold . . .

Neither the design nor the implementation of the new metric system was instantaneous. But it took hold rapidly, considering the chaos existing then in French political and social life. By 1795 provisional standards had been fabricated, and laws had been passed making the system compulsory. At the end of the century, an international conference was held in Paris to bring other nations up to date with what had been done and to show them the new standards.

Nor did the decimal calendar, but "for a while during the Revolution, Frenchmen lived on a ten-day week."

The metric system was not an unqualified success at first—not even at home in France. Use was not enforced, partly because commercial and household weights and measures remained scarce. Acceptance came so slowly, in fact, that in 1812, as a practical measure, Napoleon Bonaparte issued a decree partially reinstating the old system while retaining metric measurement standards. Only after a hiatus of 25 years was the metric system officially restored in France by passage of a law in 1837 making its use compulsory throughout the country after January 1, 1840.

After that, the metric system began to spread internationally at a rapid pace. By 1850 the Netherlands, Greece, Spain, and parts of Italy adopted it. By 1880 seventeen other nations—including Germany, Austria-Hungary,


John Quincy Adams wrote an eloquent report on the first U.S. Metric Study

Norway, and most of South America—had changed to metric. And by 1900 eighteen more were added to the list.

The Adams Study

After Jefferson's early attempts, the U.S. had shown little concern for standardizing measurement until 1816. Then, President James Madison again reminded Congress that the lack of provision for uniformity in weights and measures constituted an important piece of unfinished business. In response, the Senate the next year passed a resolution asking the Secretary of State to reinvestigate it. The result was John Quincy Adams' *Report Upon Weights and Measures,* submitted four years later in 1821.

The Adams report was the first systematic consideration of the metric system by the U.S. Government. In eloquent language, it covered the pros and cons of both widely used measurement systems in the context of the time. And for many years to come it inspired participants on both sides of the metric controversy.

Adams called attention to five features of the metric system that could be considered distinct advantages: the "invariable" standard of length taken from nature; the single unit for weight and the single unit for volume; the decimal basis; the relation of weight units to French coinage; and its uniform and precise terminology.

On the other side, he found disadvantages—notably, that the system had not actually become popular in France. And so, he presented Congress with a choice of four courses of action which, taken together, are not unlike the goals the current U.S. Metric Study was charged to explore. While extolling the virtues of the metric system, Adams suggested the following possibilities:

– "To adopt, in all its essential parts, the new French system of weight and measures . . .

– "To restore and perfect the old English system of weights, measures, moneys, and silver coins . . .

– "To devise and establish a [combined] system . . .

by adaptation of parts of each system to the principles of the other.

– "To adhere, without any innovation whatever, to our existing weights and measures, merely fixing the standard."

Adams' Advice

Adams' own preference was a two-stage approach. First, he would have the familiar English units standardized and approved without change. Later, he would have the President begin negotiating with France, Britain, and Spain to establish a uniform international measurement system.

The recommendations were in keeping with the times. By 1821 most states in the Union had already enacted laws providing for weights and measures and specifying the English units. At a time when the constitutional rights of the states were just beginning to be examined by the Supreme Court, any attempt to upset these laws by imposing the

"The preponderance of American trade at that time was still with Britain . . . "


Congressman John A. Kasson

metric system might have been disturbing. Mr. Adams was aware of this point. He was also aware that the most pressing need was for agreement on uniform standards of any sort.

In addition, he stressed international harmony of measurement. The preponderance of American trade at that time was still with Britain, and the U.S. was bounded on one side by British Canada and on the other by Spanish possessions. He therefore deemed it wise to consult both Britain and Spain before making any such radical change as adopting the metric system.

The Kasson Committee

Congress took no action in response to the Adams report, although in 1832 the Treasury Department did adopt English standards to meet the needs of customs houses.

Until the metric question was reconsidered some 40 years after the Adams report, the U.S. industrial society took form and grew large. A brief flurry of interest in the metric system, coinciding with its rapid spread from France to other nations, was cut short by the Civil War.

Then in 1863 the subject again came to the fore. President Lincoln had formed the National Academy of Sciences to advise the government on all technical matters. A committee led by Joseph Henry, an eminent physicist, was appointed at the request of the Secretary of the Treasury to reconsider weights, measures, and coinage. After two years of deliberation, the committee issued a report favorable to the adoption of the metric system. This met with the approval of Congressman John A. Kasson of Iowa, chairman of the newly appointed House Committee on Coinage, Weights, and Measures.

Metric Becomes Legal

In 1866 the Kasson Committee reported favorably on three metric bills that were eventually passed by Congress. The most important legalized the use of metric weights and measures, and it also specified English-system equivalents of metric weights and measures. One of the other bills directed the Postmaster General to distribute metric postal scales to all post offices exchanging mail with foreign countries; the other directed the Secretary of the Treasury to furnish each State with one set of metric standards.

Congressman Kasson made clear the intentions of his committee. The metric system was not being made compulsory. Rather, Congress was to permit the use of metric, while stimulating interest in reform. And this was to remain the goal of metric advocates for several more decades.


Frederick A. P. Barnard, a metric advocate.

The Controversy Smolders

Congressman Kasson had stressed the importance of educating the "rising generation" to the simplicity and utility of the metric system. Appropriately, educators themselves staged the first public set-to over the question of adopting metric. The adversaries were Professor Charles Davies of Columbia College and the President of the College, Frederick A. P. Barnard. Davies had been asked by the University Convocation of New York to head a committee to investigate what might be done to improve knowledge of the metric system. His report, submitted in 1871, recommended that nothing be done. Moreover, it raised numerous objections to the system and prophesied dire consequences to the nation if it were to be adopted.


Columbia College, 1871

Barnard delivered a rebuttal refuting all of Davies' objections and outlining a strategy for educating people in the use of the metric system. He wanted it taught in the schools, used in legislating tariffs and assessing customs duties, and put to use in a variety of other government activities, including public surveys, military and naval establishments, and post offices. Having advanced this plan, Barnard created an organization to push ahead with it: the American Metrological Society, founded in December 1873, with Barnard himself as president.

In its early years, especially while Barnard remained as its head, the Society attracted many influential members, among them: Congressman Kasson, a dozen other

U.S. Representatives and Senators, and eminent scientists and educators from the colleges and universities. In addition to its interest in advancing the metric system, the Society was concerned with internationally uniform coinage, standardized time zones, and several other reforms.

So much of the Society's energy was being taken up by other matters that it spawned a special group to promote the metric system through education. This was the American Metric Bureau, founded in 1876 with headquarters in Boston. Barnard was president of this organization also, and its executive director was a young librarian, Melvil Dewey, who later became known for his development of the decimal system of classifying library volumes.

The American Metric Bureau remained active for only a few years. During this time its most ambitious project was the purchase of metric hardware—scales, rules, and capacity measures—for resale to educational institutions at reasonable prices. When funds ran low, and particularly after Barnard's death in 1889, the Bureau's influence dwindled.

Yet the American Metrological Society and the American Metric Bureau did manage to spark some interest in measurement. Between 1877 and 1886, Congress considered several pieces of legislation dealing with increased use of the metric system. One resolution was passed in 1877 resulting in an executive-branch investigation of the desirability of making the system compulsory in all Government transactions. By and large, the study showed, the idea had little public support.

Action Begets Reaction

Another result of the early pro-metric activity was the fostering of the first organized opposition. While many individuals and groups objected to changes in the measurement system, the first to adopt opposition to the metric system as its main objective was the International Institute for Preserving and Perfecting Weights and Measures. It was founded in Boston in 1879 by a Cleveland engineer, Charles Latimer, and it made clear that the weights and measures to be preserved and perfected were strictly Anglo-Saxon.

The International Institute's thinking was greatly influenced by a contemporary movement known as "pyramidology." The main contention was that the Great Pyramid at Giza, Egypt, had been constructed by the hand of God in such a way that it contained all of His scientific gifts to mankind. By elaborately manipulating the pyramid's dimensions, pyramidologists "proved" that the Anglo-Saxon race was one of the ten lost tribes of Israel and that Anglo-Saxon weights and measures, represented by the customary English system, were of divine origin. The Institute was naturally opposed to any other measurement system and even wanted to "purify" the English system by eliminating all non-Anglo-Saxon influences.

The International Bureau of Weights and Measures was set up near Paris

The Treaty of the Meter

One of the Institute's main targets was U.S. adherence to the Treaty of the Meter, which had been signed by seventeen nations after five years of meetings (1870–1875) in Paris. The convention and the treaty that followed it accomplished several objectives. They reformulated the metric system and refined the accuracy of its standards. They provided for the construction of new measurement standards and distribution of accurate copies to participating countries. They established permanent machinery for further international action on weights and measures. And they set up a world repository and laboratory—the International Bureau of Weights and Measures near Paris—with land and buildings donated by the French Government.

The new measurement standards, including meter bars and kilogram weights, were finished in 1889 and the U.S. received its copies. Four years later the Secretary of the Treasury, by administrative order, declared the new metric standards to be the nation's "fundamental standards" of length and mass. Thus the U.S. became an *officially* metric nation. The yard, the pound, and other customary units are defined as fractions of the standard metric units.

In the Treaty of the Meter the U.S. had joined with every other major nation in the world in endorsing the metric system as the internationally preferred system of weights and measures and through which measurements are made internationally compatible at the highest level of accuracy. Yet there was no immediate and concerted effort to convert the nation practically to the system it had approved officially.

A Bill Wins Then Dies

An attempt to convert the nation was made in 1896, and for a short while it appeared that it might succeed. Representative Dennis Hurley of Brooklyn introduced a bill providing that all Government departments should "employ and use only the weights and measures of the metric system" in transacting official business and that in 1899 metric would become "the only legal system . . . recognized in the United States." Ardently supported by the Committee on Coinage, Weights and Measures, the bill passed the House by the bare margin of 119 to 117. But immediately, opponents forced a reconsideration and launched an attack stressing the difficulty of making a change. Foreseeing defeat, the Committee chairman had the bill sent back to his Committee, and there it died.

One contemporary report said that the Hurley bill failed because other Congressmen had not been fully briefed. Another claimed that too many Congressmen were afraid of adverse reaction from farmers and tradesmen in an election year.

The Arguments Crystallize

Over the next ten years, more than a dozen bills dealing with the metric system were proposed and many were debated. Support for the metric system continued to come from scientists, educators, and some government officials.

And members of the Committee on Coinage, Weights and Measures kept the subject alive in Congress.

In general the arguments, both pro and con, changed little. It was said that the U.S. would inevitably have to go metric and that the transition would become no easier as time went on. Britain and Russia seemed ready to make the changeover, thus leaving the U.S. isolated. And the intrinsic simplicity and utility of metric units and decimal arithmetic were reiterated. Opponents continued to stress costs and confusion.

The opposition was better organized and more effectively led than ever before. It was spearheaded by two men: Frederick A. Halsey, a New York engineer, and Samuel S. Dale, the editor of a Boston textile magazine. They rallied the support of engineers, manufacturers, and workmen and claimed to be "practical men, not closet philosophers or theorists." They charged that the metric system had been a practical failure in countries which had adopted it—i.e., that English and U.S. weights and measures were still the ones most commonly used even in those countries. Other arguments, some of which are still heard today in one form or another, included:

- Engineering standards (e.g., for nuts, bolts, and machine tool sizes) would have to be abandoned at great cost and inconvenience.
- The alleged simplicity of the metric system was illusory, because errors would be made through misplacing of the decimal point.
- Most of the world's commerce was being carried on in terms of English and U.S. units.
- The Government had no right to tell a man what weights and measures to use. And in any case, such laws would be unenforceable.

A Formidable Opposition

Most of the metric legislation proposed between 1896 and 1907 would have required the Government to adopt


The Great Depression intervened

the metric system first, with the rest of the country following within a few years. At first, the pro-metric factions had the momentum, but the tide turned about 1902, when Halsey and Dale managed to stir up such an outcry from a few manufacturers and influential engineers that further proposals were bottled up in Committee. They were, in fact, so successful that advocates gave up trying and decided to await a more propitious time.

The next phase of the metric controversy, which began before the U.S. became embroiled in World War I and lasted until the Great Depression set in, took place mostly outside Congress. The anti-metric forces continued to be led by Halsey and Dale and this time they had the backing of a formal organization, the American Institute of Weights and Measures.

With financial and political backing from a large portion of the nation's major manufacturers and manufacturing associations, the Institute was able to overwhelm each pro-metric proposal with organized protests and adverse publicity. In addition to publishing its own journals, bulletins, and pamphlets, the Institute enjoyed the support of some leading professional and trade journals.

The main anti-metric arguments, though not radically changed, were embellished with inflammatory flourishes. One series of articles in 1920 carried such titles as *What Real He-Men Think of the Compulsory Metric System*, *Metric Chaos in Daily Life*, and *A Metric Nightmare*. Newspaper and magazine articles sympathetic to the metric system were methodically rebutted, and those refusing to publish the Institute's replies were often charged with suppressing the facts.

Pro-Metricists Regroup

In the face of this continuing barrage of opinion, two newly-founded, pro-metric organizations began speaking out. In 1916 the American Metric Association was formed with headquarters in New York, and about a year later the World Trade Club opened in San Francisco. Of all the combatants in the metric controversy, only the American Metric Association has survived until today.

The Association drew most of its support from groups that had tended to be pro-metric in the past—e.g., scientists, educators, and members of such closely related professions as medicine, engineering, and pharmacy. It was also endorsed, and to some extent supported financially by several professional societies, notably the American Chemical Society, the American Pharmaceutical Association, and the American Association for the Advancement of Science. In fact, the Metric Association eventually affiliated itself with the AAAS. A few companies also were represented in the Metric Association, including General Electric and Goodyear Tire and Rubber, although they by no means exerted as much influence as the industrial representatives that virtually dominated the anti-metric American Institute.

Then World War II took all of our energies

The Thirty-Year Lull

In the post-war, pre-depression years, only two Congressional hearings were held on the subject, although 40 bills were introduced. Then, with the onset of the prolonged financial crisis, the metric question was shoved into the background. When times got better, the U.S. was in an isolationist mood and not disposed to considering a change to the metric system—although the time would come when metric advocates would propose a crash metric changeover as a tonic for a sluggish economy.

Sputnik opened the space age

In fact, the metric controversy remained dormant for almost three decades. The nation was too busy to consider the question during World War II, and at its end, the U.S. so dominated the world's production and exchange of goods that there seemed to be no need for a change.

Sputnik

Then came an event that suddenly focused America's attention on science and technology: the launching of the Soviet Union's first Sputnik satellite. Students flocked to

Students flocked to science courses

SI

SYSTÈME INTERNATIONAL

science courses; firms and government agencies poured money into research; and along with this resurgence of faith and interest in things scientific, the U.S. Government again began to consider seriously the desirability of increasing the use of the metric system, the predominant measurement language of science.

In 1957, the year Sputnik soared, a U.S. Army regulation established the metric system as the basis for weaponry and related equipment. A committee of the Organization of American States proposed that the metric system be adopted throughout the Western Hemisphere. The following year the major nations still using the Customary system, including the U.S. and Britain, agreed to use the same metric equivalents to define their inch-pound units. This dramatized the fact that the inch and the pound are defined by the meter and the kilogram.

Unity in Units

And two years after that, in 1960, the metric system was itself refined by a General Conference of Weights and Measures, in which the U.S. participated. Although the metric system had been the common measurement language of the 43 nations that adhered to the Treaty of the Meter, like other languages, it was spoken in various dialects. Prior to 1960 there were subtle differences in the use of metric; none caused confusion in everyday use, but where the highest levels of scientific and engineering precision were required, the metric system was not really standard and there was room for misunderstanding and error.

The General Conference of Weights and Measures ironed out these differences by agreeing on a standard metric system that might be compared with "the King's English." The result was the International Metric System, from which today all the U.S. Customary measurement standards are derived. International Metric, known in technical circles as "SI" (*Système International d'Unités*), is not an immutable measurement language. It will continue to evolve as needs change.

In May 1959, in an address to the American Physical Society, the acting Secretary of Commerce announced his intention to throw his Department's weight behind an in-depth study of the costs and difficulties which might be involved in changing the entire U.S. to metric. The action was inevitable, he implied; the only issues were when and how the change was to be brought about. Accordingly, he proposed that the Director of the National Bureau of Standards establish an advanced planning group to "assemble all available documentation and to identify possible courses of action."

Congress Seeks a Study

Congress, however, decided that the question should first be given Congressional attention, and three bills were introduced to deal with it. Two specified a metric study; the third took the form of a concurrent resolution stating that it be the sense of Congress that the President take steps to adopt the metric system as the nation's official system of measurement.

None of these bills was acted upon, but the idea of going metric or at least authorizing a metric study gained momentum in Congress. Hearings were held, although in the House none of the proposals ever reached the floor. A sense of urgency was still lacking.

Britain abandons inches and pounds

Britain Decides to Change

Finally, on May 24, 1965, the President of the British Board of Trade announced in Parliament the United Kingdom's intention to adopt the metric system over the course of the next ten years.

Britain's action made it clear that the U.S. would soon be one of the very few nations that still adhered to the Customary system. After a series of efforts by Congressman George P. Miller and Senator Claiborne Pell, participated in by Senator Robert P. Griffin, an acceptable bill was drafted. It became Public Law 90–472, which was signed into law in 1968.

Measurement Systems

Americans use a rich and varied language when talking about measurements. It is a *potpourri*. Men and women in every industry, every vocation, even every sport speak their own special dialects. The two "pure" tongues, Customary and International Metric, are often intermingled and also enriched with such special-purpose "slang" units as: barn, furlong, board-foot, pica, face-cord, therm, hand and electron volt.

" . . . we accept the dictionary for the spelling and meaning of words"

Generally speaking, people who must communicate measurements with one another regularly can do so readily enough and with a minimum of confusion. But the proliferation of terms has indeed caused some difficulties. In certain highly technical industries, for example, research scientists think wholly in terms of metric, whereas product engineers work with Customary units. Before an idea can be reduced to application, measurements must first be translated.

Clearly there would be less chance of confusion if everyone agreed to talk measurement in some consistent way—preferably in Customary, International Metric, or some other language if it were already widely accepted. We agree on a common alphabet; we accept the dictionary for the spelling and meaning of words; standard nuts are manufactured to fit standard bolts; if we live in the same time zone, we set our clocks the same. These conventions for making life simple are now taken for granted, yet in the past each of them was adopted in the face of strenuous objections.

"These conventions for making life simple are now taken for granted, yet . . . "

Can we, and should we, seek similar harmony in the way we measure? If so, which of the two major measurement languages is better? This is not an easy question to answer, because each has intrinsic or practical merits.

The Logic of Metric

No other system of measurement that has been actually used can match the inherent simplicity of International Metric. It was designed deliberately to fill all of the needs of scientists and engineers, although laymen need only know and use a few simple parts of it. It is logically streamlined, whereas other systems developed more or less haphazardly. At this time there are only six base units in the International Metric System. The unit of length is the meter. The unit of mass is the kilogram. The unit of time is the second. The unit of electric current is the ampere. The unit of temperature is the kelvin (which in common use is translated into the degree Celsius, formerly called degree centigrade). The unit of luminous intensity is the candela. These units are described more fully in Appendix Three.

All the other units of measurement in the International Metric System are derived from these six base units. Area is measured in square meters; speed in meters per second; density in kilograms per cubic meter. The newton, the unit of force, is a simple relationship involving meters, kilograms, and seconds; and the pascal, unit of pressure, is defined as one newton per square meter. In some other cases, the relationship between the derived and base units

SOME COMMON UNITS

Length	Mass	Volume	Temperature	Electric Current	Time
METRIC					
meter	kilogram	liter	Celsius (Centigrade)	ampere	second
CUSTOMARY					
inch	ounce	fluid ounce	Fahrenheit	ampere	second
foot	pound	teaspoon			
yard	ton	tablespoon			
fathom	grain	cup			
rod	dram	pint			
mile		quart			
		gallon			
		barrel			
		peck			
		bushel			

must be expressed by rather more complicated formulas—which is inevitable in any measurement system, owing to the innate complexity of some of the things we measure. Similar relationships among mass, area, time and other quantities in the Customary system usually require similar formulas, made all the more complicated because they can contain arbitrary constants. For example, one horsepower is defined as 550 foot-pounds per second.

The third intrinsic advantage is that metric is based on the decimal system. Multiples and submultiples of any given unit are always related by powers of 10. For instance, there are 10 millimeters in one centimeter; 100 centimeters in one meter; and 1,000 meters in one kilometer. This greatly simplifies converting larger to smaller measurements. For example, in order to calculate the number of meters in 3.794 kilometers, multiply by 1,000 (move the decimal point three places to the right) and the answer is 3,794. For comparison, in order to find the number of

10

Metric is based on Decimal system

Names and Symbols for Metric Prefixes

Prefix	means
tera (10^{12})	One trillion times
giga (10^{9})	One billion times
mega (10^{6})	One million times
kilo (10^{3})	One thousand times
hecto (10^{2})	One hundred times
deca (10)	Ten times
deci (10^{-1})	One tenth of
centi (10^{-2})	One hundredth of
milli (10^{-3})	One thousandth of
micro (10^{-6})	One millionth of
nano (10^{-9})	One billionth of
pico (10^{-12})	One trillionth of

inches in 3.794 miles, it is necessary to multiply first by 5,280 and then by 12.

Moreover, multiples and submultiples of all the International Metric units follow a consistent naming scheme, which consists of attaching a prefix to the unit, whatever it may be. For example, kilo stands for 1,000: one kilometer equals 1,000 meters, and one kilogram equals 1,000 grams. Micro is the prefix for one millionth: one meter equals one million micrometers, and one gram equals one million micrograms. For the meaning of the other prefixes, see the table on page 25.

Metric calculations are so much easier, in fact, that one authority is convinced the U.S. aerospace industry alone would save about $65 million a year in engineers' time by converting entirely to metric.

The Merits of Customary

In contrast, the Customary system seems to have no logical patterns. But on the other hand, it does have its own practical merits, although they are somewhat more subtle. In some ways, Customary units are still closely related to everyday human experience and even human anatomy, from which they were derived centuries ago. The foot is roughly the length of a human foot; the yard is approximately the distance between a grown man's nose and the fingertips at the end of his outstretched arm; a mile is about 2,000 paces.

"... one authority is convinced the U.S. aerospace industry alone would save about $65 million a year in engineers' time"

The seeming multiplicity of Customary units is in reality often a convenience for those who use them. Most people find it easiest to comprehend numbers that are between 1 and 1,000—preferably between 1 and 10. By picking from the wide assortment of Customary units, it is usually possible to wind up with a convenient number. The householder buys a few tons of coal for the winter. The farmer delivers a few hundredweight of produce to the market. The grocer sells a few pounds of potatoes to a customer. A pipe smoker buys a few ounces of tobacco.

"The farmer delivers a few hundredweight . . . The grocer sells a few pounds . . . "

The multiples in the Customary system are frequently based on powers of 2 and 12. Therefore, they do not easily lend themselves to decimal arithmetic. Nevertheless, intuition easily grasps binary fractions—i.e., halves, and halves of halves. The number 12 also has a special practical virtue in doing arithmetic. It is conveniently small, and it is divisible by 2, 3, 4, and 6—twice the number of divisors of 10. Even the French, fathers of the metric system, recognize the handiness of 12. A few years ago a British building contractor, specializing in partly prefabricated construction, decided to convert his plans to modular units of 40 inches, on the theory that this length was close enough to one meter (39.37 inches) so that he could bid on some school buildings in France. He was surprised to learn later that French schools were being designed to modular units of 1.2 meters, because these could be divided into 200, 300, 400 and 600 millimeter subunits.

The Potpourri

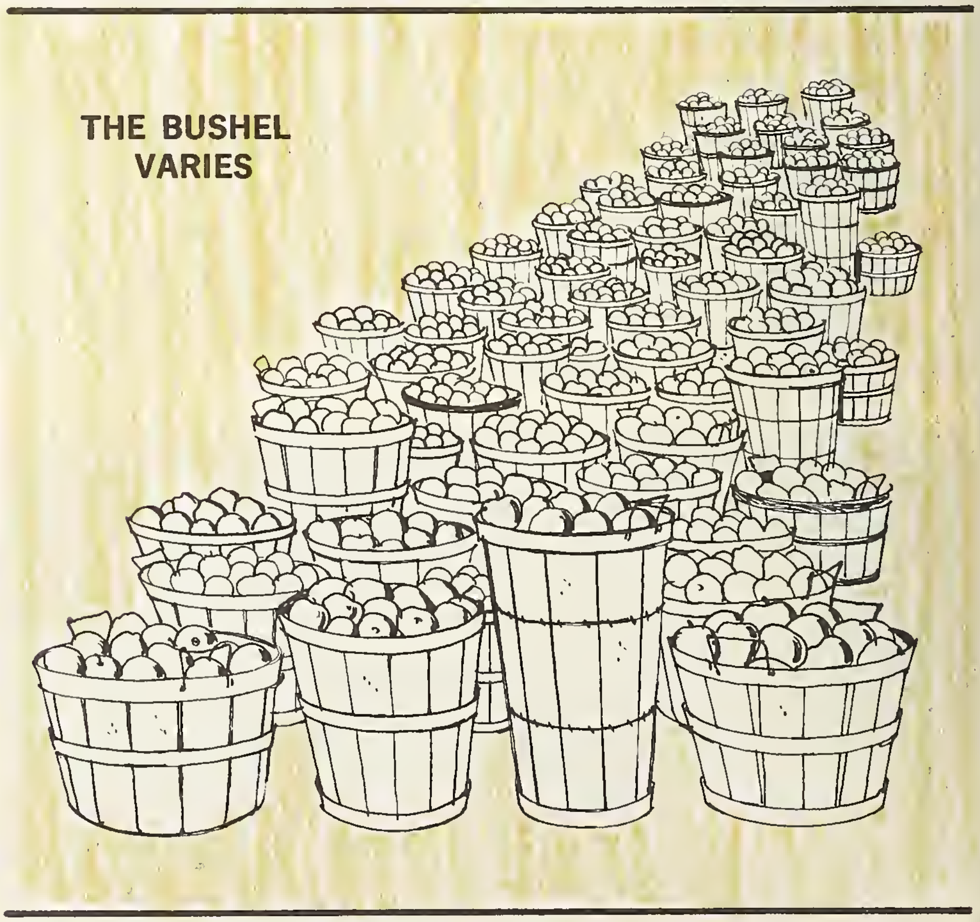
With both systems accepted and in use in the United States, people in different walks of life have compromised in different ways to take advantage of the convenience and handiness of the Customary system and the logical simplicity of International Metric. The Customary system still predominates, but metric is slowly gaining ground, especially in highly technical industries, in education, in pollution standards, and in international trade and relations.

In addition there remains a host of miscellaneous

"Racing fans are committed to the furlong and the hand."

units, which belong strictly to neither the Customary system nor International Metric, but which are used by certain groups of people almost as part of a private language. Printers still talk of picas and points. Racing fans are committed to the furlong and the hand. It seems almost as if every commodity were measured in a different way; there are such oddities as cords and board-feet of wood. The standard U.S. bushel contains 2,150.42 cubic inches, equal in capacity to a cylinder 8 inches deep and 18 1/2 inches in diameter, interior measure; but the size of the bushel varies in practice. There are long tons (2240 pounds), metric tons (2200 pounds), and short tons (2000 pounds).

There is obviously plenty of chance for confusion. In the construction industry, for example, the mixing of concrete is sometimes specified in terms of gallons of water per bag of cement. But near our northern border misunderstandings are likely to occur, because Canadians speak



of the Imperial gallon, which is 20 percent larger than the U.S. gallon, and they also market cement in a different sized bag.

Even scientists and engineers speak special measurement dialects. There are, for instance, more than a dozen units of energy, including ergs, electron volts, frigories, horsepower-hours, joules, kilowatthours, therms, watt-seconds, British Thermal Units, metric tons of TNT, and six kinds of calories.

Whether in Customary or metric, a few things are still measured crudely. One cannot trust a shoe to fit unless one tries it on. A "mile down the road" may be as much as three miles; to be told a "kilometer down the road" may be just as vague. And cooks throughout the world add a "pinch" of this or a "dash" of that, whether they use metric or Customary recipes.

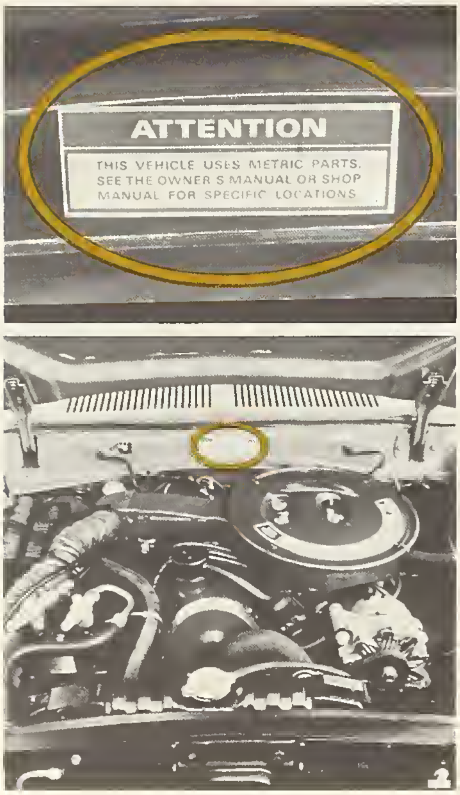
"One cannot trust a shoe to fit unless one tries it on."

Metric Beachheads

The metric system is slowly advancing in our society under its own power, albeit sporadically and in piecemeal fashion. By and large, these changes have taken place in activities and disciplines which are more or less self-contained. The pharmaceutical industry more than a decade ago gave up the apothecary's traditional drams, grains, and minims and converted to milligrams, grams, and milliliters; they had no serious interface problems with other industries (see Chapter V). Physicians, whose medical school training in chemistry is metric, learned easily enough to write prescriptions in metric units, and pharmacists learned to fill them.

"Physicians . . . learned easily enough to write prescriptions in metric units . . . "

With few exceptions, the language and tools of U.S. science are entirely metric. Even in work only peripherally related to science, scientists tend to think in metric terms. The physicist directing the building of the new National Accelerator Laboratory in Batavia, Illinois had to design the circular ditch that would house the accelerator. This had to be an enormous trench with a reinforced concrete structure, requiring the labor of thousands of workmen and



". . . some automobiles made in the United States are being assembled with engines, transmissions, and other parts built to metric specifications."

many engineers. The choice of diameter for the trench was somewhat arbitrary; but thinking like a physicist in metric units, the director chose one kilometer.

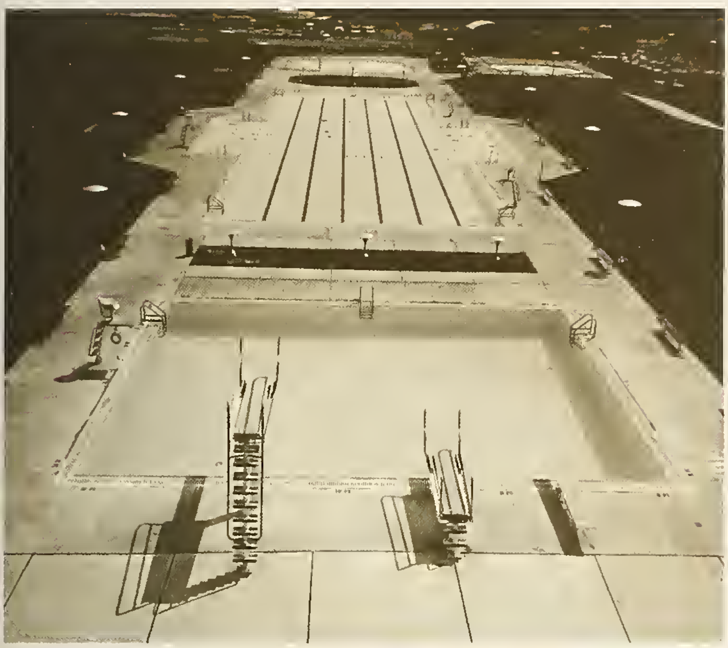
In mathematics and science education, throughout most of the country the metric system is taught to some extent, even to very young children. Soldiers interviewed on television speak naturally of "advancing 3 kilometers to Hill 803," an unnamed hill that is 803 meters high. Their ammunition is measured in metric. One of the largest government agencies, the National Aeronautics and Space Administration, decided last year to use International Metric in its documents and reports.

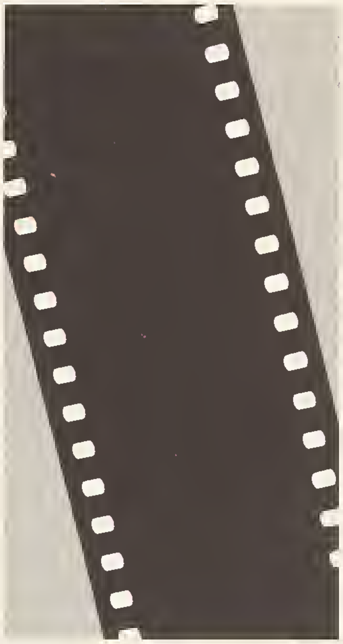
The two systems agree on the use of the candela (the unit for luminous intensity) and on the measurement terms used to describe the electric current that flows into our homes, the radio waves in the air, and other electrical phenomena. The electrical units, such as ampere, volt, watt, and hertz (cycles per second), are parts of the International Metric System. But they have also long been used in the Customary system. Thus, three of the six base units of the International Metric System—the ampere, the candela, and the second—are also used in the Customary system.

Automobile mechanics have added metric tools to their toolboxes, because foreign vehicles have metric parts. In fact, even some automobiles made in the United States are being assembled with engines, transmissions, and other parts built to metric specifications. Statutory standards for automobile emissions of hydrocarbons, carbon monoxide and oxides of nitrogen read in "grams per mile"—another metric infiltration.

Swimming pools for outdoor competition are being built to metric dimensions so that our swimmers can practice for international metric-distance events. American skis, made to standard feet and inch lengths a few years ago, are now sold in centimeter sizes. The width of photographic film is expressed in millimeters, even though sprocket holes are spaced six to an inch.

Some Metric Beachheads in the U.S.





Comparing the Commonest Measurement Units

Approximate conversions from Customary to metric and vice versa.

	When you know:	You can find:	If you multiply by:
LENGTH	inches	millimeters	25
	feet	centimeters	30
	yards	meters	0.9
	miles	kilometers	1.6
	millimeters	inches	0.04
	centimeters	inches	0.4
	meters	yards	1.1
	kilometers	miles	0.6
AREA	square inches	square centimeters	6.5
	square feet	square meters	0.09
	square yards	square meters	0.8
	square miles	square kilometers	2.6
	acres	square hectometers (hectares)	0.4
	square centimeters	square inches	0.16
	square meters	square yards	1.2
	square kilometers	square miles	0.4
	square hectometers (hectares)	acres	2.5
MASS	ounces	grams	28
	pounds	kilograms	0.45
	short tons	megagrams (metric tons)	0.9
	grams	ounces	0.035
	kilograms	pounds	2.2
	megagrams (metric tons)	short tons	1.1
LIQUID VOLUME	ounces	milliliters	30
	pints	liters	0.47
	quarts	liters	0.95
	gallons	liters	3.8
	milliliters	ounces	0.034
	liters	pints	2.1
	liters	quarts	1.06
	liters	gallons	0.26
TEMPERATURE	degrees Fahrenheit	degrees Celsius	5/9 (after subtracting 32)
	degrees Celsius	degrees Fahrenheit	9/5 (then add 32)

These examples, though far from exhaustive, do indicate that metric measurements and practices have established many beachheads in the United States.

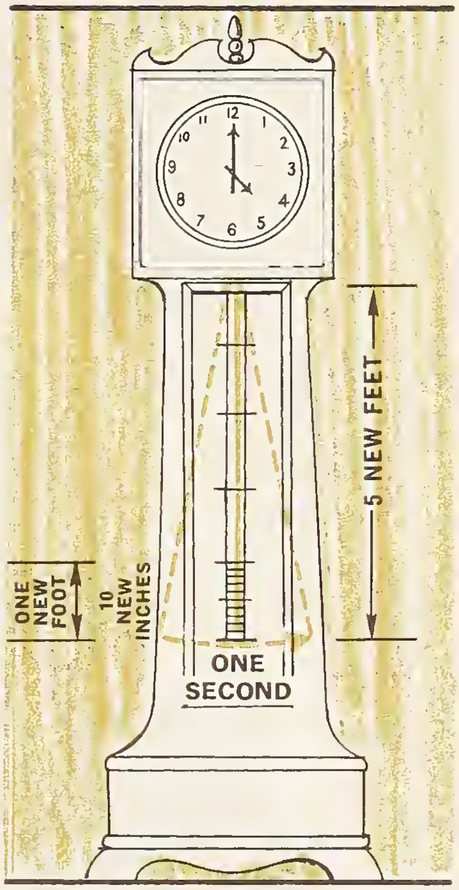
Do-It-Yourself Systems

Many other measurement systems have been conceived. As recounted in Chapter II, Thomas Jefferson proposed that the length of a rod, swinging as a pendulum with a period of two seconds, be the standard of length. This length (about 58.7 regular inches) would be divided into five new feet, each foot being subdivided into 10 new inches. For the standard of mass, he proposed a cubic inch of rain water and called this mass an ounce. Thus, the names "inch," "foot" and "ounce" would be retained, although their sizes would be changed considerably.

During the last 100 years, there have been many proposals for basing measuring units on physical constants of nature, such as the speed of light, the gravitational constant, and atomic constants. Albert Einstein once proposed that the diameter and mass of the hydrogen atom and the speed of light be the primary units of measurement, from which all other units could be derived. None of these proposals has ever been adopted by any nation.

Some have argued that, no matter what base units are used, their multiples and submultiples be related by binary numbers: the powers of 2 and the fractions 1/2, 1/4, 1/8, 1/16, and so on.

In principle, almost any precisely defined and consistent measurement system could serve us satisfactorily. In practice, however, it is unrealistic to consider for general use any choice of measurement system that is alien to our culture or to that of the rest of the world. The U.S. therefore really has only two practical alternatives: either to allow its measurement system, which includes some metric units, to develop without overall design, or to elect as a society to adopt the measurement system that has virtually achieved worldwide acceptance and to work out a policy and program for changing to it.



JEFFERSON'S PROPOSED LENGTH STANDARD
length of pendulum rod is about 58.7 regular inches

CHAPTER IV

Arguments That Have Been Made For Metric and For Customary

Perhaps the longest running debate in the history of this country is whether the United States should convert to the metric system. In the course of almost two centuries dozens of arguments have been advanced, attacked, and defended with a passion inspired by a topic with implications that are both intensely practical and intellectually stimulating.

Accuracy depends not on the measurement system used, but on the tools and the skill of the person who uses them

The purpose of this chapter is to list, without disputing or evaluating them, the arguments that are made today. Some of these arguments have many adherents; some have only a few. Thus, they are significant only to the extent that they reflect the diversity of viewpoints that are possible. The U.S. Metric Study was conducted on neutral ground. The conclusions of this report are based, not on unsupported arguments, but on the evidence marshalled in the surveys and public hearings described in Chapter I.

Some of the arguments catalogued in this chapter are thought-provoking, even compelling; a few may seem completely lacking in merit. Many may seem intemperate, reflecting, as they do, the prejudices of particular groups or individuals.

Neither those who favor going metric nor those who oppose it have a monopoly on pure reason—or on bias.

Not a few of the common arguments are demonstrably false, even a bit frivolous. It is said, for instance, that the metric system, because it has roots in science, somehow makes measurement more accurate. But measurement depends entirely on the accuracy of the measuring tools and the skill of the person who uses them.

Some people argue on the other side that the U.S. has achieved its status as an industrial power through the use of inches and pounds. This is clearly beside the point: what has been achieved is due to technological skill and high standards of design and workmanship.

Serious arguments, however, have been advanced by both pro-metric and pro-customary spokesmen. By and large, the arguments fall into four categories:

Computers can handle any units

The convenience, utility, or intrinsic merit of the metric or Customary systems in everyday life as well as in industry, commerce, and government.

The problems that a metric changeover would entail and also the opportunities it could afford for improving many activities of society.

The ways in which going metric might affect the United States' relations with the rest of the world.

The implications for the future well-being of this country.

Which System Makes Calculations Easier?

Pro-Metric:

"It's easy to compute with metric units. All you have to do in many cases is add a zero or move a decimal point."

"There are only a few units and the relationships among them are pretty simple. No need to remember how many cubic inches in a gallon or whether an ounce is fluid or avoirdupois."

"Decimal relations are intellectually more satisfying."

"The International Metric System has different terms for mass (the kilogram) and force (the newton), eliminating a confusion between mass and force that has perplexed generations of students."

Pro-Customary:

"Practically speaking, it's often easier to do simple arithmetic in your head with Customary units, because both the duodecimal and binary bases are handier. The duodecimal (base 12) has more factors than the decimal (base 10), and binary (base 2) is the natural arithmetic for making yes-no choices or designing computers."

"If we are going to change, let's look for some combination of number bases better than either decimal or duodecimal."

"This is an age of computers. If you have a really complicated problem, the machine can handle any units, and so there is no reason to change to a decimal base."

Which System Is Personally More Convenient?

Pro-Metric:

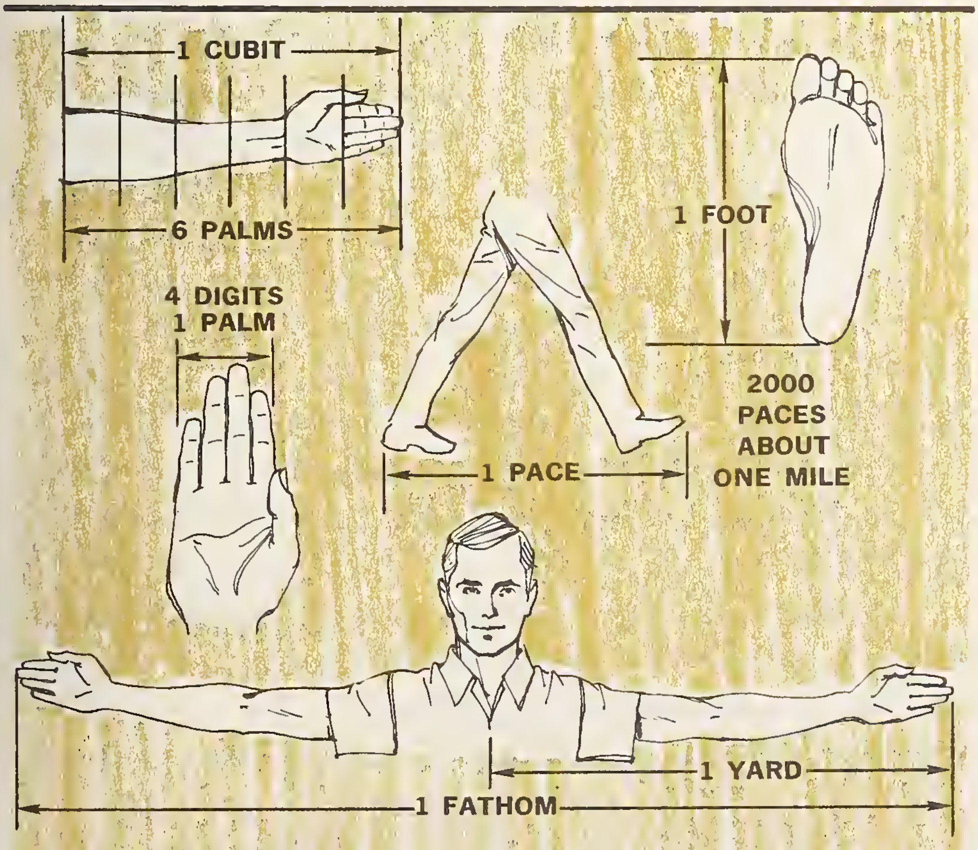
"Customary units of length suggest a close relationship to human measurements—e.g., the foot and the yard (or pace). Actually these units are directly defined in terms of metric measurement standards."

"The metric system has a more fundamental relationship to human anatomy. It is based on the number 10; we have 10 fingers; and from antiquity people have learned to count on their fingers."

Pro-Customary:

"Your foot may not be exactly one foot long, but it's pretty close and, in general, Customary units are related to everyday experience." (The diagram below illustrates man as a "measuring rod.")

"Even some scientists argue that units like the candela are artificial."



MAN AS A MEASURING ROD

"For a while you might not understand what you read in the newspaper . . ."

"The purported logic of metric unit names is violated by the use of the kilogram as the base unit of mass. Why not the gram?"

"In the International Metric System the derived units with hard-to-remember names—such as the pascal, the siemens, the weber, and the tesla—are proliferating."

Problems and Opportunities Within the U.S.

Pro-Customary:

"Changing would cause confusion. Consumers would not know whether they were getting their money's worth for things sold by length, weight or volume. For a while you might not understand what you read in the newspaper or heard on television."

"Many companies would have to carry double inventories of spare parts during the transition period."

People would have to be retrained

"People would have to be retrained. And during the retraining period they would be deprived of invaluable experience—the intuitive feel for measurements on which craftsmen, mechanics, and engineers depend. The result would be a temporary loss of productivity."

"Dealing with unfamiliar quantities might result in safety hazards due to mistakes."

"Everybody would have to pay for the changeover, because industry would have an excuse for higher prices, labor an excuse for higher wages, and government bureaucracies an excuse for higher appropriations."

The intuitive feel for measurements

"A coordinated conversion program, even if largely voluntary, would be simply another government encroachment on free choice."

"Conversion might be easy enough for big firms with engineering staffs and foreign trade departments. But small businesses would find it very difficult."

"During transition the nation would be part metric and part Customary. Buyers and sellers could get badly out of phase with one another as to the availability and demand for parts."

Pro-Metric:

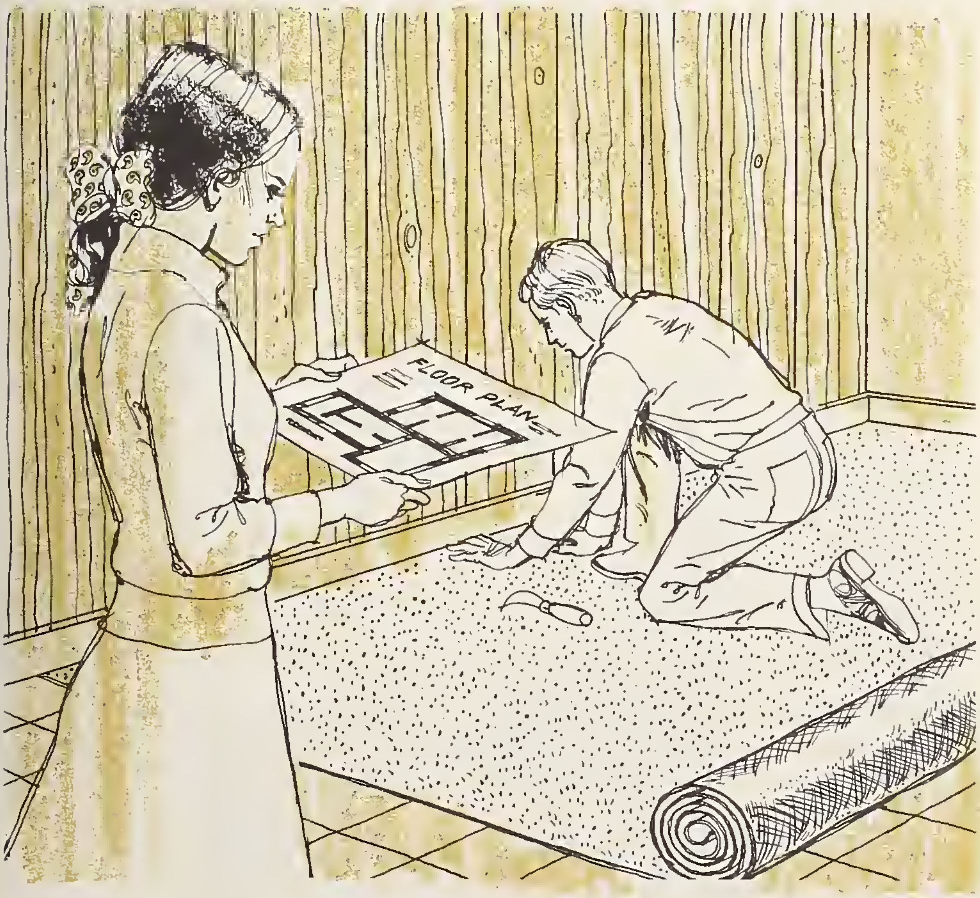
"Experience has shown that conversions of this kind turn out to be much easier and less costly than anticipated. For example, the Swedes, with careful planning, managed to change overnight from driving on the lefthand side of the road to the righthand side—with no increase in traffic accidents. And individual British firms have found from actual experience that full productivity was regained within a very short time after changing to metric."

"Metric is easier to learn; thus schools would have extra time to teach some of the new subjects now being introduced into the curricula."

"Metric is easier to use and, therefore, engineers would save time and make fewer errors."

"The necessities of conversion would offer opportunities: During adjustment to the new measurements, there would be a chance to clean house and eliminate many of the superfluous varieties of nuts and bolts, and other com-

Changes are not always as formidable as they seem



COMPARISON OF CALCULATIONS CUSTOMARY VS. METRIC

EXAMPLE: CARPETING

Customary units:

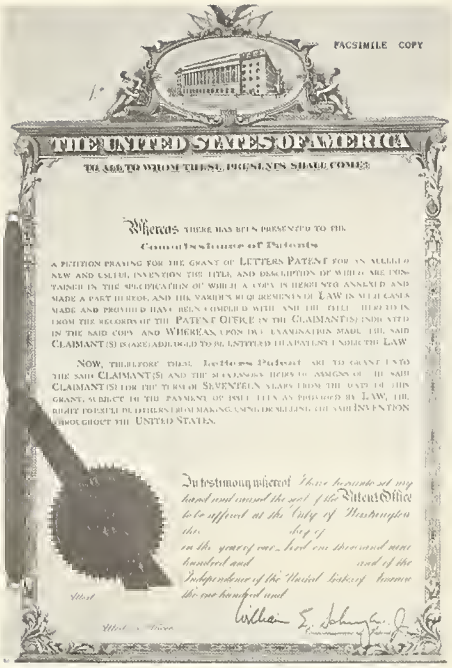
Calculate the amount of carpeting to buy for wall-to-wall carpeting of a room 18 feet 4 inches long and 11 feet 8 inches wide, using carpet 12 feet wide.

$$Area = length \times width$$
$$= \left(\frac{18}{3}+\frac{4}{36}\right) \times \left(\frac{12}{3}\right)$$
$$= 24.44 \text{ square yards to buy}$$

Metric units:

Calculate the amount of carpeting to buy for wall-to-wall carpeting of a room 5.59 meters long and 3.81 meters wide, using carpet 4 meters wide.

$$Area = length \times width$$
$$= 5.59 \times 4$$
$$= 22.36 \text{ square meters to buy}$$



Creative people would exploit the opportunity to do things better

mon goods. Manufacturers' inventories might actually be reduced."

"There would be an opportunity to improve the technical quality of building codes and other engineering standards. And schools would have an added reason to revamp textbooks and curricula."

"Many changes would probably go far beyond what was utterly necessary. Faced with the task of doing things differently, creative people would exploit the opportunity to do things better. Conversion to metric could stimulate invention and innovation."

"Small businesses and self-employed craftsmen would benefit from a coordinated conversion program. As it is, they are being left behind by some big firms that have the expert staffs and international connections to adapt independently to the increasing worldwide demand for metric goods."

"Speaking a common measurement language, scientists, engineers, businessmen, educators, and government officials would communicate with one another more freely and with less risk of misunderstanding."

"A changeover to the metric system would be a stimulus to the economy comparable to the space program."

We want to have our say in setting international standards

The U.S. and the World

Pro-Customary:

"Let's not risk our industrial success with a measurement system promoted by countries that have not done as well technologically as the U.S."

"Going metric would open the way to imports from countries that do not now make products to Customary specifications."

"Our export trade is so small compared with our Gross National Product that the advantage of manufactur-

Speaking a common measurement language would make things easier


Our exports are crucial

ing according to metric standards would be insignificant."

"Within our borders the Customary system works all right. Foreign considerations do not warrant disrupting our trillion dollar economy."

Pro-Metric:

"We would fortify our position as a leader by joining the rest of the world in a common measurement system. Almost all the other English-speaking nations have converted to metric or are in the process of doing so."

"Travelers, traders, and all other U.S. citizens who have dealings abroad are handicapped to the extent that they are unfamiliar with the commonly accepted measurement language."

"Though small in relation to the total economy, our exports are crucial to maintaining a favorable trade balance in an increasingly metric world."

"Our economy today, as never before, depends on trading raw materials, manufactured products, even technological ideas with countries that have changed to metric or committed themselves to do so. We put ourselves at a competitive disadvantage by using a measurement system different from that of the world market."

"We want to have our say in setting international standards of all sorts, especially those concerned with industrial products. Going metric would help to win acceptance for our ideas."

"Our military allies are either metric or committed to change to metric. Military coordination and logistics would be simplified if we, too, converted to metric."

"We can better do our part to aid the development of other nations if we adopt the measurement language that is familiar to almost all of them."

"U.S. companies that want to make metric products for sale in the U.S. or in foreign markets may find it advantageous to build the plant abroad and employ foreign workers familiar with the metric system. Export of jobs to metric countries is already a problem."

Implications for the Future

Pro-Customary:

"If we decide to go metric, we are likely to pick the wrong time. No one can guarantee what the economic conditions will be throughout the transition period. The measurement conversion might complicate all our problems."

"Even in good times the nation is faced with complex problems. Why add to them a troublesome change in measurement?"

Pro-Metric:

"The nation is already heading toward the metric system, although slowly and in an unorganized way. It will never cost less than it will right now. Postponing the decision to change transfers a greater burden to future generations of Americans."

"The costs and inconveniences of metric conversion would be temporary; they would stop at the end of the transition period. The benefits would continue indefinitely."

We put ourselves at a competitive disadvantage by using a measurement system different from that of the world market

* * * * *

The very fact that many of the arguments listed above tend to contradict one another shows how easy it is to take sides on various aspects of the metric question. But the main issue, as was indicated in Chapter I, and will be elaborated upon in the remainder of this report, is not so much the contrasting merits, in the abstract, of the metric and Customary systems. Rather, it is what the response of the U.S. will be to an accomplished fact: the judgment by virtually all other nations of the world that metric will be the universal measurement language.

The next chapter describes in general terms what would be entailed in a program that would conclude with the nation becoming predominantly metric. The succeeding chapters are devoted to an analysis of the advantages and disadvantages of the alternatives facing the nation.

CHAPTER V

Going Metric: What Would It Really Mean?

The main reason going metric has been so controversial in the past is that it was never clear what the debate was really all about. Some people assumed that it would mean an abrupt and mandatory changeover: at some specific date in the near future the inch and the pound would be outlawed. People at the other extreme viewed it as a painless and casual drift toward the use of more metric measurements at little cost or inconvenience.

We shall certainly not go metric by an abrupt and mandatory changeover. Such a crash program would dislocate our lives in an intolerable way.

Neither can we expect that a drift to metric would be without cost or inconvenience. Our experience since Congress legalized the metric system in 1866 suggests that if the nation prefers to drift to metric, it would still be having to cope with two measurement systems at the end of this century. Since the use of the metric system in the U.S. is increasing, throughout the prolonged period of gradual change there would be substantial costs and inconveniences, primarily those associated with maintaining dual inventories, training people in both measurement systems, and printing metric and Customary dimensions on documents and labels. Small businesses would have to tag along as well as they could.

Soft and Hardware

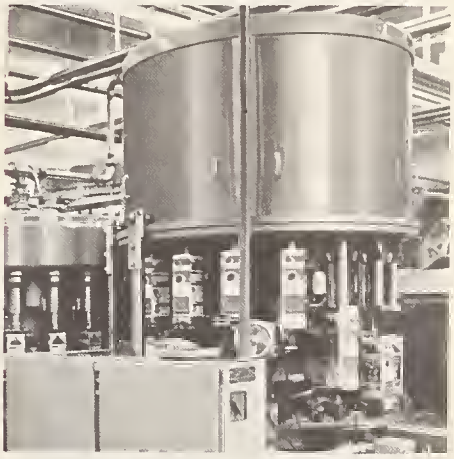
When we talk about going metric, we really have to consider two kinds of changes, "soft" and "hardware." A soft change is simply a trade of one measurement language for another. Example: the weather announcer who begins reporting the temperature in degrees Celsius instead of degrees Fahrenheit is making a soft change. Hardware changes involve altering sizes, weights, and other dimensions of physical objects. Example: if the dairy industry starts selling milk by the liter (1.05 quarts), the milk distributor has to modify his machinery to fill a slightly larger container.

A hardware change is almost always preceded by a

Over 100 Years Ago

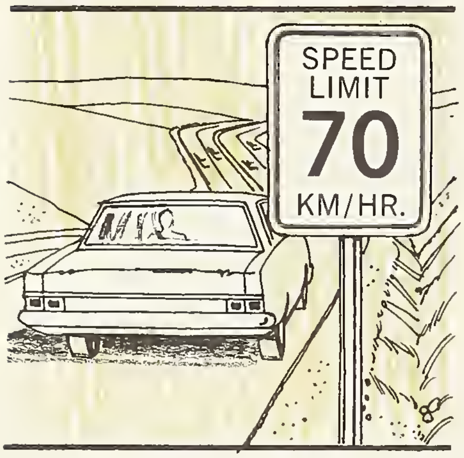
It shall be lawful throughout the United States of America to employ the weights and measures of the metric system; and no contract or dealing, or pleading in any court, shall be deemed invalid or liable to objection because the weights or measures expressed or referred to therein are weights or measures of the metric system. (*United States Code:* Act of July 1866.)

" . . . the weather announcer who begins reporting the temperature in degrees Celsius instead of degrees Fahrenheit . . . "



" . . . if the dairy industry starts selling milk by the liter . . . "

"If a recipe calls for 250 milliliters of oil . . . "



If traffic signs were to read in kilometers, meat were sold by the kilogram, and . . .

soft change. Suppose that new cookbooks are written with recipes in metric language—i.e., convenient fractions of kilograms and liters. At first, the American housewife follows these recipes by making soft changes. If a recipe calls for 250 milliliters of oil, she looks at a conversion table for translating milliliters to liquid ounces, then measures out slightly more than eight ounces (one cup) of oil.

So far she has made only a soft change. Suppose then, she breaks her measuring cup. Since her cookbook reads in metric units, it would be foolish to buy a new cup graduated in ounces, and so she buys one marked off in milliliters. This is a hardware change. In this case, the cost of the hardware change is zero; she had to buy a new cup anyway. But if the use of the conversion table confuses her and she throws away her ounce-marked cup in frustration, the price of the new metric measure is an "extra" hardware cost of conversion.

Metric Momentum

For industrial engineers, factory workers, carpenters, surveyors, building inspectors, butchers, school teachers, and people in almost every walk of life, going metric would mean acceptance of metric as the preferred system of measurement and ultimately, thinking *primarily* in metric terms instead of *primarily* in Customary terms.

The use of metric units has already made considerable headway in the U.S., as was pointed out in Chapter III. In a few fields—notably the physical sciences, pharmacy and medicine—people have converted much of their thinking, talking, and writing to metric units. Electrical units are the same in metric and Customary. Nevertheless, our national measurement language is still only slightly metric.

If schools were to give greater attention to metric than to Customary, if a large number of industries were to convert to metric, if our traffic signs were to read in kilometers instead of miles, if a man buying a shirt were shown a 40 or 41 centimeter collar instead of a 16 inch collar, if milk were sold by the liter and meat by the kilogram, then the metric system might, in not many years, become as widely used as the Customary system.

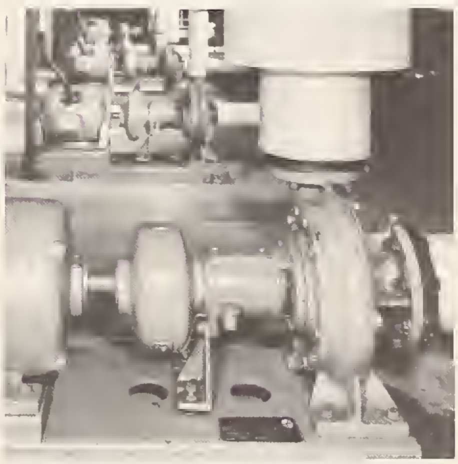
From that point on, metric habits of speech and metric ways of thinking would gain momentum. And after a couple of generations, "inch," "pound," and other Customary words of measurement might sound almost as archaic as "cubit" or "league." We would then unquestionably be a predominantly metric nation.

" . . . only when they wore out or became obsolete."

Rapidly, Slowly, Never

People making the change to metric units would make an assortment of soft and hardware changes, as necessary either to do their jobs or to keep up with what was being said in the newspapers and on television. In even a concerted program for going metric, some things would be changed rapidly, some slowly, and some never. In most cases, things would be replaced with new metric models only when they wore out or became obsolete. This would certainly be true, for example, of existing buildings, aircraft carriers, railroad locomotives, power generating plants, and even such things as hair dryers.

In many instances industry and commerce would make metric changeovers much as the housewife did when she broke her non-metric measuring cup. A pump in a chemical factory, for example, might with careful maintenance last ten years before it wore out and had to be replaced. But if a critical part failed after, say, five years, the user might well decide to buy a new pump of improved design and lower running cost, rather than fix the old one. And if he were going metric and metric pumps were available, the new pump would, of course, be one built to metric standards.



" . . . the user might well decide to buy a new pump of improved design and lower running cost . . . "

Somewhat analogous is the problem of rewriting real estate deeds in metric dimensions – meters instead of yards and hectares instead of acres. There would be no good reason to do this until the property changed hands and was resurveyed. As a matter of fact, some deeds in New Orleans are still written in terms of the French foot of

a hectare is
10,000 square meters

Do you know how
many square yards
or square feet are
in an acre?

pre-Napoleonic times, and in the Far West there are still tracts that are described not in acres but in square *varas*, a holdover from the Spanish grant days.

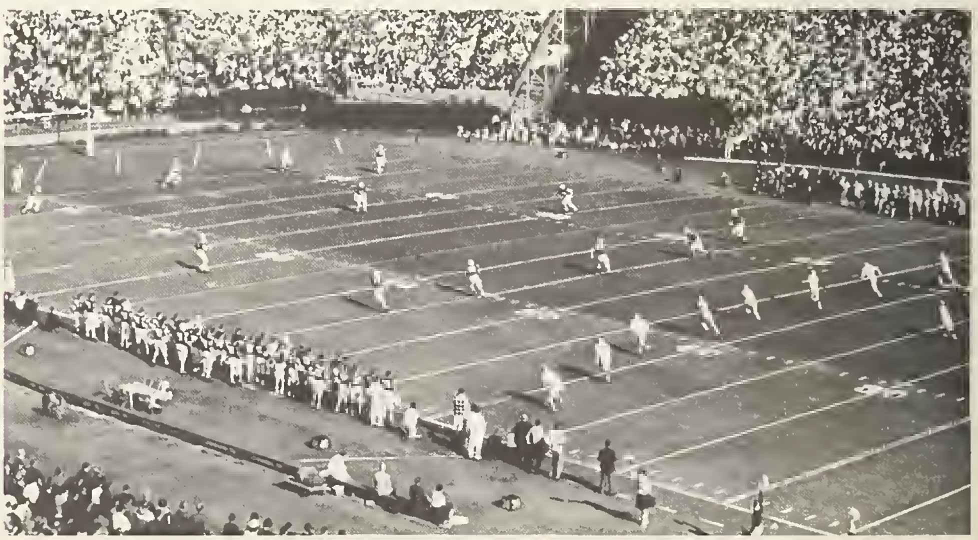
In parts of France to this day, after almost 200 years of the metric system, some consumers still order *une livre de beurre* (one pound of butter). They get a half-kilogram package, to be sure, but the point is that no one has forced them to give up an old familiar name. And manufacturers continue to make concessions to non-metric thinking; until recent years in Germany, butter was packaged in 125-gram bars for people accustomed to buying it in quarter pounds. And many Germans call the half kilogram *ein pfund* (one pound).

Our railroad tracks would stay the same

The Rule of Reason

Some measurements and some dimensions would never need to be changed. It would be preposterous ever to tear up all our railroad tracks just to relate them to some round-number metric gauge. Americans would not be likely to translate into metric such sayings as "a miss is as good as a mile," or to rewrite the words to the song *I Love You a Bushel and a Peck.*

In sports, going metric is not likely to present much of a problem. Soccer is internationally the most popular game by a wide margin; however, there is no standard size for a soccer field. Cricket is played throughout the old



" . . . it would be quite unnecessary to change the length of U.S. football fields . . . "

British Empire, but although most of the nations that play it have either gone metric or are doing so, they will presumably cling to the traditional Imperial dimensions of the cricket pitch. Similarly, it would be quite unnecessary to change the length of U.S. football fields, even if our kind of football ever became an international sport. And keeping them as they are, no sports announcer who wants to keep his audience would ever seriously say: "The Redskins have the ball; first down and 9.144 meters to go."

Some units that are not part of the International Metric System may continue to be used wherever they are believed to make communications and calculations clear and easy. Even in metric countries meteorologists still speak of "bars," one bar being roughly normal atmospheric pressure, and of the "millibar," which is one-thousandth of a bar. Astronomers prefer to talk of distance in "light years," instead of many trillions of kilometers. Such convenient units as these are not likely to be discarded.

Even if it were to be specified that only International Metric units were to have full legal standing, many other measurement terms would persist in our culture—perhaps forever.

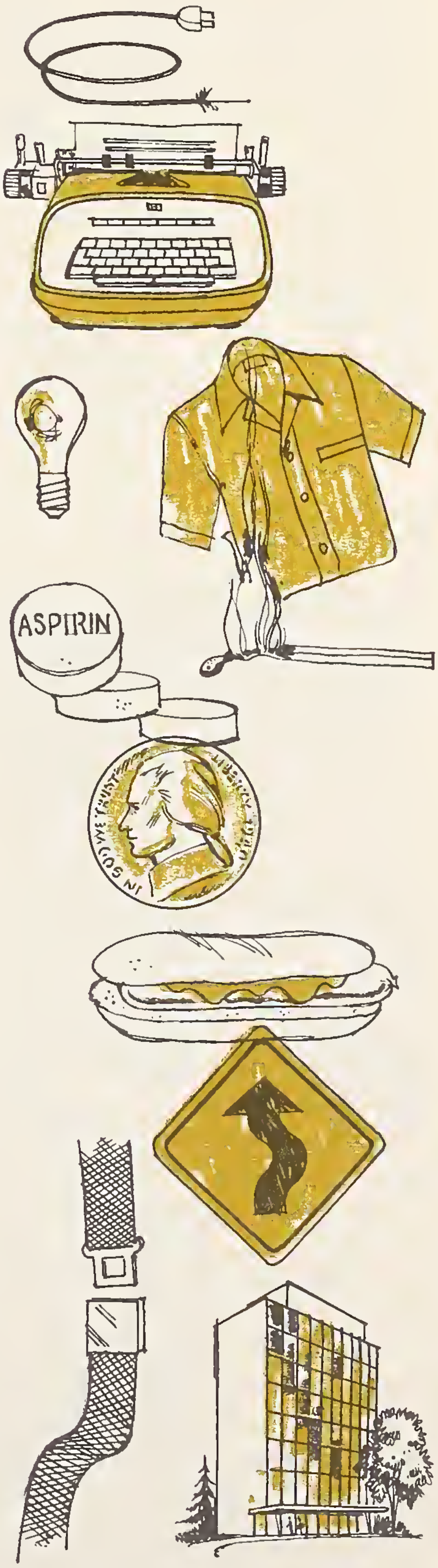
A Dictionary for a Technical Society

An adequate understanding of what a change to metric entails depends on some appreciation of what engineering standards are and the role they play in our economy.

Broadly speaking, engineering standards are agreements that specify characteristics of things or ways to do things—almost anything that can be measured or described. They cover an enormous range: e.g., the diameter of wire; the length and width of typewriter paper; the purity of aspirin; the fire resistance of clothing; the meat content of frankfurters; the symbols on highway signs; the way to test for sulphur in fuel oil; the technical basis for local building codes; the strength of a safety belt; the wattage of light bulbs; the weight of a nickel.

Taken together, engineering standards serve as both

WHAT ARE ENGINEERING STANDARDS?



A METRIC CONVERSION CASE STUDY

Pharmaceuticals

About fifteen years ago the major U.S. drug manufacturers changed their internal operations and most of their products to metric. They did it with dispatch, and they found it surprisingly painless.

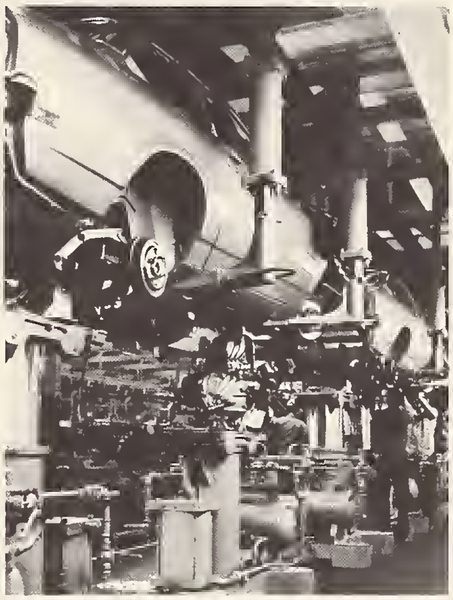
In their judgment, they have more than recouped the costs of changing over. The advantages they gained include: easier training of personnel; economies in manufacturing; reduction in errors; simplified specifications, catalogs, and records; and improved intracompany communications. There have been no apparent disadvantages.

Rather than divorcing themselves from the Customary environment, the pharmaceutical companies changed only what they had to change in order to make and market products in metric units. It was possible to limit the scope of the change because the industry deals primarily with volumes and weights of substances, hardly at all with lengths. Each firm could deal independently with its own problems, and so industry-wide coordination was not needed.

Here is how the changeover is regarded in retrospect:

- Costs were actually low—less than anticipated. One large company says that costs in terms of employee time and equipment modification came to $250,000, which was only ½ to ⅔ of its preconversion estimate.
- The same company believes it easily recovered the costs, although it has not tried to put a dollar value on the benefits that have accumulated since conversion.
- Retraining workers was no problem and took less time than had been anticipated. The industry was already using metric units for a few products; thus most workers were not confronted with something entirely new. A program of dual labeling and marking (first Customary with metric in parentheses, then the reverse) helped workers become gradually familiar with metric units.
- Only scales and volume measuring devices were modified. Most process machinery did not need to be changed at all. Many scales were changed simply by affixing a metric dial or indicator; some needed new weights or beams. In all cases, needed parts were easily supplied by scale manufacturers.
- Some suppliers were originally reluctant to furnish their products in metric quantities, but since the whole pharmaceutical industry was changing, they soon complied with the demand.
- Users (pharmacists and physicians) presented no problem. They had already been educated in metric units.
- An odd problem arose with alcohol. Federal regulations require that alcohol must be stored, sold, and taxed in Customary amounts. In this area, one of the few that demanded coordination outside the drug industry, conversion to metric has yet to be achieved. In contrast, Federal narcotics reports must be in metric units.
- Each firm converted at its own pace. One of the largest took about one year; a competitor took twice as long. Both felt that they could have moved faster.
- Careful planning assured a smooth transition.

a dictionary and a recipe book for a technical society. Without them we would have chaos, inconvenience, and higher costs for almost everything. Mass production would not be feasible if there were no assurance that two parts, such as a nut and a bolt, would fit together. Automobile brakes would be untrustworthy if all brake fluid did not meet standard performance requirements. Electric clocks would keep different time if all household current did not alternate precisely 60 times a second.



"Mass production would not be feasible . . . "

Indeed, where standards have not been established, or when two different standards exist, life is much more complicated. In Europe, for example, standard household current is 220 volts, 50 hertz (cycles per second); in the U.S. it is 115 volts, 60 hertz. An American-made electric razor would not work on European current. For that matter, it could not even be plugged in because the receptacles are different.

Standards of voltage and frequency differ around the world

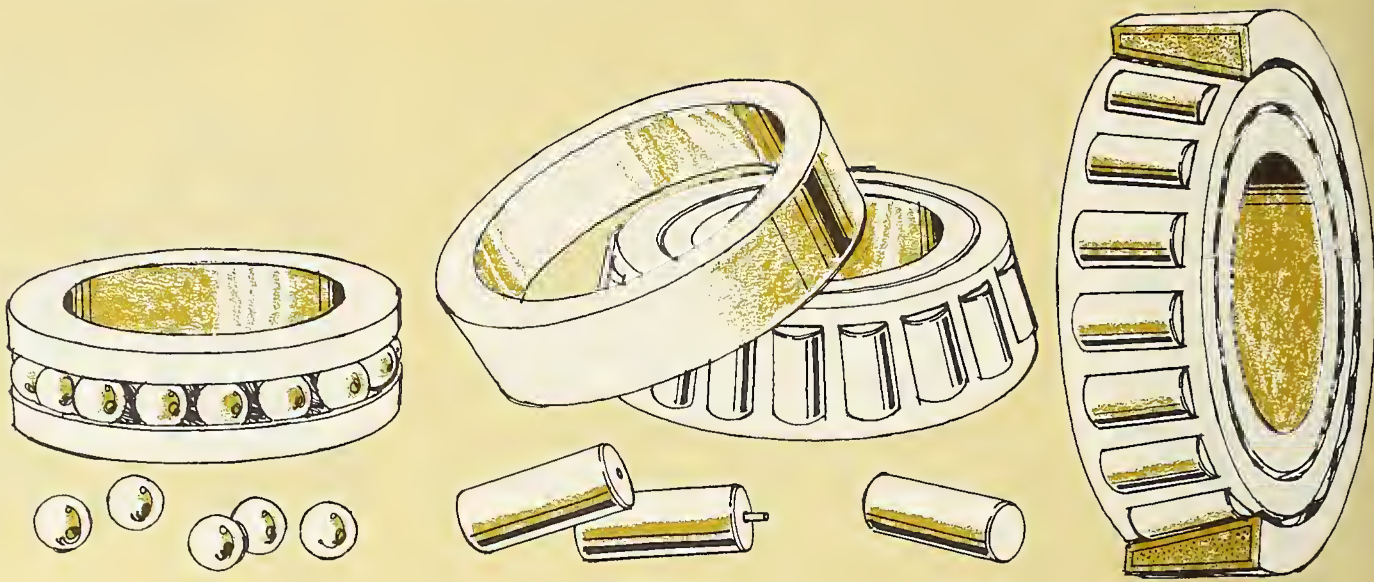
How Standards Develop

Engineering standards are developed by many organizations or groups at different levels: a single firm, a national group such as a trade association, or an international group. A company may develop its own standards for products it makes. A local government issues codes and regulations for building construction, driving, highways. In either case, their standards may not be in agreement with those issued by other companies or other governments.

For things generally used, such as television, national standards are essential if the system is to function. For example, a television set must be able to receive programs on all channels, and television stations must broadcast in a prescribed way. The development of standards for such a complex system can be costly and time consuming; it took 10 million engineering man hours to develop national standards for color television.

The Department of Defense and the General Services Administration have issued for government use about 40,000 procurement standards encompassing most indus-

A METRIC CONVERSION CASE STUDY



Anti-Friction Bearings

Metric units usually prevail in technologies that first developed on the European continent. Customary units have the upper hand in technologies first developed in the U.S. and Great Britain. The anti-friction bearing industry represents a mixture of both.

Ball bearings and parallel roller bearings, originating in Europe, are designed to metric standard sizes. These sizes are also used in the U.S., although they may be described in terms of inches.

Tapered roller bearings, on the other hand, originated in the U.S. and were therefore designed to Customary standard sizes. Now, many U.S. manufacturers are beginning to design their new tapered roller bearings to metric standard sizes. These firms are concerned about expanding their overseas operations and increasing their exports to an otherwise metric world.

The companies involved in this changeover say that it has been on the whole rewarding. They have been able to produce complete lines of tapered roller bearings with a reduction of superfluous types, and they have improved their competitive positions in the world market. They report no noteworthy disadvantages. Here is how they regard the changeover:

- No substantial costs can be attributed directly to going metric. With different parts of the world using different measurement systems, they have to pay the costs of labeling drawings in both Customary and metric units, but this was a cost they paid before anyway.
- Since the conversion involves design alone, only the engineering staff has had to be retrained. At one of the largest companies the engineers learned what they needed to know informally.
- It has not been necessary to replace or even greatly modify a single piece of Customary manufacturing machinery to produce to metric standard sizes. With dual labeling and conversion charts, any worker in any plant has been able to produce any bearing on any suitable piece of equipment.
- While going metric, one manufacturer has developed a new line of tapered roller bearings that incorporates the best features of both Customary and metric technologies. The company hopes that this line will win acceptance in the U.S. and ultimately throughout the world.
- Until this new line is widely accepted, there is no need for the industry to coordinate its efforts or set a conversion timetable for the entire field of tapered roller bearings. In the meantime, each company is applying metric to new designs only.
- Some customers still need bearings in Customary sizes, and these are being supplied. By and large, however, U.S. industry has readily accepted the new metric designs.

trial products, food, clothing, and other consumer goods. This number is about twice the number of standards issued by private groups. In the absence of a standard issued by a private group the government's procurement standard may be used as a national standard.

Private voluntary groups, numbering in the hundreds, have issued about 20,000 standards. About one-fifth of these standards are recognized as national standards by a voluntary national coordinating body called the American National Standards Institute, which represents the U.S. in international groups.

"U.S. participants in international standards negotiations need to be adept in the use of metric units . . ."

International Agreement

The leading international groups are the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), in which all major nations are represented. IEC is concerned with the standardization of electrical and electronic equipment; ISO is responsible for all other fields. The work is done in technical committees, subcommittees and working groups.

U.S. participation is voluntary and is not supported directly by the Government. The U.S. participates in all 70 IEC technical committees and 96 of the 139 ISO technical committees; participation in subcommittees and working groups is much less, amounting to about 50 percent. After member countries of IEC or ISO reach a consensus, a recommendation is published for adoption by any country as its national standard.

U.S. participants in international standards negotiations need to be adept in the use of metric units, for the International Metric System is the official measurement language of both IEC and ISO.

Increasingly, countries are adopting IEC and ISO Recommendations instead of first developing their own national standards. At the same time existing national standards can form a basis for agreement on international standards. The significance of this with respect to a metric change will be explained in the next chapter.

CHAPTER VI

The Metric Question in the Context of the Future World

The U.S. Metric Study was prompted by the increasing worldwide use of the metric system. Congress was concerned about the effects of this world trend on the U.S. economy, now and in the years to come. Congress asked, particularly, for assessments in three areas: international standards, foreign trade, and relations with our military allies.

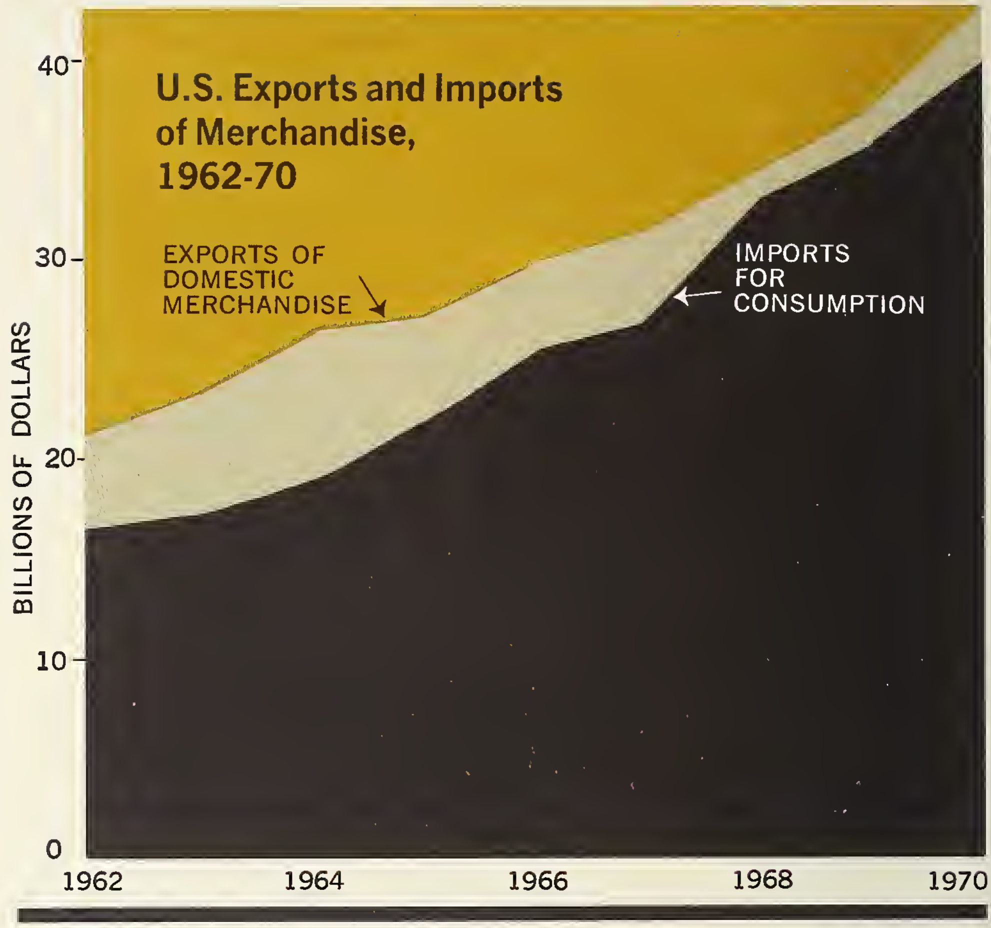
Two of the Study's special investigations—one on international standards, the other on world trade—provided most of the information for these areas. The Department of Defense study covered military relations. (All three of these studies are covered in detail by special reports cited in Appendix Two, p. 164.)

Many of the participants in the investigations of international standards and world trade believe that the Customary system is already becoming a burden in our international relations—a burden that is easy to bear now, but which will become heavier with time.

The difficulty is not so much that we talk a measurement language different from that of other countries. Rather, it is that many of our engineering standards (explained at the end of the last chapter), based on Customary units, are incompatible with standards used elsewhere. And this hampers the export of some U.S. products.

A potential customer in another country may prefer a certain U.S. machine, but he may be less likely to import it if standard parts for repair and maintenance are not readily available in his country. As the rest of the English-speaking world changes to metric, this will become even more of a handicap.

This problem is already with us and is becoming more troublesome. Imports of materials and equipment are increasing, and overseas subsidiaries of U.S. companies are having to develop standards programs that are independent of the parent company, because U.S. Customary standards do not adequately meet their needs. Alluding to these complications, one participant in the U.S. Metric Study remarked that these are now "little clouds, no bigger than a

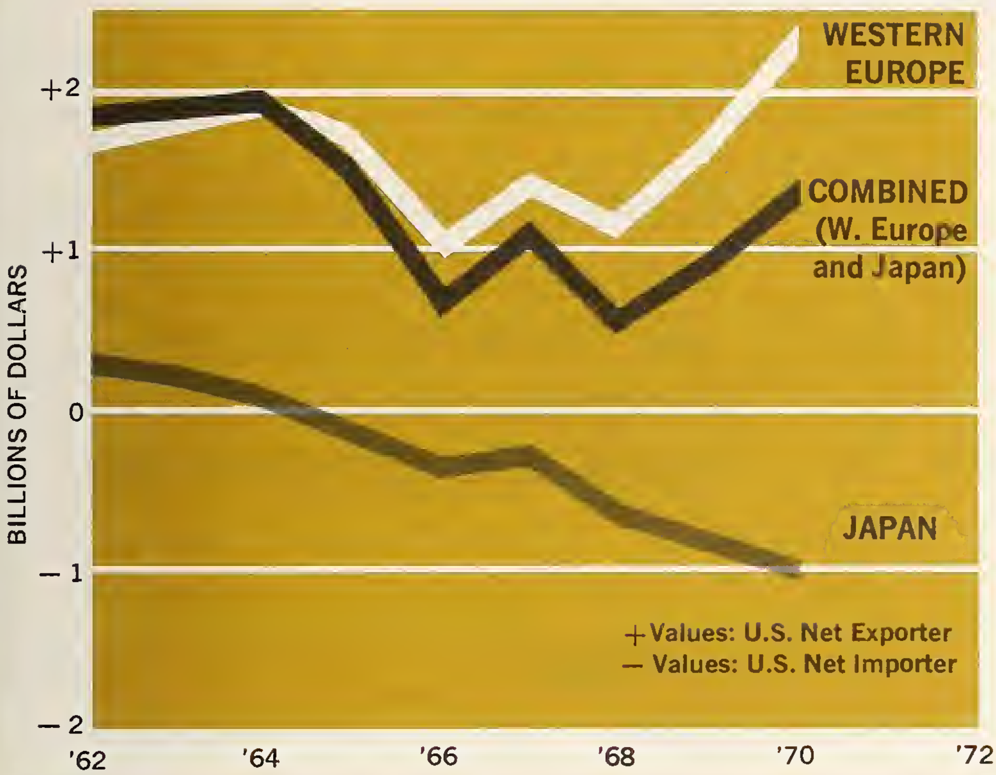


man's hand," but they point up the urgency for the U.S. to strengthen its position in world standards-making before they grow much larger.

Help or Hindrance to Trade

The mere existence of international standards that differ from U.S. national standards is not in itself the problem. The degree to which they can impede U.S. trade depends on how they are applied. For international standards can be a means of fostering or hindering trade. Between 1967 and 1970, for example, Britain, France, and West Germany agreed among themselves on comprehensive electronic standards based on metric units. The purpose was to facilitate trade among the three countries by setting up uniform schemes of quality assurance and product certification—analogous to an underwriter's seal of approval. It follows that nations not party to the scheme

Annual U.S. Balance of Trade
Technology—Intensive Products



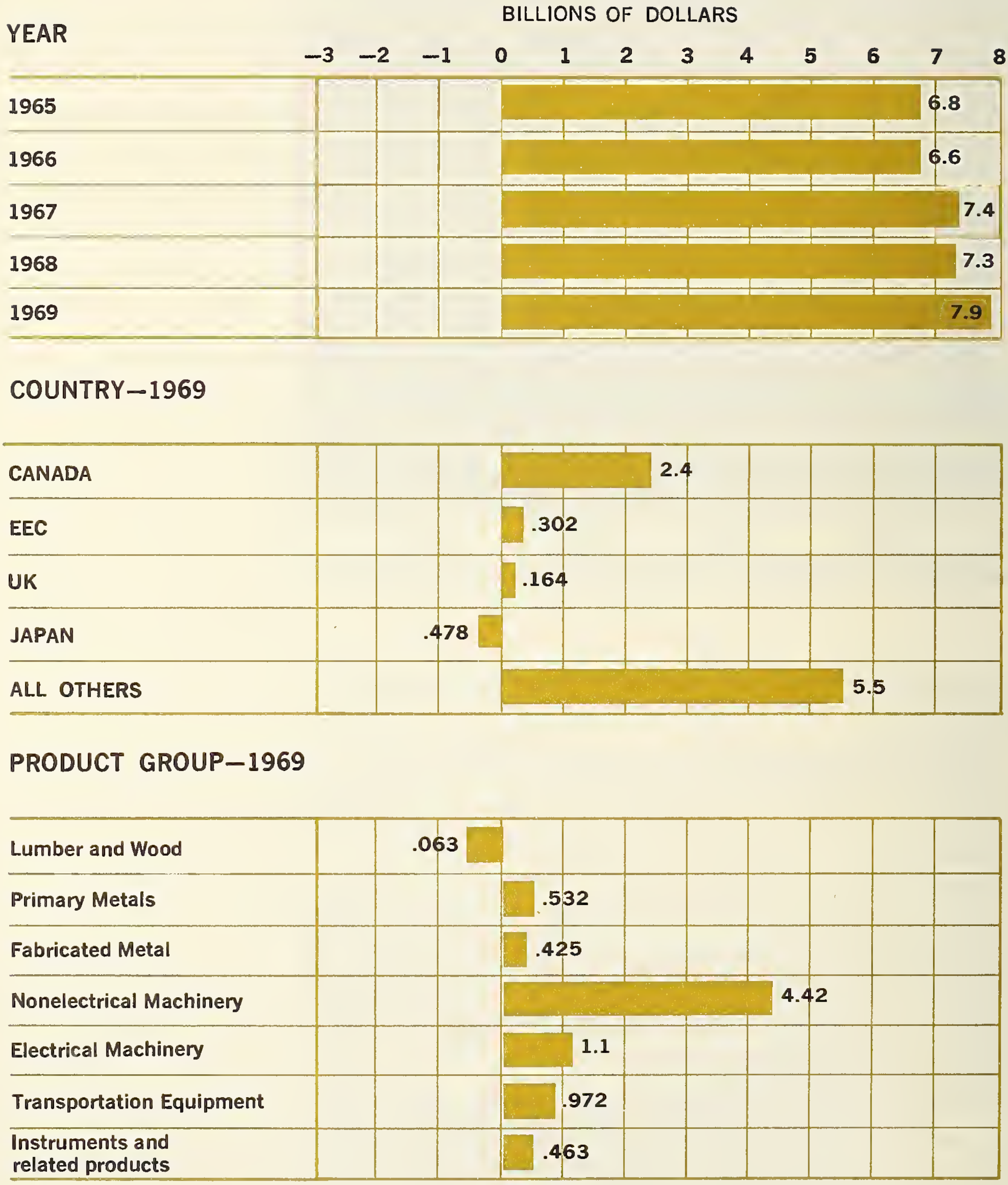
would find it harder to sell electronic products to the three countries.

It now appears that this agreement, initially limited to three nations and one class of products, will be extended to include the rest of Western Europe and to embrace other products as well.

As was pointed out in Chapter V, the International Metric System is the official measurement language of the two main world standards-making bodies: the International Standards Organization (ISO) and the International Electrotechnical Commission (IEC).

The measurement language that is used has a direct bearing on the choice of dimensions for products that must be compatible. Standard sizes tend to be expressed as small whole numbers or simple fractions that are easy to remember and easy to do calculations with. As an illustration, a metric-minded standards group, when setting the

Trade Balance in Machinery, Instruments, and Other Measurement Sensitive Products



diameter of a thin wire might make it exactly 1 millimeter (equal to 0.03937 inch). But if the standards makers were inch-minded, they would probably pick 0.04 inch for the diameter, and let metric users worry about the cumbersome corresponding decimal number (1.016 millimeters).

This natural preference for easy numbers leads to the incompatibility, for example, of steel bars and rods produced in the U.S. and in metric countries. In the U.S. the range of sizes is usually covered in increments of 1/16 inch in the small sizes, 1/8 inch in the intermediate sizes, and 1/4 inch in larger sizes. In metric countries the increments are usually 1, 2, or 5 millimeters.

Where U.S. technology has taken the lead it influences international standards

Advancing U.S. Ideas

It would be economically beneficial for the U.S. to play a more vigorous role in the making of international standards. U.S. industry is already influential in the development of these standards. This is particularly true where U.S. technology has taken the lead – e.g., integrated electronic circuits, commercial aircraft, automobile wheels, computers, oil drilling machinery, videotape.

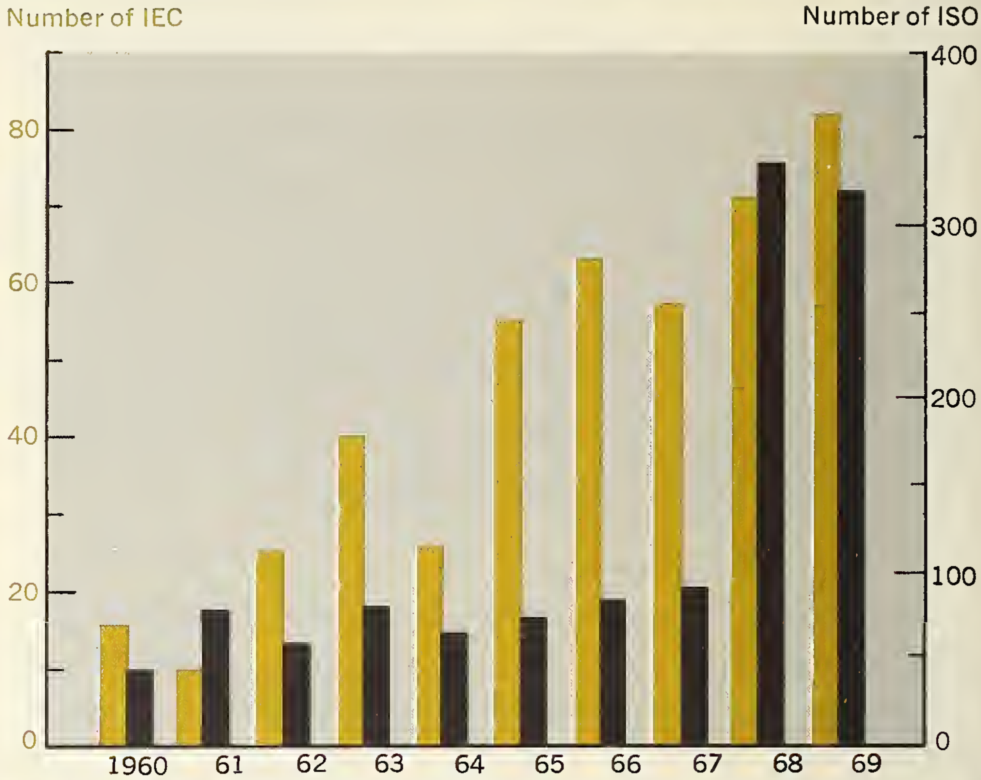
Our opportunity to exert further influence is great. To date, relatively few international standards have been adopted. But in the next decade the number on the books is expected to multiply roughly tenfold. (See bar chart on "Trends in ISO and IEC Standards, 1960-1969.") The international standards that exist today are but a few patches in a mosaic that an increasingly interdependent world will need for the exchange of products, materials, and ideas.

In the give and take of international standards making, compromises tend to result in all parties giving a little ground and thus sharing in the cost of changes. Therefore, if the U.S. fully participates in the making of the great majority of international standards that remain to be developed, it would not be the only country that would have to adjust its national standards. All countries would share in the costs of conforming.

This is a critical point, because most of the concern

International Standards Now, Contrasted With Those to Come

Trends in ISO and IEC Standards — 1960-1969



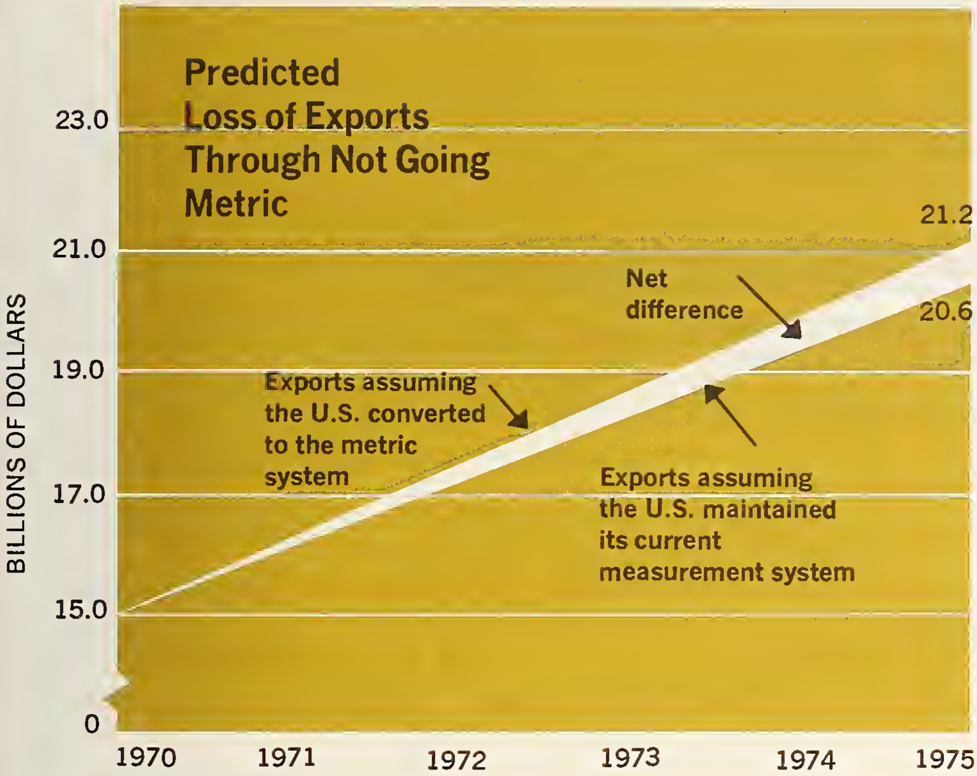
about the cost of a metric conversion in the U.S. is based upon the assumption that it would require wholesale revamping of our national standards in order to conform to world metric standards.

The Need for Action Now

The urgency for the U.S. to participate more vigorously in world standards-making was stressed in an interim report of the U.S. Metric Study. Entitled *International Standards*, it was sent to the Congress in December 1970. The most important recommendations were:

That Federal and non-government standards organizations develop together a firm U.S. policy about effective participation in international standards activities.

That this action should be taken as soon as possible, regardless of any decision about the nation's going metric.



(Based on estimates of international trading firms dealing in machinery, instruments, and other measurement sensitive products)

The Crucial Balance of Trade

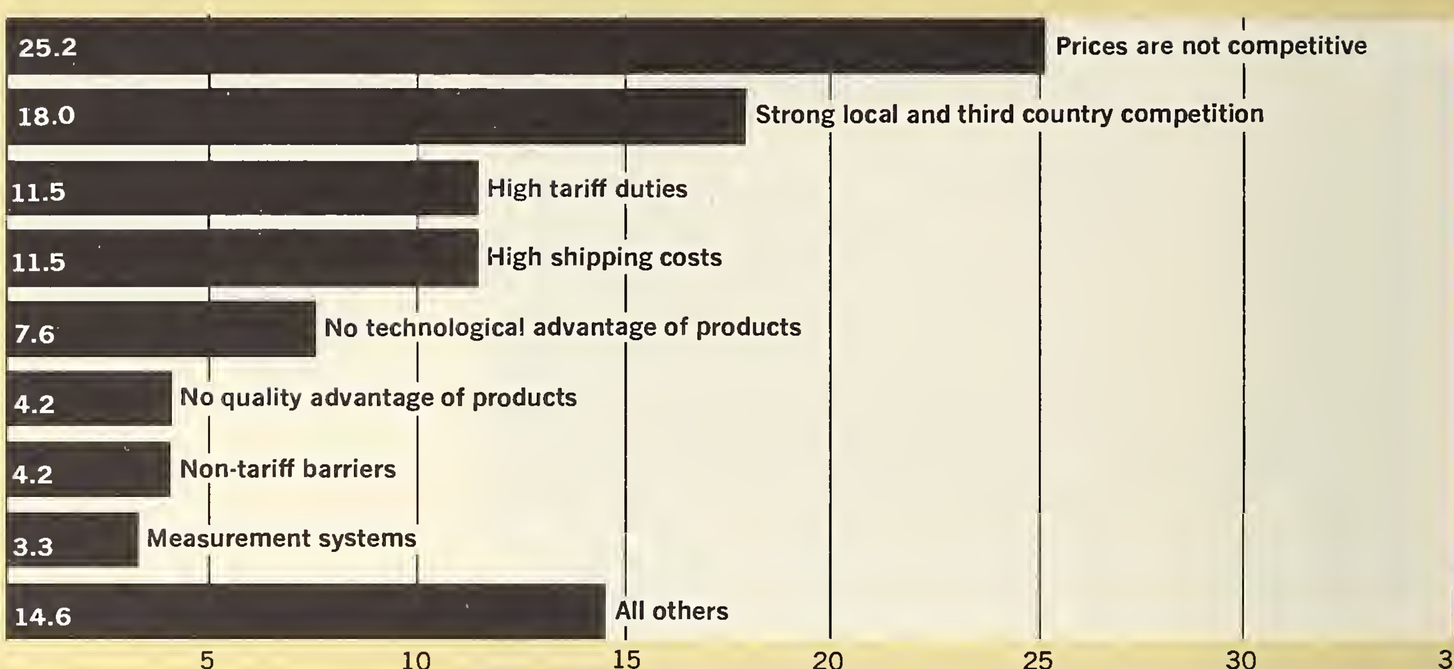
In world trade, standards are important mainly in "measurement-sensitive" products. These are products in which dimensions are critical—e.g., tractors, clinical thermometers, vacuum pumps, typewriters, computers. In 1969 the U.S. exported about $14 billion worth of measurement-sensitive products and imported about $6 billion worth. The difference, $8 billion, was considerably more than the nation's favorable balance of trade in 1969, which was only $1.3 billion. (It was $2.7 billion in 1970.)

Standards-based agreements, such as the quality assurance and product certification scheme mentioned earlier in this chapter, could be a non-tariff barrier against our exports. And a relatively slight drop in our exports of measurement-sensitive products could mean the difference between a favorable and an unfavorable U.S. trade balance (see bar charts on the trade balance in measurement-sensitive products, p. 58).

EXPORTS

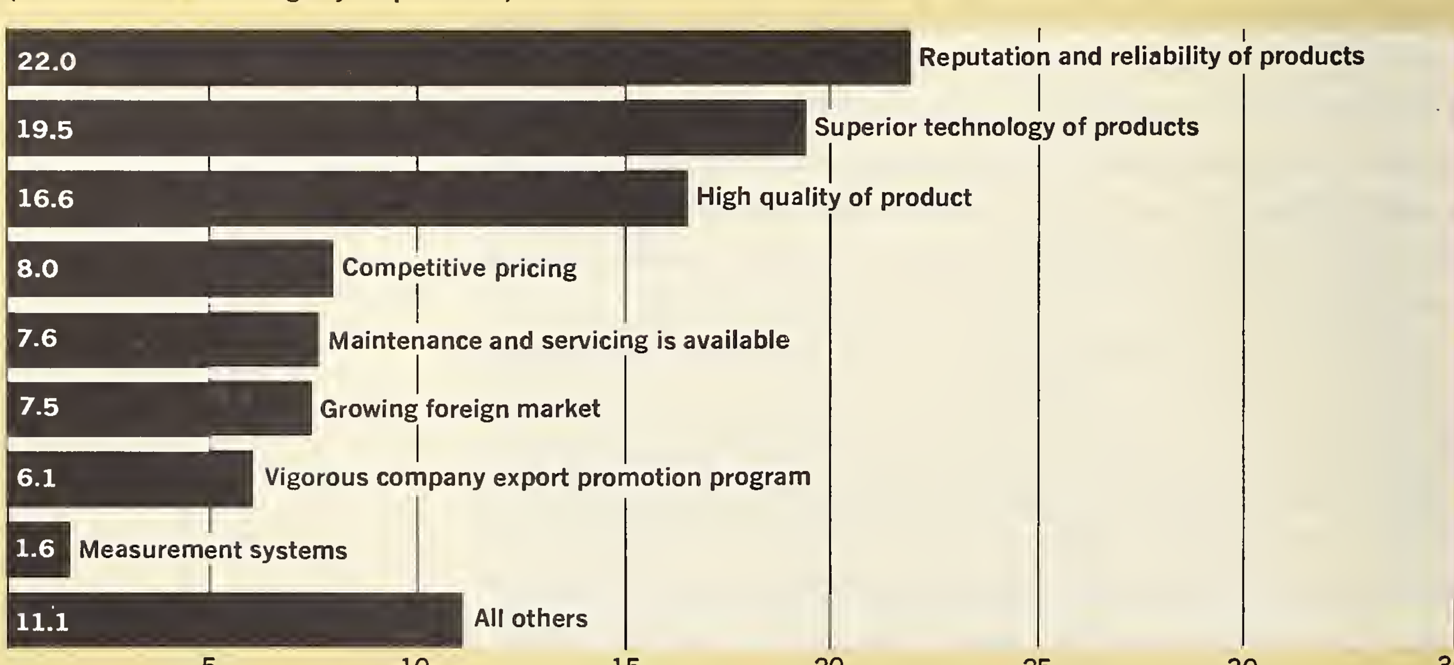
Factors DETERRING U.S. Exports of Machinery, Instruments, and Other Measurement Sensitive Products

(Percent of total rankings by respondents)



Factors PROMOTING U.S. Exports of Machinery, Instruments, and Other Measurement Sensitive Products

(Percent of total rankings by respondents)



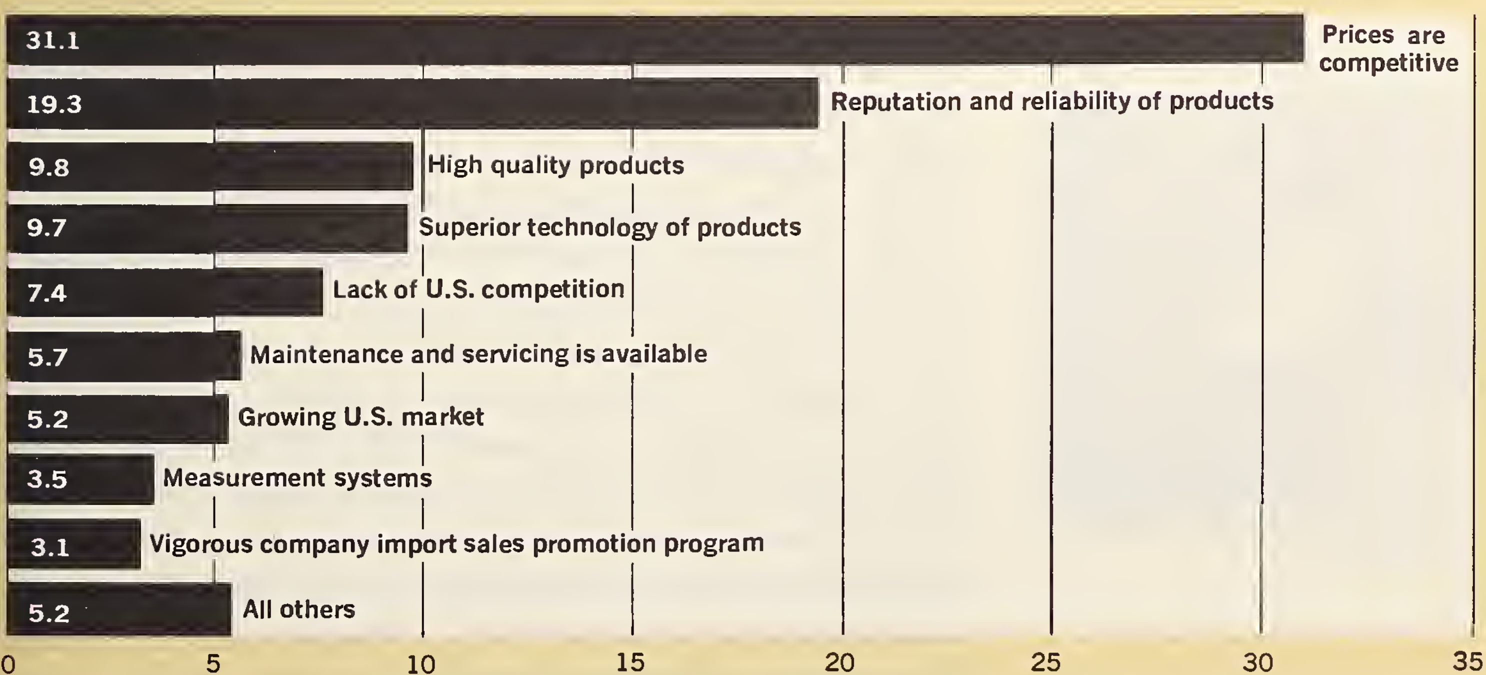
IMPORTS

Factors DETERRING U.S. Imports of Machinery, Instruments, and Other Measurement Sensitive Products

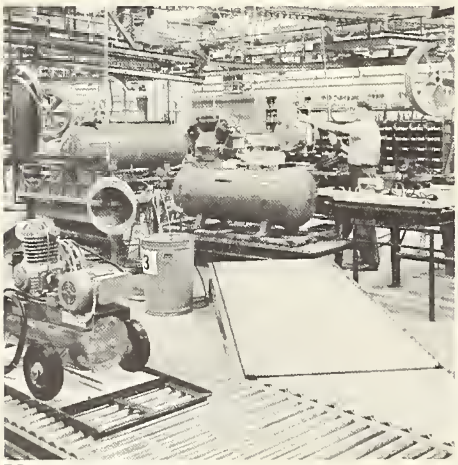
(Percent of total rankings by respondents)

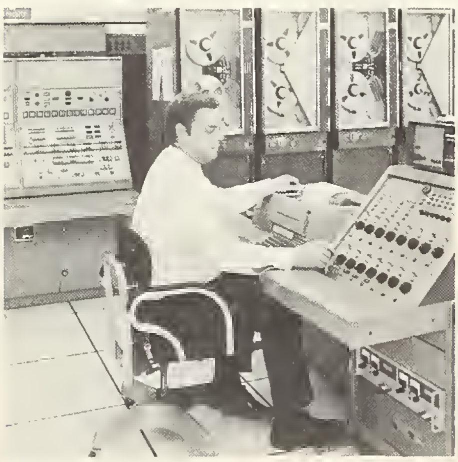
Factors PROMOTING U.S. Imports of Machinery, Instruments, and Other Measurement Sensitive Products

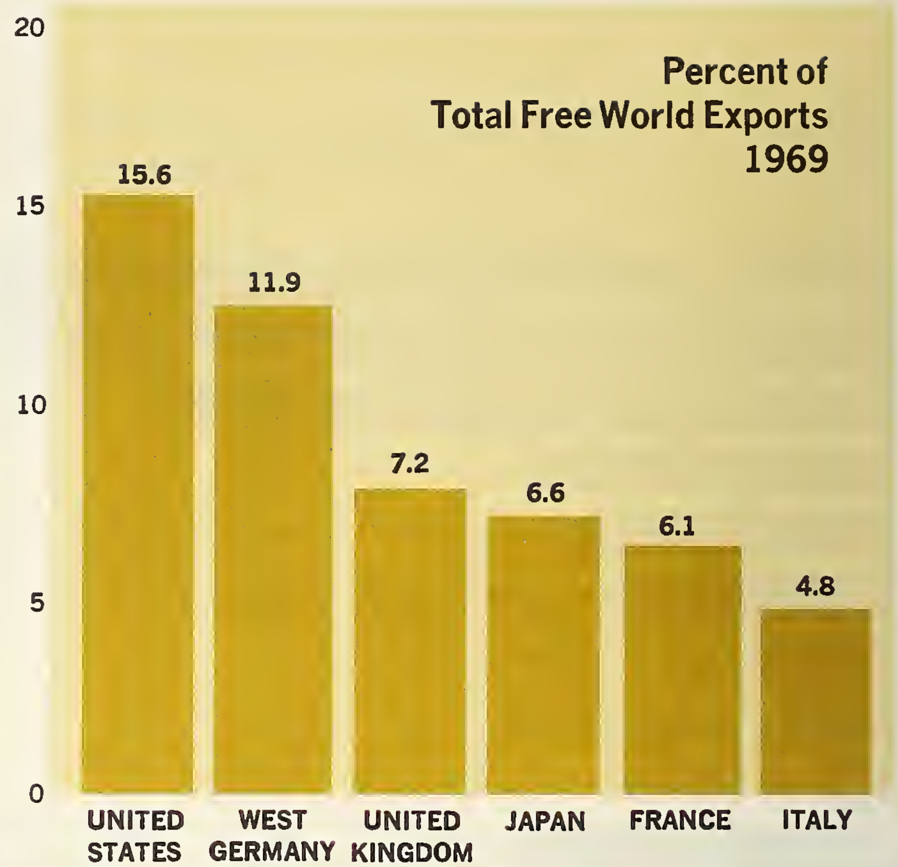
(Percent of total rankings by respondents)




Measurement-sensitive products such as tractors . . .

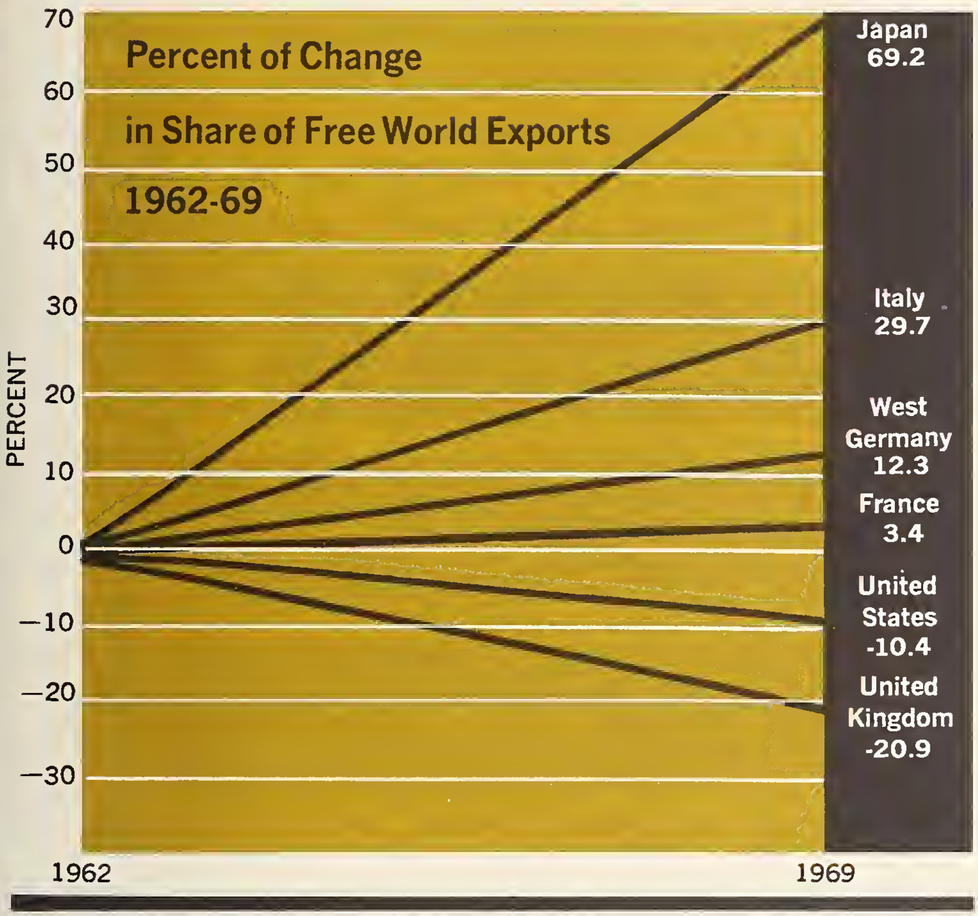

Vacuum pumps . . .


and computers



So far the effect of world standards developments seems to be slight. The U.S. Metric Study asked exporters of measurement-sensitive products for their views about factors influencing their trade. Differences in measurement systems and standards seemed relatively unimportant; they put more emphasis on reliability, reputation, price, superior technology, and high quality of product (see bar charts on factors influencing exports, pp. 62 and 63).

They were also asked to estimate how much they would expect to export in 1975 if the U.S. had gone metric by 1970. The chart titled "Loss of Exports Through Not Going Metric" (p. 61) shows that, in their opinion, going metric would have increased 1975 exports by about $600 million. (The actual economic benefit to the nation of this marginal improvement in trade is a part of the analysis of Chapter IX.) Importers, asked the same hypothetical question, estimated no difference in 1975 imports of measurement-sensitive products.

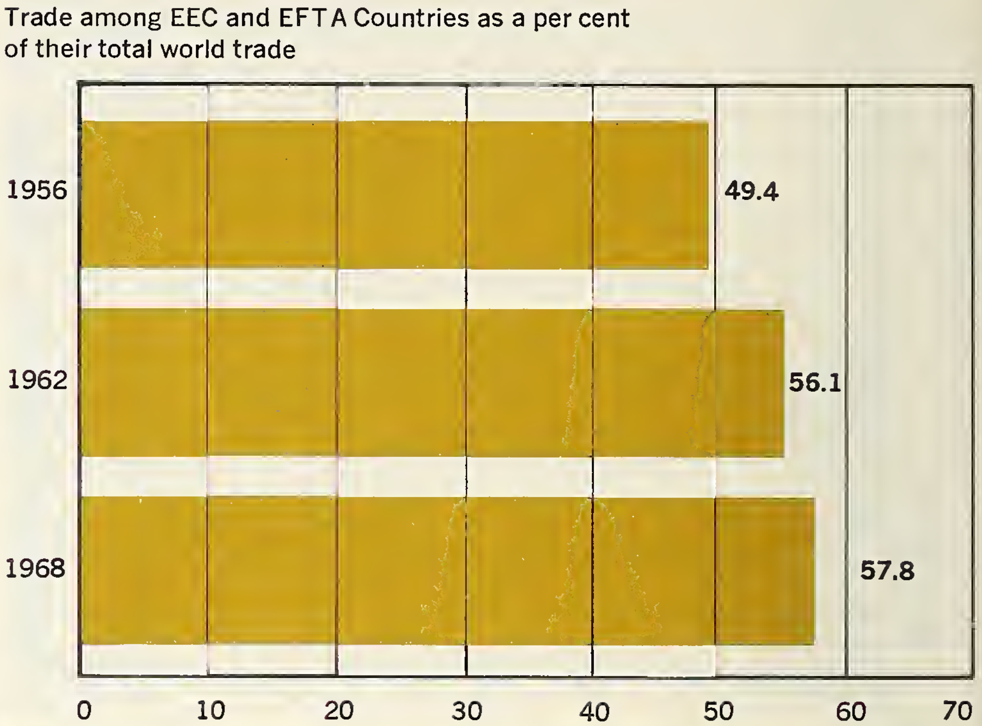


Apparently, the metric question has hardly affected the absolute amount of U.S. trade. The U.S. still is the leading exporter in the free world (see bar chart on "Percent of Total Free World Exports", p. 64). But there are indications that our share of the world market is diminishing (see chart on "Percent of Change in Share of Free World Exports, 1962–1969", p. 65). This is partly because Western European nations have been steadily lowering barriers of trade among themselves. These barriers are due to become lower still as national differences in engineering standards are ironed out. They regard these differences as one of the most troublesome obstacles to trade. Understandably, since Western Europe is exclusively committed to the metric system, the standards they agree upon will be metric- based. This effort will further strengthen Western Europe as a unified market and will tend to reduce the U.S. share in its trade (see bar chart on trade among Western European countries, p. 66).

Multinational corporations are already assembling . . .

. . . complex products from components made in different countries

Western European Countries Are Selling More to Each Other Than to the Rest of the World.



There are a few areas in which U.S. and European engineering standards are likely to remain in conflict. Paradoxically, these concern electricity, a field in which Customary and metric measurement units are identical. In view of the tremendous investments that have already been made in power generating and distributing equipment, appliances, and machinery, it is hard to imagine either the U.S. or Europe compromising on a common voltage and frequency for household electric current.

The Multinational Corporations

Another factor that is tending to integrate the world economy is the rise of giant multinational corporations, many of them either partly or entirely owned by U.S. companies. In hearings last year before the Joint Economic Committee of the U.S. Congress, it was brought out that the total annual output by multinational firms of goods and services is about $450 billion. This exceeds the total output of all the less developed countries, and it rivals that of the Soviet Union, China, and Eastern Europe combined. In fact, $450 billion is almost half the gross national product of the U.S.

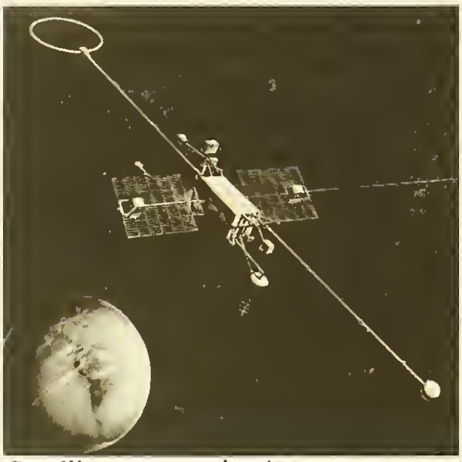
Because many of these firms are American-owned, the U.S. plays an even larger role in world commerce than U.S. export-import figures would indicate. The startling fact is that U.S. businesses abroad account for roughly half of the $450 billion output of multinational corporations. Even in highly industrialized nations their impact is impressive. In the United Kingdom, for example, the output of U.S. subsidiaries is about 14 percent of the total economy, and they account for almost 25 percent of Britain's manufactured exports.

At the rate multinational corporations appear to be growing and proliferating, some day in the not-too-distant future they may control most of the industrial output of the world. In any case, they will help to bring about worldwide uniformity of engineering standards. For they are already assembling such complex products as automobiles, computers, and factory machinery from components made in different countries. In effect, this huge but almost invisible segment of American industry is already going metric.

Small companies that supply them will have to go along. Congress is already concerned about self-employed workers and small companies that may have trouble keeping up with the change. When increased use of metric in large companies and government activities reaches a substantial level, then workers and small companies may find themselves at a competitive disadvantage. As will be discussed in Chapter VIII, a national program of metric change designed to take account of their needs could ensure that the benefits of the change were shared by all Americans.

Converging Cultures

Customs and cultures around the world are coming to resemble one another. More and more, people are traveling



Satellite communication

to foreign countries. Satellite communication has, for some, become a form of instant travel. And the enormous outpouring of the multinational corporations is in its own way making the world more closely knit.

Thus, our culture and customs are being exported in many ways. But one thing the U.S. cannot expect to export is the Customary system of measurement. Most people in other countries are never going to use it; those that have used it are abandoning it.

Relations with Allies and Other Countries

Whatever machinery, engineering plans, and other measurement-sensitive goods and services we supply to developing countries would be more effective if these goods and services conformed to the measurement system and practices of the users. These countries are metric almost without exception. Moreover, we are increasingly tending toward multilateral aid programs, in which we cooperate with other industrial countries. These are all metric or committed to changing to the metric system. Conflicts in measurement systems cause confusion and reduce, to some extent, the effectiveness of these programs.

Mexico bears the cost of dual capability

Our neighbors, Canada and Mexico, are hoping that the U.S. will decide to change to the metric system. In a *White Paper on Metric Conversion,* issued in January 1970, the Canadian Government stated that conversion to metric is "a definite objective of Canadian policy." In outlining factors that will have to be taken into account in making the change, the White Paper points out one that is especially important: "Because of the close ties between the United States and Canada in science, technology, industry and commerce, each country has a special interest in the course likely to be followed by the other in respect of metric conversion . . . . The question is a complex one because the United States, which is Canada's main export market, has not made a decision to convert."

Canada is handicapped too

Mexico is even more anxious that the U.S. decide to convert to metric. Mexico has long been a metric nation.

Yet in order to trade with the U.S., it must maintain a capability not only in metric but also in our Customary system. The cost of maintaining this dual capability is the major cost experienced by any nation during a transition to metric. (This factor is part of the analysis of benefits and costs in Chapter IX.) Thus, Mexico is forced to bear this cost as long as the U.S. remains on the Customary system. The same is true for other Latin American countries.

A U.S. decision to go metric would be welcomed by its military allies

A U.S. decision to go metric would be welcomed also by its military allies. The Department of Defense points out in its metric study report that the compatibility and interchangeability of equipment between the U.S. and its allies would expedite repairs, make possible support in areas where support is now nonexistent, simplify procurement across national boundaries, and increase communication of all data, including designs, operations, and training. A Defense advisory committee has suggested, furthermore, that defense budgets on both sides of the Atlantic have been so seriously reduced that more selectivity, less duplication, and greater interdependence may be necessary in the future. More will be said on this subject later in this report, mainly in Chapter IX.

More selectivity, less duplication, and greater interdependence

Even in outer space international standards may play a role. Nations with major programs have given thought to cooperating with one another in order to reduce duplication of missions and thus cut costs. In fact, the U.S. and the U.S.S.R. have begun discussions to standardize the escape hatches of space vehicles so that either nation can rescue an astronaut or cosmonaut.


Even in space

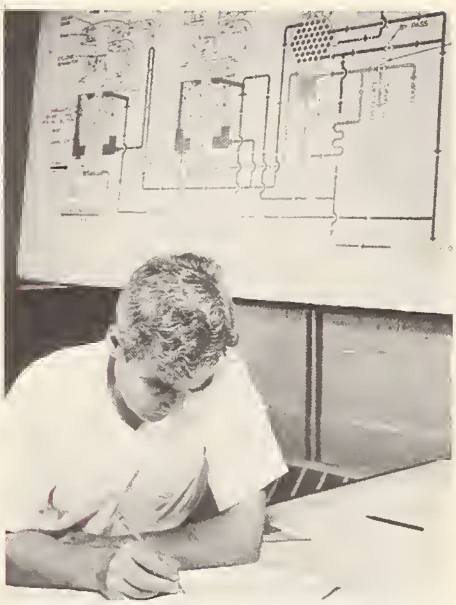
* * * * *

A metric America would seem desirable in terms of our stake in world trade, the development of international standards, relations with our neighbors and other countries, and national security. What the participants in the U.S. Metric Study think about changing to metric and how the change should be made is the subject of the next chapter.

SOME GROUPS THAT PARTICIPATED IN THE

METRIC STUDY

Going Metric: The Broad Consensus


"... the level of sophistication concerning measurement and engineering standards covered a wide range."

It is perhaps surprising that any general pattern of agreement should have emerged from the U.S. Metric Study, considering the great diversity of the participants.

Opinions came from many different cross-sections of society. On a national scale, for example, whole industries were asked for their collective views and estimates of costs and benefits. At the grass roots level, individual citizens expressed their personal thoughts in correspondence and in the public hearings. And in between, ideas were collected from large and small firms, labor unions, professional and technical societies, and other groups with special interests.

As was noted in Chapter I, the participants included representatives associated with: manufacturing and nonmanufacturing industries, organized labor, small businesses, engineering and scientific disciplines, education at all levels, advertising, publishing, law, medicine, public health, agriculture, forestry, fisheries, agencies of Federal, state, county, and local government, real estate, college athletics, finance, insurance, warehousing, transportation, construction, communications, retailers, wholesalers, chiefs of police, fraternal organizations, exporters and importers, home economists, and consumers. The wide diversity of the participants in the Study required many compromises in the questions that could be asked of them. The questions had to be geared to the capabilities of the potential respondents. Moreover, the choice and wording of questions were cleared by panels of special interest groups convened by the Office of Management and Budget.

Even among industrial firms, the level of sophistication concerning measurement and engineering standards covered a wide range. Some companies, such as those that sell bulk materials by the lot or the carload, need seldom worry about precision measurements or complex systems of engineering standards. But others that deal in high-precision products—e.g., automobiles and electronics—maintain special departments that work full time on measurements, composition of materials, and other standards. One

Questionnaires were mailed to a representative sample of U.S. manufacturers


Measurement is especially critical to companies that deal in high precision products


Company spokesmen considered many factors.

large automotive company, for instance, keeps a file of 61,000 different engineering standards that are continually augmented and revised.

Thus the U.S. Metric Study adopted several different approaches, some complex and some simple, all with the hope of letting each sector of society express itself on its own terms and on its own level of sophistication. (See the "Methodologies" section, pp.139-149 of Appendix One.) Some people filled out questionnaires; others were interviewed in person or over the telephone; still others presented and discussed their views at the public hearings. As can be seen in the following paragraphs, there were some differences of practice, opinion, and judgment.

But on three fundamental questions there was a clear consensus:

- Is increased metric usage in the best interests of the United States?
- If so, should there be a coordinated national program to change to metric?
- Over how many years should the change be made?

These questions are treated in this chapter. Estimates of benefits and costs are covered separately in Chapter IX.

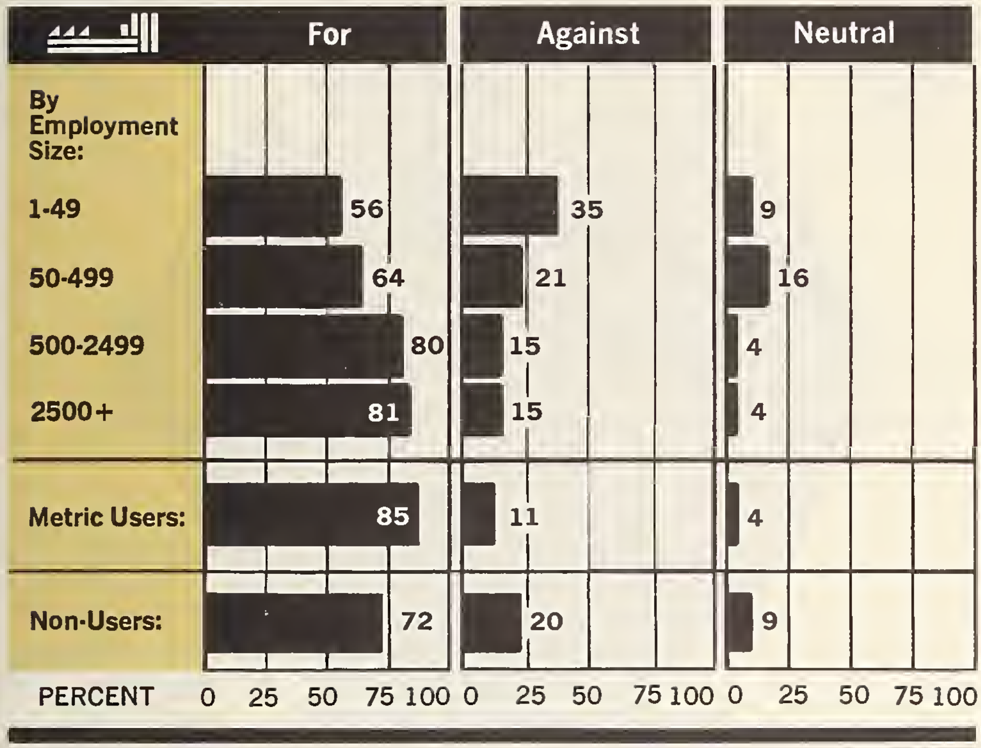
Manufacturing Industry

The information for this sector came from answers to detailed questionnaires mailed to almost 4,000 firms and followed up in some cases by personal visits or telephone interviews. The companies were chosen to be a representative sample of some 300,000 U.S. firms that manufacture products, and they ranged from tiny operations employing only a handful of people to giants with payrolls of tens of thousands.

Eleven percent of these companies reported that they make some use of the metric system. But metric measurements and standards have pervaded U.S. manufacturing much more widely than this figure would indicate. A disproportionately large number of the big and very big com-

Manufacturers Attitude Toward More Metric In the United States as a Whole

(Weighted by Size of Company)



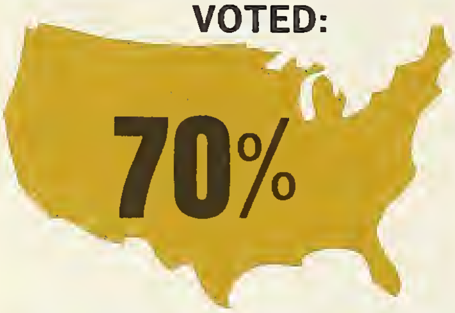
The primary metals industry offered interesting contrasts

panies use metric in at least some of their operations; firms that said they make some use of metric actually account for nearly 30 percent of employment in manufacturing. However, the actual extent of use is unknown.

Manufacturers who now use metric to some extent were queried about the kinds of advantages and disadvantages that they might expect in a national changeover to metric. They were asked about such factors as: the training of personnel, engineering design and drafting, inventories of parts and products, manufacturing operations, exports and imports, domestic sales and competition, communications and records. Most were unable to explain where greater use of the metric system would be, for themselves, either a help or a hindrance.

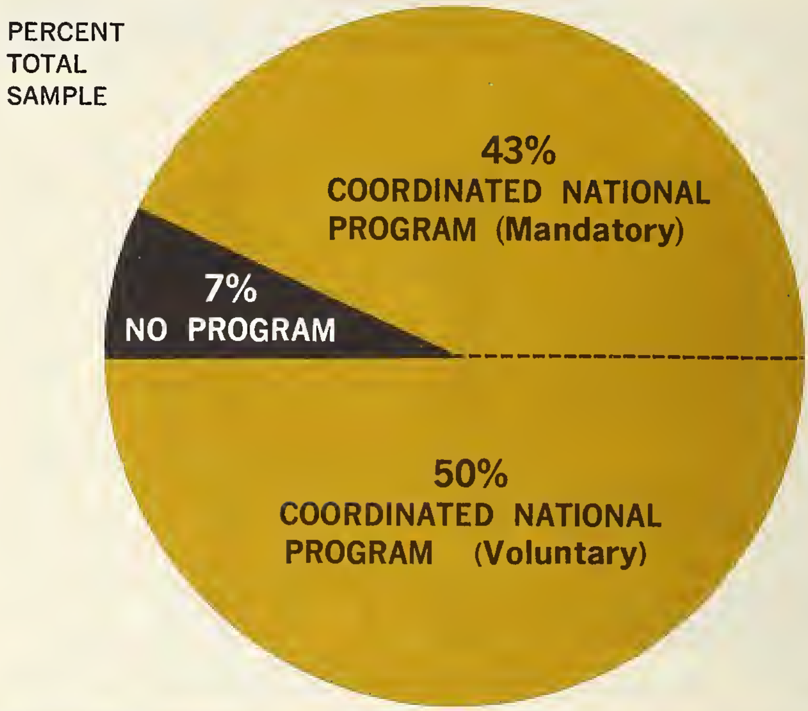
Sentiment for or against going metric varied greatly even within the same kinds of industry. Large firms tended to be more in favor than small ones, although some small businessmen were among the most outspoken

MANUFACTURERS VOTED:



INCREASING USE OF METRIC GOOD FOR COUNTRY

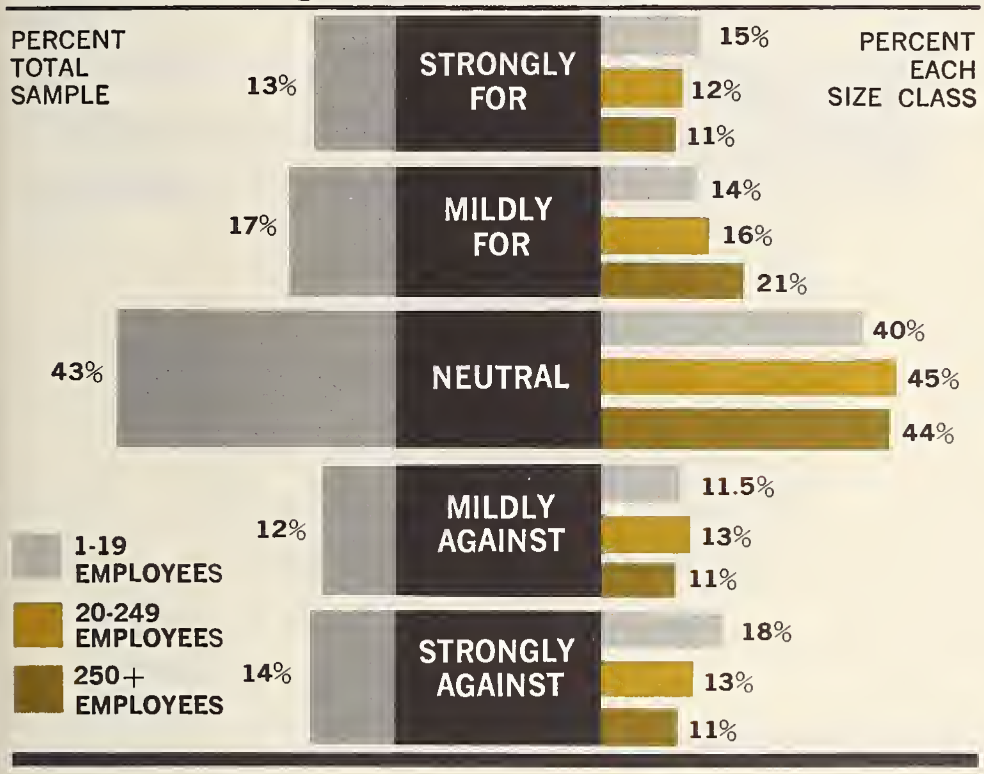
Manufacturing Businesses:
If Increased Metric Usage is in "Best Interests of United States," What Course of Action?

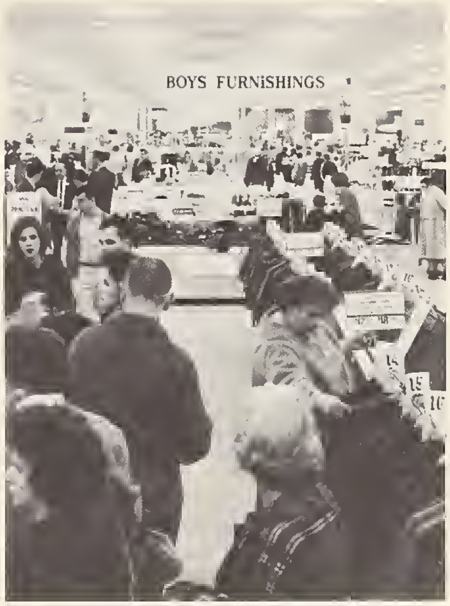


advocates of a metric changeover through a national program. Companies substantially involved in international activities tended to be more favorably disposed to metric. The aluminum industry was, on the whole, pro-metric; the steel industry was not.

As to whether a unilateral increase in metric use for their products would be desirable (irrespective of what the nation may decide), manufacturers were about evenly divided. But as to whether increasing the use of metric would be good for the country as a whole, an overwhelming majority voted "Yes." About 70 percent of those answering this question (representing 80 percent of the total employment) said that more use of metric would be in the best interests of the U.S. Then the companies were asked, if it is found that increased metric usage is in the best interests of the U.S., what course should be followed? More than 90 percent of those who responded preferred a coordinated national program, based on either voluntary participation

Non-Manufacturing Businesses:
Attitude Toward Increased Metric Usage in Own Company Without Awaiting a National Decision





The sample of Nonmanufacturing businesses covered an enormous range, including agriculture, retail stores, zoological gardens.

or mandatory legislation. Only 7 percent favored no national program for going metric.

Nonmanufacturing Businesses

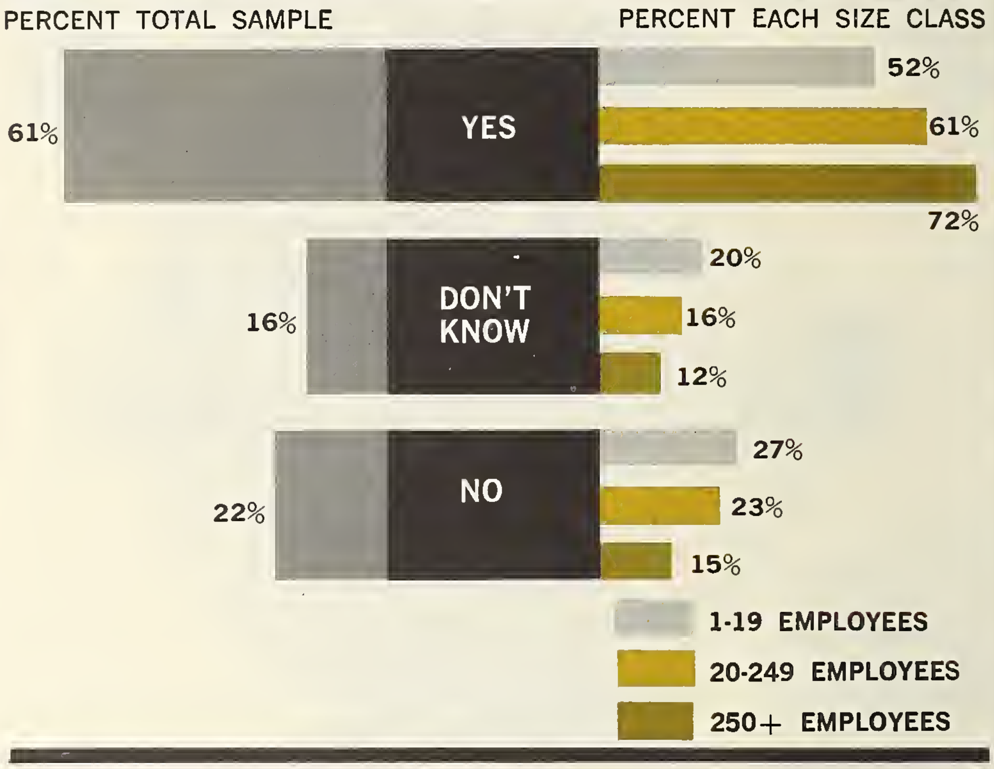
The companies in this sector are engaged in such a variety of activities that gross figures of metric usage would mean little. Nevertheless, some general conclusions about attitudes can be drawn.

Few companies saw reason to change their use of measurements unless the whole country decides to do so. But 6 percent of those interviewed said they intended to increase their own use of metric in the near future, chiefly to enhance their prospects in world trade.

Participants in the survey were asked whether increasing use of the metric system is in the nation's best interest. Sixty-one percent said that it is. Eighty-six percent of the nonmanufacturing businesses were in favor of a national conversion program. In fact, a majority held this view in

"A public hearing was devoted to education . . . "

Non-Manufacturing Businesses:
Is Increased Metric Usage in the "Best Interests of the United States"?



every industry, from agriculture to utilities.

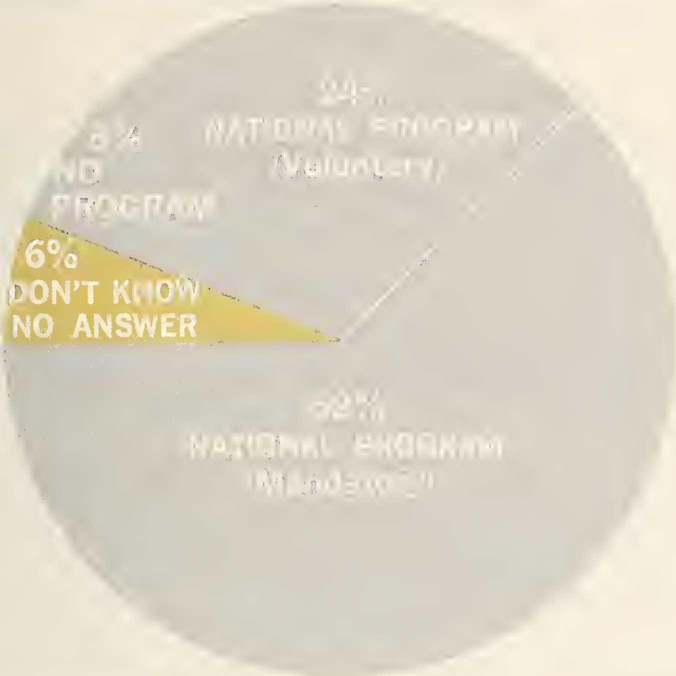
Education

Educators are nearly unanimous in their endorsement of the metric system. A public hearing devoted to education was attended by representatives of all leading teacher and school administration societies as well as many firms in the educational field. They represented a total of 1,600,000 people.

Speaking for more than one million of these, one participant said in a prepared statement: "The National Education Association believes that a carefully planned effort to convert to the metric system is essential to the future of American industrial and technological development and to the evolution of effective world communication." He further urged that, starting with the upcoming school year, all teachers should teach metric as the primary system of weights and measures in the U.S.

Non-Manufacturing Businesses:
If Increased Metric Usage Is in "Best Interest of the United States," What Course of Action?

PERCENT
TOTAL
SAMPLE



1-19 EMPLOYEES

20-249 EMPLOYEES

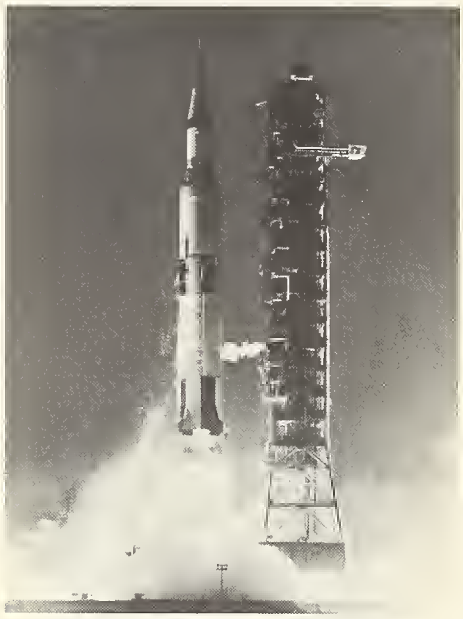
250+ EMPLOYEES

Virtually all the individuals in the educational system and the firms associated with it make some use of the metric system and are in favor of a planned conversion program, a finding supported by a special survey conducted as part of the U.S. Metric Study. This survey found that about 10 percent of the boys and girls in elementary and intermediate grades are taught something about metric units. Nevertheless, like their parents, they still think primarily in terms of inches, pounds, and degrees Fahrenheit—inevitably, since they live in a mostly non-metric environment.

Government

The Department of Defense expressed no view as to whether increasing use of the metric system is in the best interests of the nation. Nevertheless, the Department stated in its metric study report that the armed forces could make a changeover to metric without impairing their func-

General John J. Pershing: "Americans were able readily to change . . . to the metric system."



NASA is switching to metric units

tions, assuming that industry would first convert through a coordinated national program. The Department of Defense would not take the lead by writing metric units into its specifications, but would follow industrial practices.

As to whether conversion would be in the best interests of the military, the Defense report said: "Although the use of a simpler system would have no outstanding military advantage, the slight advantage expected would be amplified because of its widespread nature. The compatibility of U.S. and foreign equipment will enhance combined military operations and simplify logistic support requirements."

This conclusion is consistent with one reached by General John J. Pershing more than 50 years ago, shortly after he had commanded the U.S. Army in World War I. He wrote in a letter: "The experience of the American Expeditionary Forces in France showed that Americans were able readily to change from our existing system of weights and measures to the metric system . . . . Not the least advantage . . . is the facility which that system gives to calculations of all kinds, from the simplest to the most complex. I believe that it would be very desirable to extend the use of the metric system in the United States to the greatest possible extent; but I can readily see that there would be many practical obstacles in the attempt entirely to replace our existing system by the metric."

The views of 55 other Federal Government agencies were collected in a separate report. The results roughly paralleled those of the manufacturing industry survey. More than half the agencies make some use of metric—generally in medicine, electronics, physical science, and other fields where it is already the dominant measurement language—and one-fifth expect to use metric more extensively regardless of national policy and trends. As was mentioned earlier in this volume, one of the largest agencies, the National Aeronautics and Space Administration, last year began entirely on its own to convert to metric language. Forty of the 55 agencies estimated that long-term advantages of going metric would outweigh disadvantages, and almost all of these favored a coordinated national conversion program.

A survey was undertaken by the State-County-City Service Center, which represents such groups as the National Governors Conference and the National League of Cities. The indication was that only a coordinated national program would persuade state, county, or local governments to go metric.

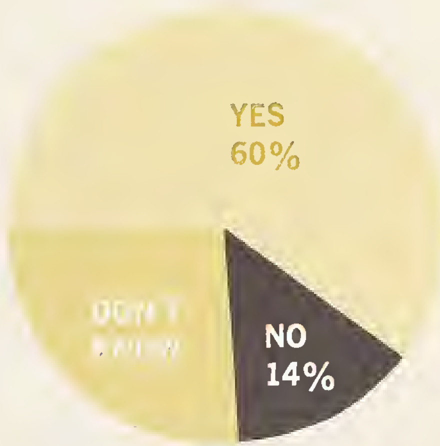
Nevertheless, some government agencies at these levels are already making some use of the metric system, especially in connection with pharmaceuticals, laboratories and testing, and the purchase and repair of certain metrically designed equipment, such as foreign vehicles. In addition, the American Association of State Highway officials has begun to publish recommended tests in both metric and Customary units.

Earlier this year the Legislature of the State of Indiana passed a joint resolution urging the U.S. Congress to adopt the metric system.

Views of Federal Civilian Agencies

Based on the 394 Responses From 55 Civilian Agencies

Favor Coordinated National Program



Advantages Would Outweigh Disadvantages

Public Knowledge of Metric

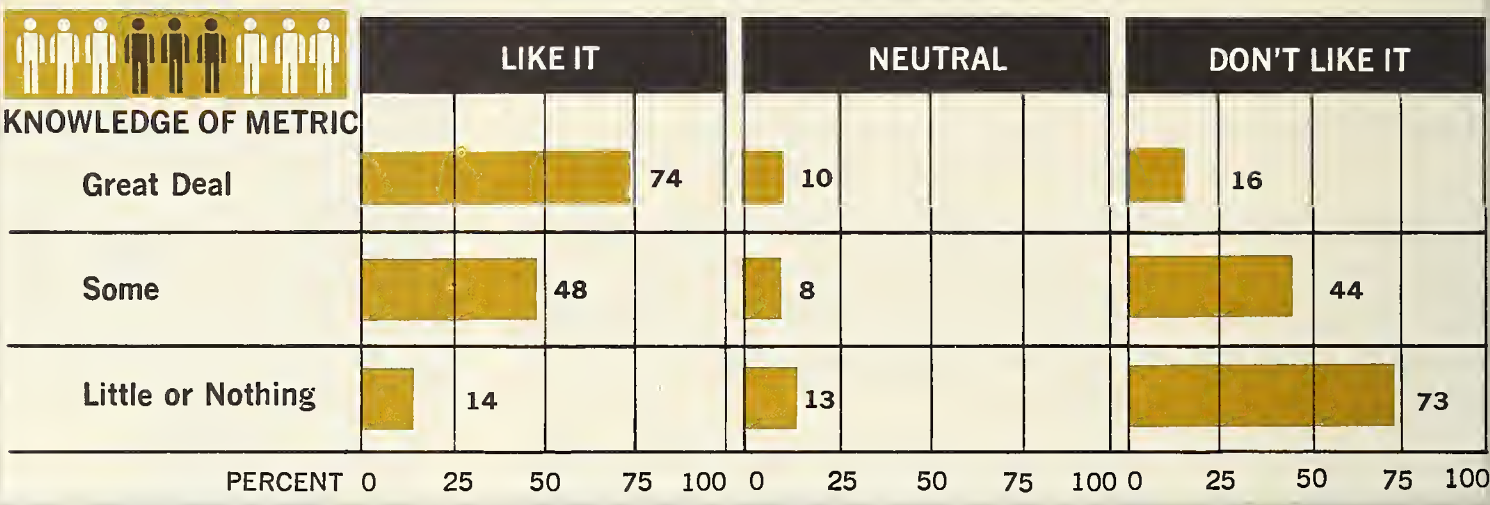
In order to probe public information and attitudes, the U.S. Metric Study enlisted the help of the Survey Research Center of the University of Michigan. The staff of the Center selected a sample of 1,400 families representative of the 62 million family units in the United States and then proceeded to interview the individuals in person.

The general public, it is apparent, knows little about the metric system. Only 40 percent could name a single metric unit, and only half of those were familiar with relationships among metric and Customary units.

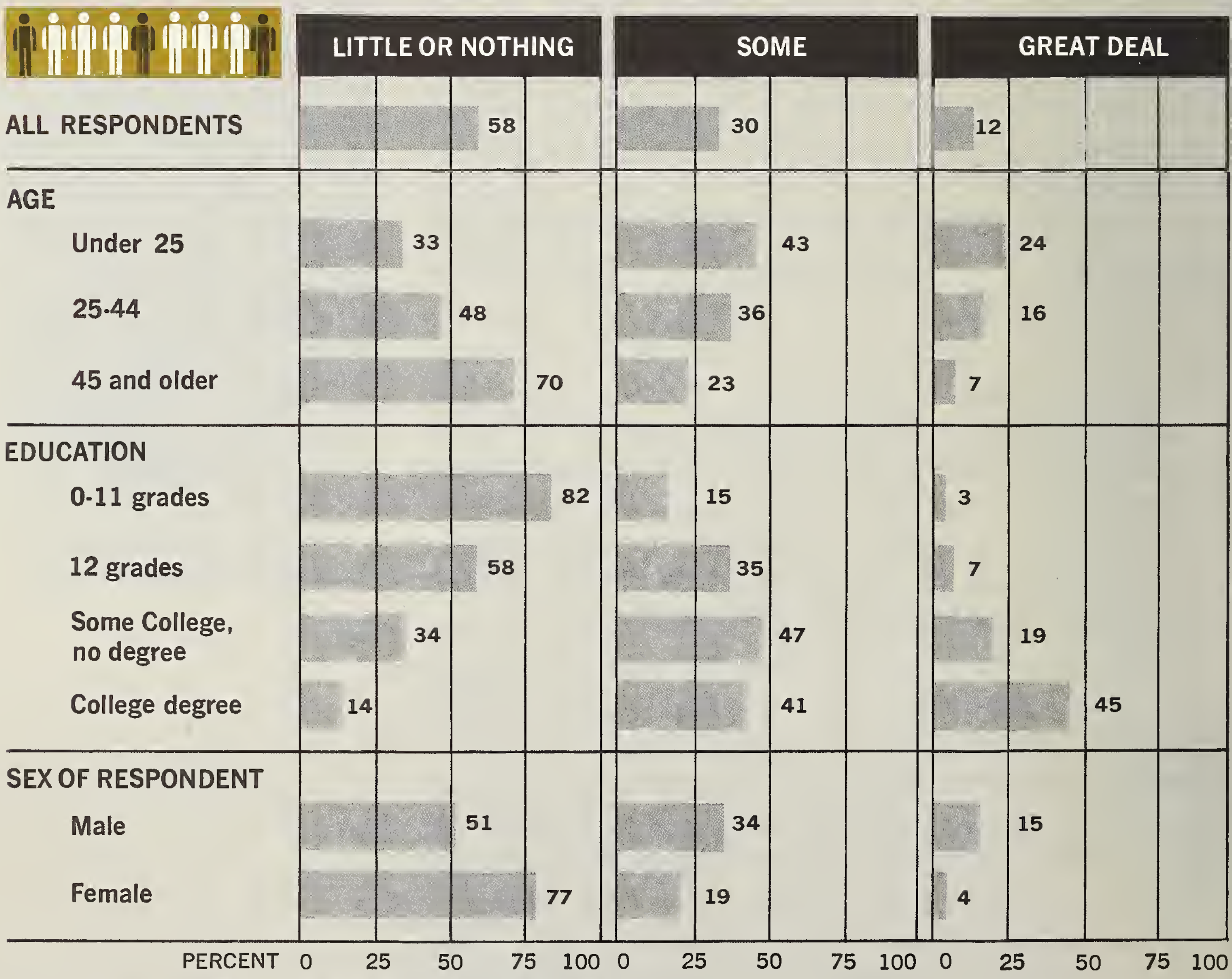
As the chart on "Public Attitudes Toward Metric" (p. 80) indicates, the more people know about the metric system the more they favor it. Rather consistently, those with more formal education or more experience using metric units seemed the most confident that they could master it

PUBLIC ATTITUDES TOWARD METRIC

The More People Know About Metric The More They Like It



How Much The Public Knows About The Metric System



Source: Survey Research Center, Institute for Social Research, 1971 with little difficulty and believed that metric conversion was in the best interest of the U.S. For these reasons the surveyors judged that a program of public education would be essential to the success of a national conversion program.

". . . a program of public education would be essential to the success of a national conversion program."

Consensus for Ten Years

The clear consensus for the length of the changeover period was ten years. At the end of this time the nation would be predominantly (not exclusively) metric.

Some participants in the study preferred that the change be made more quickly; a few wanted more time. Nevertheless, all could be accommodated by a ten-year transition period, because those who could move faster would do so as soon as their customers and suppliers were ready. Those who needed more time could take it, since the nation's goal in a ten-year program would be to become mostly (not entirely) metric.

10 Years
to switch the roles of metric and Customary

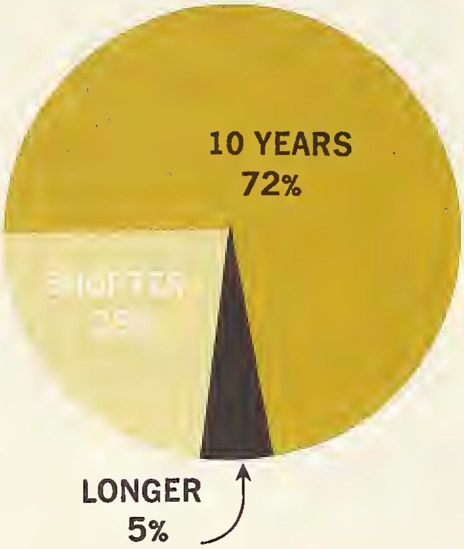
Most manufacturing firms judged that the ten-year period would be close to optimum for them (p. 82). Weighting manufacturers according to size (i.e., value added in manufacturing), the Study found that 82 percent thought the changeover period should be ten years or less. The average of the periods chosen was 9½ years.

In its study the Department of Defense concluded: "The DOD is dependent upon the National Industrial Base, and the rate of conversion within the DOD will be dependent on how well conversion is carried out by industry."

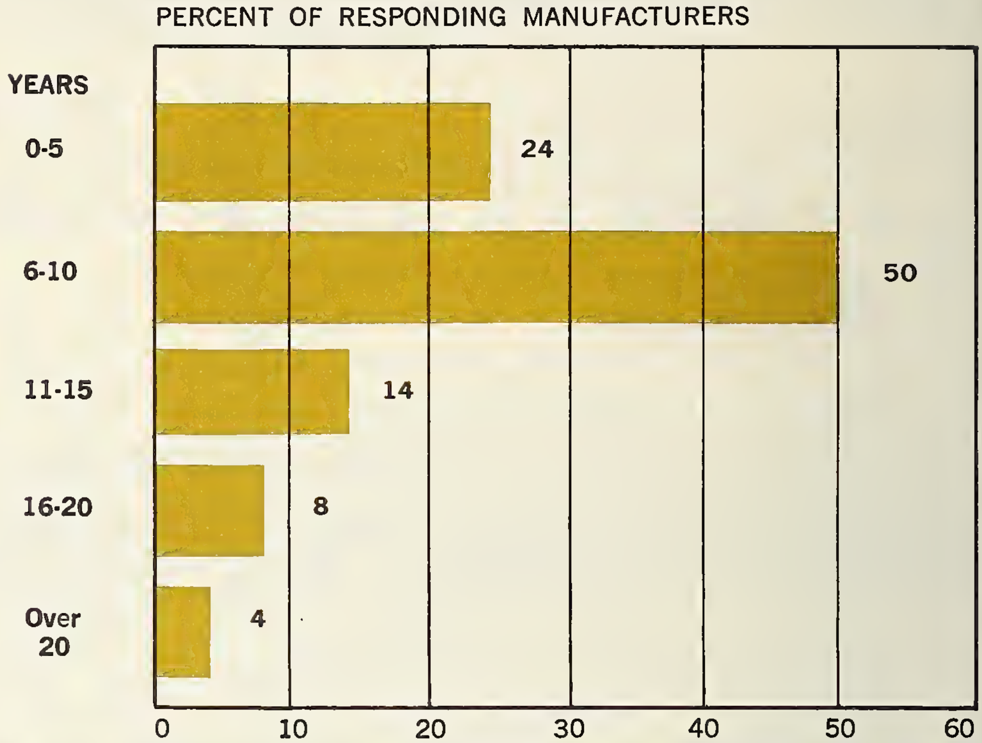
Nonmanufacturing businesses, with generally much less hardware needing conversion, were in favor of a shorter transition period. They thought that the nation as a whole might make the changeover in six to ten years. But speaking for themselves, most were willing to complete the task in five years or less. "Immediately" was the optimum period most often cited by spokesmen for eight nonmanufacturing industries: finance, insurance, agriculture, services, real estate, forestry and fisheries, retailers, and transportation.

Attitudes of Federal Civilian Agencies Regarding Length of Transition Period

Based on the 394 Responses From 55 Federal Civilian Agencies

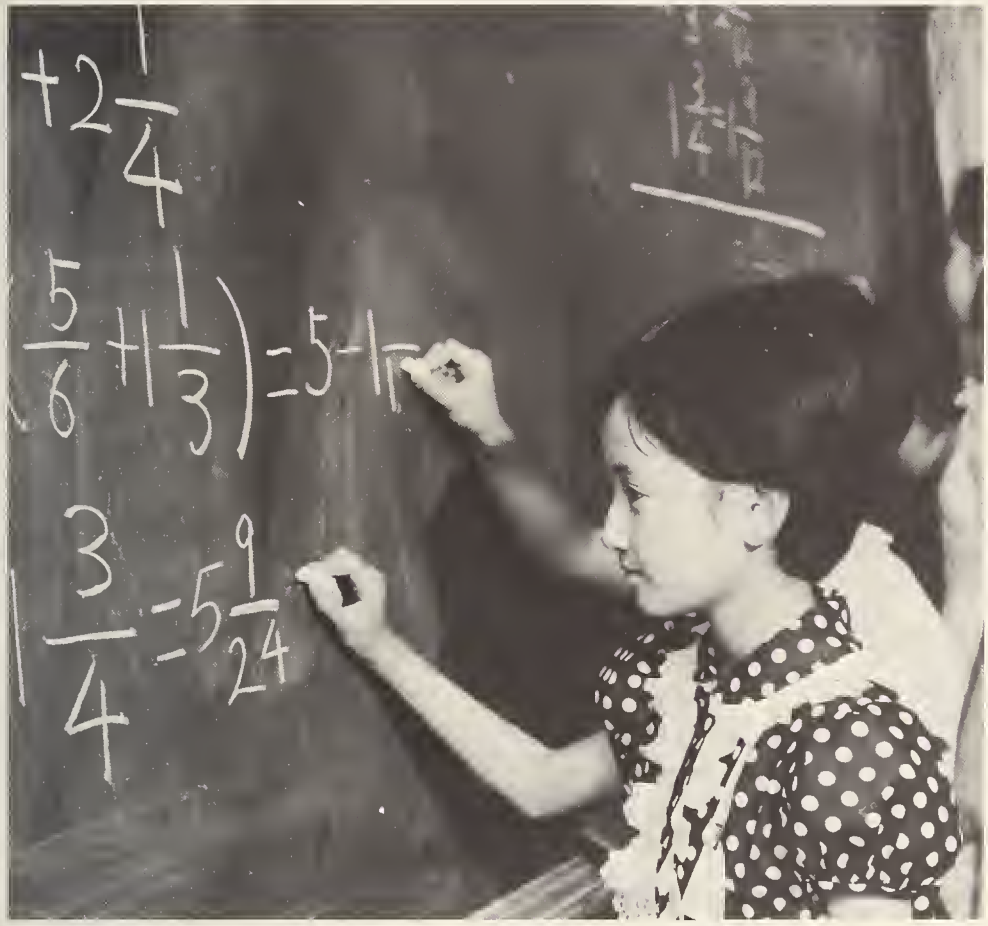


Manufacturing Industry Survey: Choice of Optimum Period for Metric Changeover



In the commercial weights and measures field, the adaptation to metric of devices now in use would take considerable time. The survey of this field points out that there are relatively few trained personnel who can do the work. Because of the large numbers and varieties of devices now in use, ten years would be required to complete adaptations.

As was pointed out earlier in this chapter, the National Education Association has urged that, starting this fall, all children be taught metric as the primary language of measurement. A survey conducted especially for the U.S. Metric Study suggests, however, that school systems are not ready to move that rapidly. The consensus was that for primary and secondary education a five-year transition period would be a bit tight, since two or three years would be needed for planning. But textbooks would probably present no obstacle; one major publisher of science texts assured



"The National Education Association has urged that . . . all children be taught metric as the primary language of measurement."

the survey team that he could convert his entire line of books from Customary to metric units in successive printings over three years.

* * * * *

The U.S. Metric Study has provided answers to three fundamental questions posed near the beginning of this chapter. The clear-cut consensus of the participants in the Study is that:

- Increased use of the metric system is in the best interests of the United States.
- The nation should change to the metric system through a coordinated national program.
- The transition period should be ten years, at the end of which the nation would be predominantly metric.


TIME
TABLE
Education
100
75
50
25
0
1972 1974 1976 1978 1980
METRIC CONVERSION
PARTICIPATION
by Group
METRIC STUDIES
METRIC SYSTEM
SCHEDULES
PLANNING

CHAPTER VIII

Recommendation and Problems Needing Early Attention

On the basis of the evidence marshalled in the U.S. Metric Study, this report recommends that the United States change to the International Metric System through a coordinated national program over a period of ten years, at the end of which the nation will be predominantly metric.

Within the broad framework of the national program, industries, the educational system, and other segments of society should work out their own specific timetables and programs, dovetailing them with the programs of other segments. This can be done effectively only after there has been a decision to go metric and after joint planning by all groups to be affected by the change. Because of the scope of such a program, the Federal Government would have to firmly back it.

There will have to be a central coordinating body. It could be constituted in different ways. Congress could assign the coordinating function to an existing Government agency, or it might appoint a special group, such as a national commission, to perform the task. In any case, the coordinating body will have to be able to draw upon all segments of the society for information and advice. At the end of the period of transition to metric, or possibly earlier, the coordinating body will have completed its work and will then cease to function.

The coordinating body would work with all groups in the society that were formulating their own plans, so as to ensure that the plans meshed. It would help to decide how the public could best be familiarized with the metric system. It would advise government agencies, at all levels (state, local, and Federal), of changes in codes and regulations that would require attention. And it would have to anticipate and deal with other special problems, such as those described later in this chapter.

Groups of industries would coordinate their efforts with the help of trade associations and agencies of Federal, state and local governments. State weights and measures

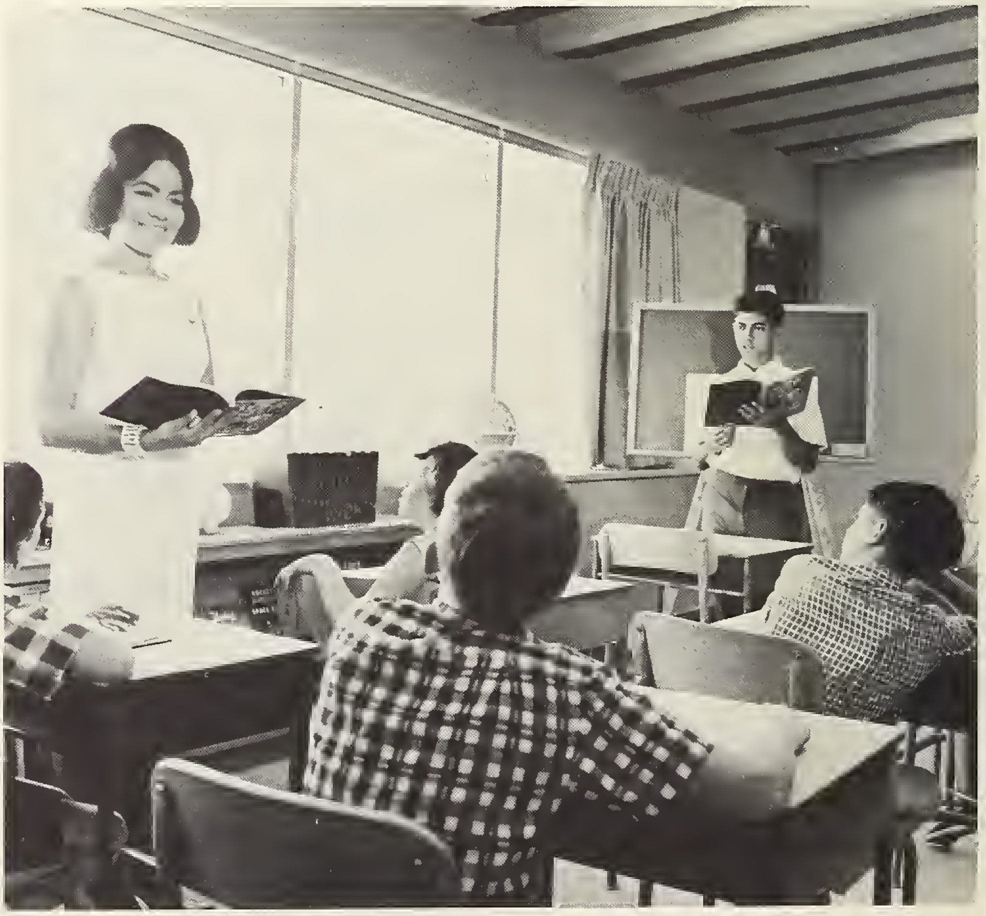
All interests should be represented

agencies would cooperate in making the changeover through their National Conference on Weights and Measures. Other groups, including educators, labor, standards making bodies and consumers, would be brought in at the start. A hierarchy of definitive plans would be developed by all these participants for themselves. And each plan could provide for contingencies, such as failures to meet deadlines.

Education and International Standards

Two areas merit immediate attention, even if a national program is not adopted: education and international standards.

It is urgent that the U.S. begin now to participate more vigorously in world standards-making. As was discussed in Chapter VI, international standards will increasingly influence world trade. The great majority of these standards

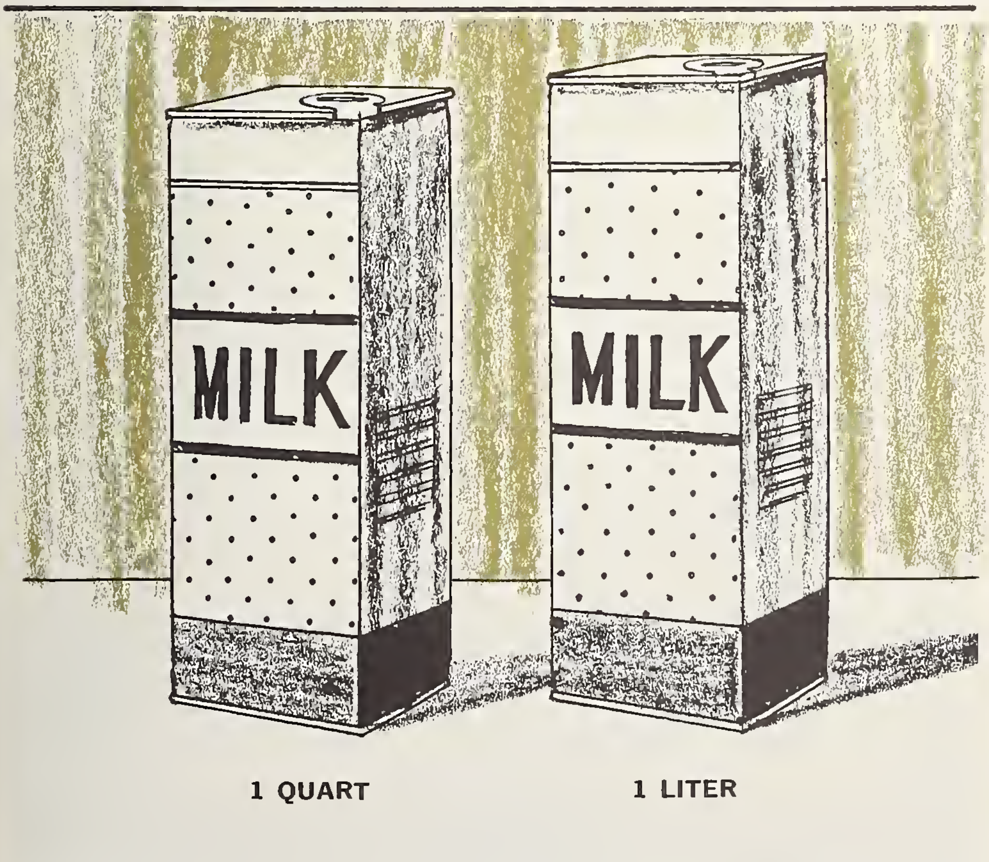


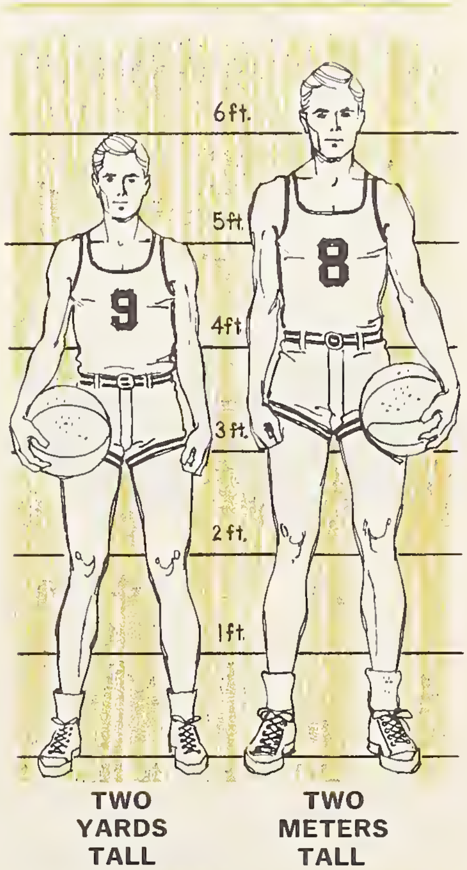
" . . . as early as possible, all children should be taught metric as the primary language of measurement."

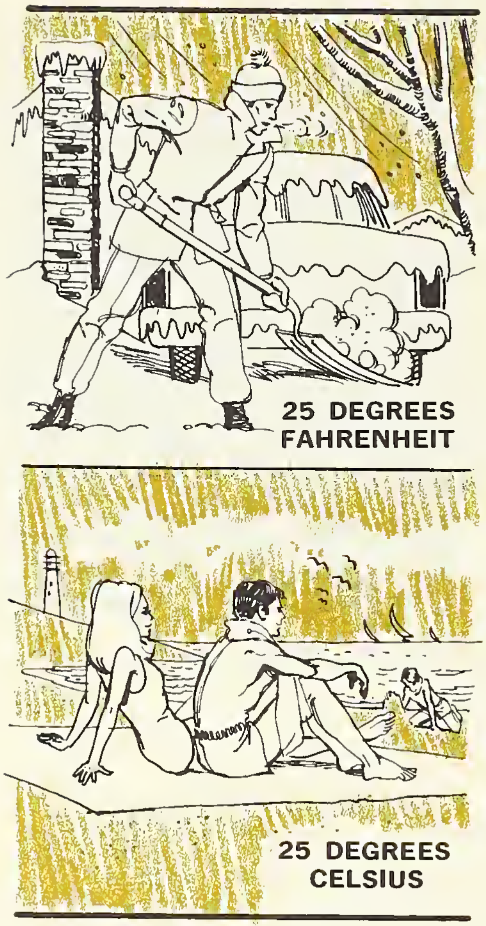
remain to be developed. Thus, the U.S. has the opportunity to ensure that its practices and technology are taken into account in international standards negotiations. And as the nation changed to metric, it would be changing to metric-based international standards that it helped to set. In this way the cost of hardware modifications in a U.S. change to metric could be greatly reduced.

Almost all the participants in the U.S. Metric Study stressed the importance of education in any change to metric. Citizens need to be informed of what the change would mean in their jobs and everyday lives. Metric measurement needs to be taught more vigorously in the schools. As was pointed out in the previous chapter, the National Education Association has urged that, as early as possible, all children be taught metric as the primary language of measurement. Timely government assistance may be needed to help develop teacher training plans and materials.

Vocational education







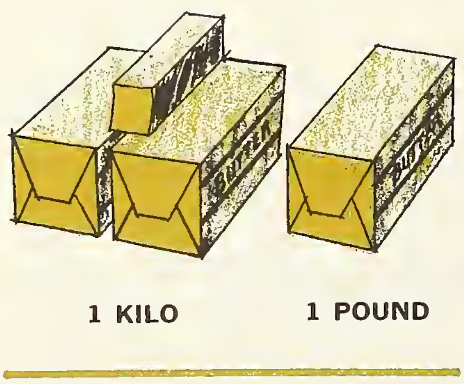
Educating the public to think in metric terms

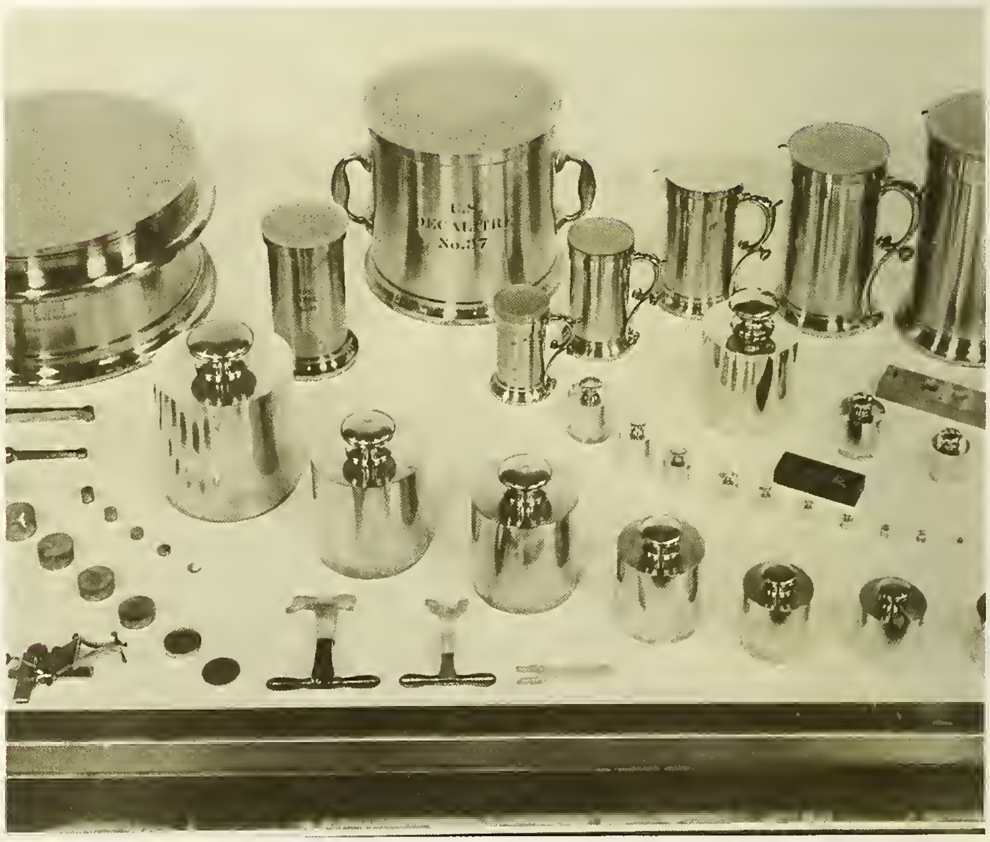
Children starting school this fall will be 35 years old at the turn of the century. To fail to train them adequately in metric will be to fail to equip them properly for the world they will inherit.

Through newspapers, magazines, radio, television, and other media, the British Metrication Board is informing people about kilograms, meters, degrees Celsius, and a few other metric units they are likely to encounter in everyday life, trusting them to pick up on their own any more technical details they may desire to know.

A U.S. national program could presumably rely on a similar approach to adult education. The American Association of Museums has volunteered to display popular exhibits on the metric system. And the Advertising Council, which helped greatly to publicize such national programs as the Peace Corps and the campaign against cancer, has offered to help in a national metric changeover.

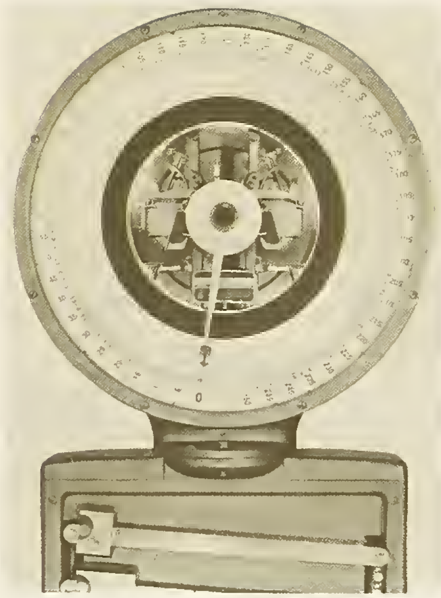
Education, formal or informal, will be buttressed by encounters with the metric system in everyday life—hear-





Standard weights & measures for commerce ing weather reports in degrees Celsius, buying cloth by the meter, potatoes by the kilogram, and milk by the liter. In this way metric habits of speech and ways of thinking will gain momentum.

Chapter V gives an overview of how a national change to metric should be approached. It also provides the context for the problems discussed in this chapter. In any coordinated national program, a number of special problems would warrant special treatment. Many of them could be anticipated in the early planning stages.

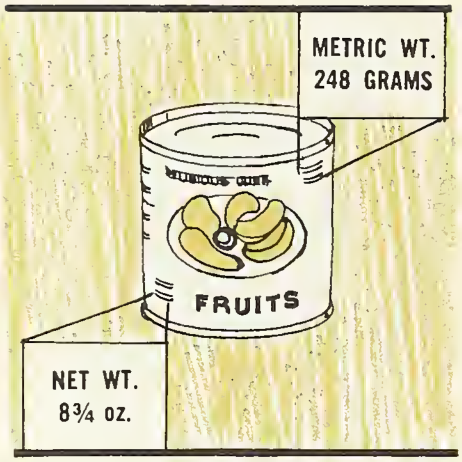


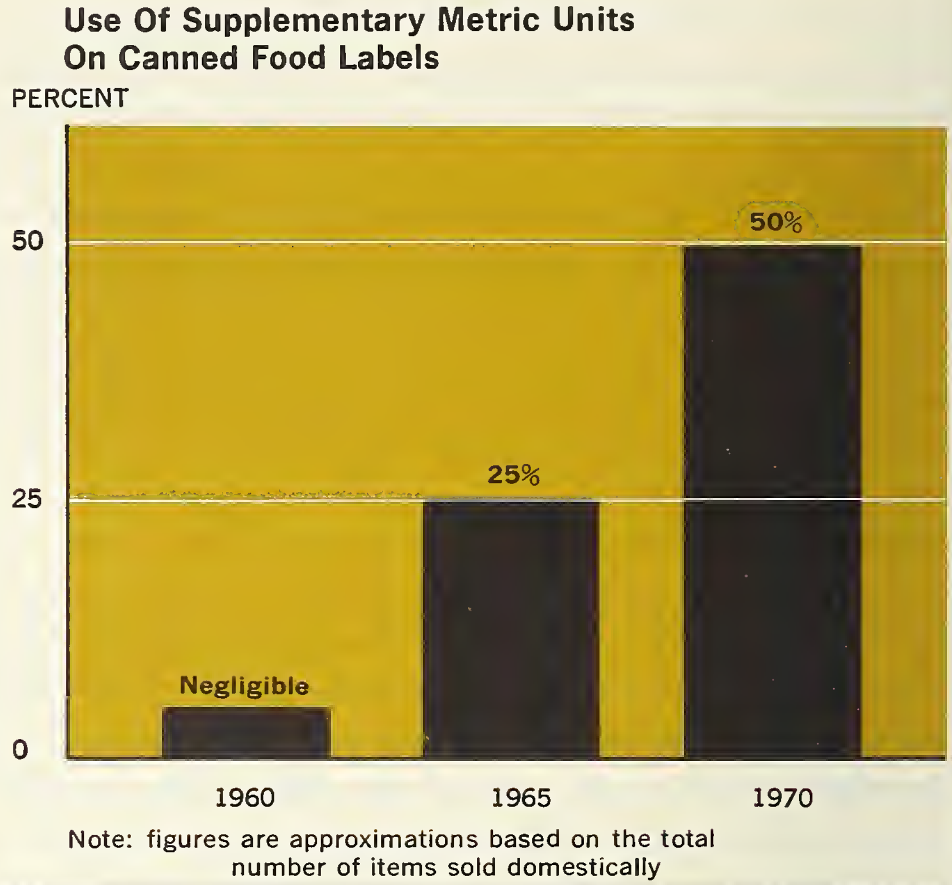
Weights and Measures

Weights and measures in commerce would play such an important role in a metric changeover that the U.S. Metric Study conducted a special survey of this field. Manufacturers of weighing and measuring devices foresaw no problems in switching their production to metric devices. But because many scales in use are worth the cost of adapting and, as was pointed out in Chapter VI, relatively few people are trained to work on them, adapting them would require several years.

The Post Office alone uses 240,000 scales. Most of them are the little sixteen-ounce beam scales used to weigh letters; it would probably be cheaper to replace these. But 35,000 larger and more expensive postal scales, the weights and measures survey found, would have to be modified over the course of five years. Meanwhile, each post office would display a dual set of rates and would begin charging postage by grams instead of by ounces, as soon as its scales were changed.

The commercial weighing and measuring field strongly favored a coordinated program that provided for timely amendments in weights and measures laws in order to minimize the side-by-side use of two measurement systems. The program would require goods to be labeled, at the start, in both Customary and metric units. After a while, the Customary units could be eliminated. This plan would not be practical, however, for marketing meat,






Most goods are sold in prepackaged forms

cheese, and other commodities sold by the piece—at least not with scales that automatically weigh the package and print out the price. State and local weights and measures laws would have to provide for a transition period during which such scales could continue to be calibrated in Customary units until the day they were converted.

Consumers might be apprehensive about price increases linked to metric conversion. For instance, the price of a liter of milk would have to be greater than the price of a quart (0.946 liter). The public education program mentioned earlier would help to clarify such questions.

Small Business

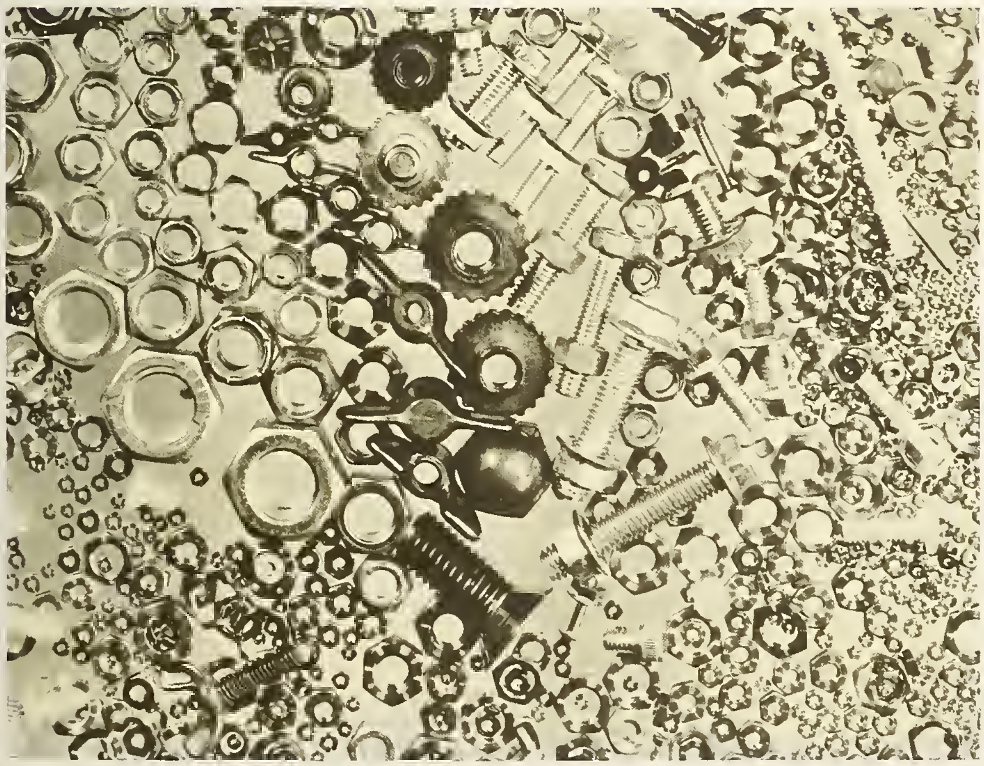
Congress is already concerned—as are others, including the Small Business Administration—that small businesses are being placed at a disadvantage, even now, as the nation increases its use of the metric system. Most large companies have technical, financial, and managerial resources for planning their own metric changeover and dealing with it over a long period. Small businesses do not possess such resources. The small businessman is less likely to be in a position to decide when to go metric; large companies tend to set the pace. Moreover, the small businessman is more dependent on the ready availability of standard parts and supplies. It is for these reasons that spokesmen for small business favor a coordinated national program, in which no one would be left behind.

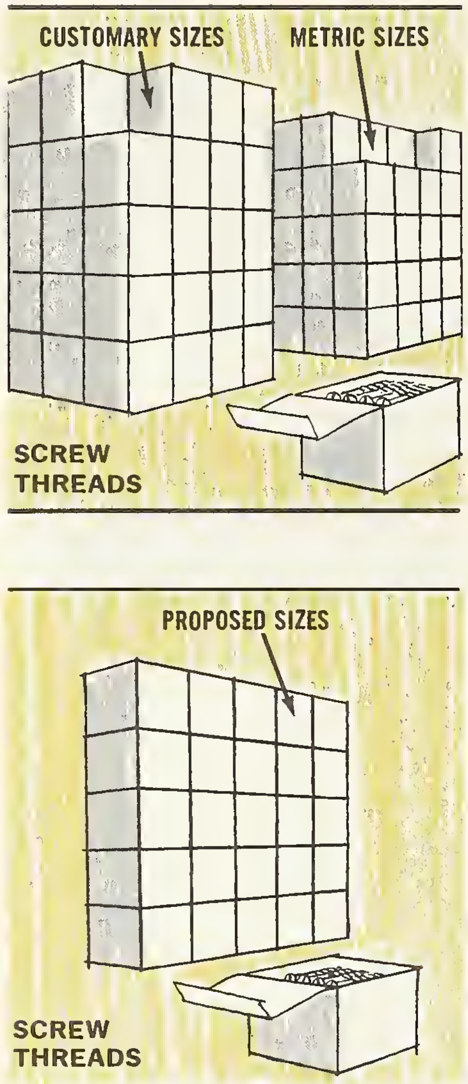

Technical assistance programs

In a national program the Government would have a special responsibility to ensure that small businesses, including self-employed craftsmen, are properly informed and their interests adequately represented. In particular, the metric system should be brought into all vocational and on-the-job training programs. These and other forms of technical assistance might warrant Government support.

Engineering Standards

One of the most important prerequisites of metric conversion would be a reevaluation of engineering standards.


Opportunities for cost savings and technological improvements



Reducing superfluous inventories

As a matter of fact, some of these are already under scrutiny. Early this year, quite independently of the U.S. Metric Study, the Industrial Fasteners Institute issued a report entitled: *A Study to Develop an Optimum Metric Fastener System*. (This report is printed as an addendum to the U.S. Metric Study special report on *Engineering Standards,* cited in Appendix Two.) It is intended to be the first step in the development of a complete range of threaded fasteners which, while eliminating many superfluous items, will satisfy stringent domestic engineering requirements.

So far, the Institute has been working on only screw thread sizes—not on the many other requirements for a fastener (e.g., bolt length and head shape). Even on this limited basis, the proposed new system drastically reduces the variety of fasteners that would have to be manufactured and kept in stock. At the present time there are 59 Customary screw thread sizes principally used in the U.S., and 57 metric sizes are being added, making a total of 116. Under the new system there would be only 25 screw thread sizes, leading to a drastic reduction in the inventories suppliers and users would have to maintain. This new set of fasteners would not only simplify design, manufacturing, and repair, but also would be technologically superior. Eventually, the Institute hopes, the new fastener system will be accepted as a superior international standard.

Similar opportunities for cost savings and technological improvements exist throughout the field of engineering standards.

Antitrust

An effective metric conversion program would require many efforts comparable to the study now being made by the Industrial Fasteners Institute. A principal goal in such a program would be to recoup costs, in part by reducing superfluous varieties of standard parts and materials. This would involve expanded cooperation by businesses through trade associations and standards-making bodies. To the extent that competitors worked together antitrust

Federal leadership would help to solve antitrust problems

considerations would arise.

Although Federal leadership in a national program would minimize the antitrust problem, some accommodations would have to be made to permit cost-saving coordination while avoiding illegal restraints on trade. The policy of the antitrust agencies of the Federal Government is that it is not the concerted form of the action which is the criterion of legality, but rather the effect of the joint action upon competition. Early in the planning for a national program to change to the metric system, antitrust questions would have to be resolved by business and industry, on the one hand, and the Department of Justice and the Federal Trade Commission on the other.

Cooperation With Canada

Canada, our major trading partner, has decided as a

Canada, our major trading partner, has already decided to change

matter of government policy to change to the metric system. But, as was explained in Chapter VI, the Canadians have put off starting a full scale program, largely because of their uncertainty as to what the U.S. might do in this regard.

In the event that the United States decides to change to the metric system under a national program, it would be helpful for both countries to cooperate to the fullest extent possible.

Who Pays for Conversion?

The cost of going metric should be borne in such a way as to minimize the overall cost to the nation and to avoid bureaucratic waste. The British seek to attain this end by "letting the costs lie where they fall." As a result, British metrication is being coordinated by a small group at very modest cost to the taxpayer. The general rule is that everybody in the society, including government agencies, must share in the temporary costs, as they will in the continuing benefits. The same philosophy was followed by Japan in its conversion to the metric system.

This philosophy does not exclude the kinds of assistance suggested earlier in this chapter for small businesses. Nor does it exclude some help during the transition period in the form of accelerated depreciation for machinery and investment tax credits. Even under the present tax laws, metric conversion costs would be tax deductible.

Tackling the Change

Many participants in the Study, as well as those who have observed metric programs in other countries, suggest that almost all machinery could be continued in use—or at least phased out only when it wore out or became obsolescent—with careful planning and an adequate transition period.

A recent U.S. Air Force study indicated that many machine tools can produce metric parts with little more than the adjustment of a dial, while others require only minor modification. The recent redefinition of the inch as exactly 2.54 centimeters makes possible the conversion of some inch-based machines to metric by using gears of 254 or 127 teeth.

Conversion tools

Many engineering drawings, handbooks, and other costly paperwork are usually obsolete within a few years after publication; when updated in due course, it would be reasonably cheap to translate dimensions into metric units. The British have found that retraining workers is unexpectedly easy; it is most efficiently done if a man is taught on the job and told only what he needs to know to do his work.

Many participants in the U.S. Metric Study expressed confidence that they could tackle the change to metric. A representative of the trucking industry pointed out at one of the public hearings that his industry has made several drastic technical changes in recent years. He added: "No metric conversion could approach the difficulty of doing what is now being demanded of us for safety's sake." And a labor spokesman said: "Metric is here, so let's get on with it."

It is often argued that the most favorable time for a metric changeover is now, before our society gets any bigger, more complex and, therefore, harder to change. On the other hand, there are reasons to believe that some difficult changes have become easier and may become easier still.

Computers and computer-controlled machinery will make the change easier

Computers have already reduced drastically much of the drudgery that would be involved in translating one measurement language to another. Numerically controlled machine tools, which are increasingly used in manufacturing, are guided by a kind of computer program. Guidance to metric dimensions needs only a change in the program. The trend to prepackaged goods in the supermarket—already above 90 percent—has eliminated at least some of the confusion that a metric changeover would impose on the consumer. As similar technologies emerge, other ways to facilitate the nation's change to metric can be expected.

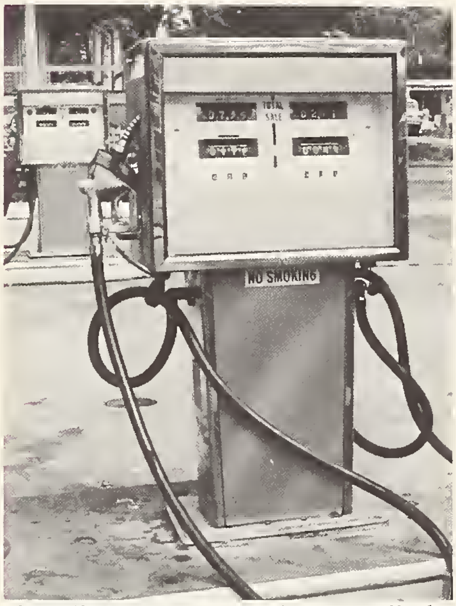

ADVANTAGES
DISADVANTAGES

CHAPTER IX

Benefits and Costs

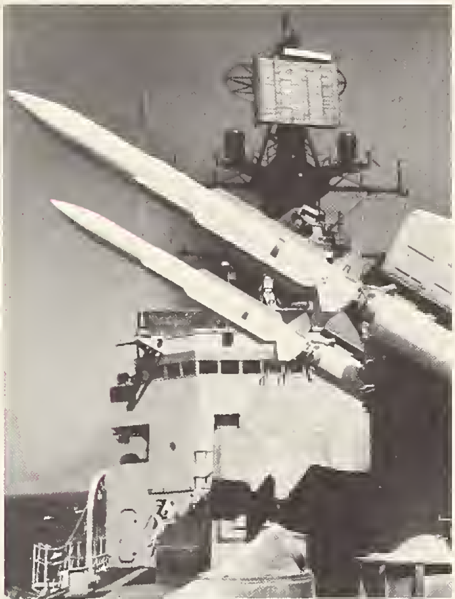
This report has deferred until now a dollars-and-cents evaluation of why going metric by a coordinated national plan would be more advantageous than going metric without such a plan.

What kinds of costs were considered? They included out-of-pocket payments for physical changes in things: for example, modifying scales or buying new ones, altering gasoline pumps, adjusting or replacing machinery, repainting highway signs, rewriting plans and specifications. They also involved intangibles, such as having to learn new words and how to use them, having to work more slowly for a while in order to avoid mistakes, having to do arithmetic in order to understand an item in the newspaper.



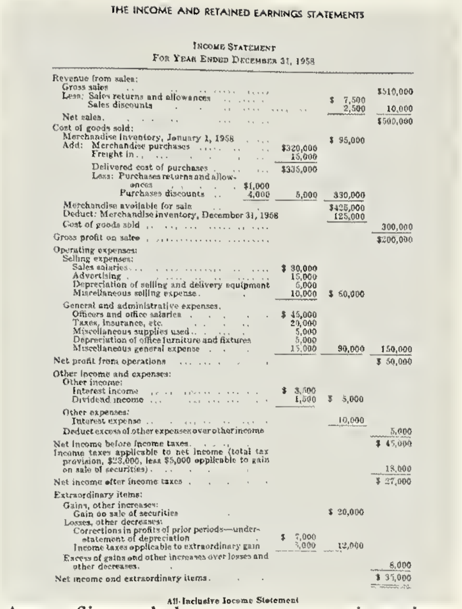
Gasoline pumps would eventually be modified

Putting price tags on benefits is even more problematic. Some metric calculations are easier; indeed, educators say schoolchildren learn the metric system more quickly, and time could be saved for other topics. Compatibility and interchangeability of military equipment used by the U.S. and its allies would facilitate repairs and maintenance.


Greater compatibility with our allies would reduce costs

Another category of benefits is not only intangible but also indirect. They are in the nature of by-products. People, while making the metric change, would have opportunities to do other worthwhile things that are not directly related to any measurement system. Translating textbooks into metric terms would provide opportunities for curriculum improvements. In thinking out new metric standards, engineers would have an opportunity to weed out superfluous sizes and varieties of parts and materials, and even to incorporate superior technologies. International standards activities would be facilitated.

Taking advantage of these opportunities would, in effect, be benefits and would therefore help to recoup the costs of going metric. In Britain, for example, major attention is being given to reducing unnecessary varieties during the change to metric. As an illustration, one manufacturing firm is well on its way to reducing its stock of fasteners (e.g., nuts, bolts, rivets) from 405 sizes to fewer than 200,


THE INCOME AND RETAINED EARNINGS STATEMENTS

INCOME STATEMENT
FOR YEAR ENDED DECEMBER 31, 1958

Revenue from sales:				
Gross sales				$510,000
Less: Sales returns and allowances			$ 7,500	
Sales discounts			2,500	10,000
Net sales				$500,000
Cost of goods sold:				
Merchandise inventory, January 1, 1958			$ 95,000	
Add: Merchandise purchases		$320,000		
Freight in		15,000		
Delivered cost of purchases		$335,000		
Less: Purchases returns and allowances	$1,000			
Purchases discounts	4,000	5,000	330,000	
Merchandise available for sale			$425,000	
Deduct: Merchandise inventory, December 31, 1958			125,000	
Cost of goods sold				300,000
Gross profit on sales				$200,000
Operating expenses:				
Selling expenses:				
Sales salaries		$ 30,000		
Advertising		15,000		
Depreciation of selling and delivery equipment		6,000		
Miscellaneous selling expense		10,000	$ 60,000	
General and administrative expenses.				
Officers and office salaries		$ 45,000		
Taxes, insurance, etc.		20,000		
Miscellaneous supplies used		5,000		
Depreciation of office furniture and fixtures		5,000		
Miscellaneous general expense		15,000	90,000	150,000
Net profit from operations				$ 50,000
Other income and expenses:				
Other income:				
Interest income		$ 3,500		
Dividend income		1,500	$ 5,000	
Other expenses:				
Interest expense			10,000	
Deduct excess of other expenses over other income				5,000
Net income before income taxes				$ 45,000
Income taxes applicable to net income (total tax provision, $23,000, less $5,000 applicable to gain on sale of securities)				18,000
Net income after income taxes				$ 27,000
Extraordinary items:				
Gains, other increases:				
Gain on sale of securities			$ 20,000	
Losses, other decreases:				
Corrections in profits of prior periods—understatement of depreciation		$ 7,000		
Income taxes applicable to extraordinary gain		5,000	12,000	
Excess of gains and other increases over losses and other decreases.				8,000
Net income and extraordinary items				$ 35,000

All-Inclusive Income Statement

A profit and loss statement is neither feasible nor necessary

and another is replacing 280 sizes of ball bearings with only 30 types made to metric standards.

The U.S. Metric Study sought estimates of benefits and costs from trade associations, labor unions, business firms, government agencies, educators, importers and exporters, and others in a position to have firsthand knowledge of their fields. The "Methodologies" section of Appendix One describes how these data were solicited.

Profit and Loss

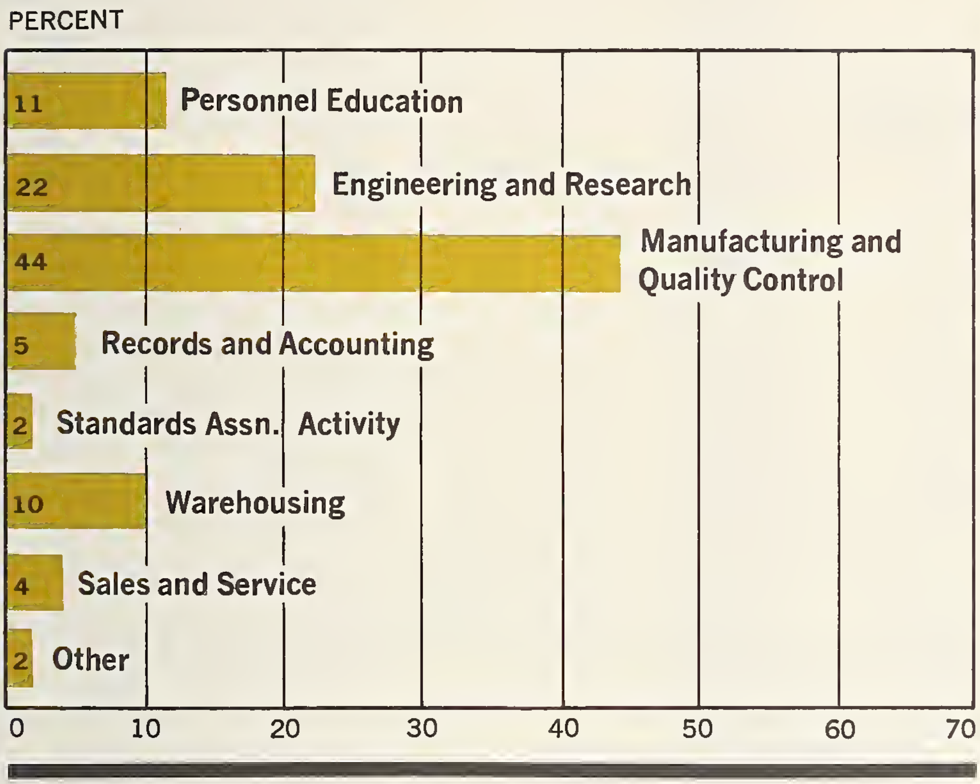
The ideal outcome of this procedure would have been a simple aggregate figure—like the bottom line of a profit-and-loss statement—representing the net benefit (or cost) to the nation of going metric under a coordinated national plan. The figure would have resulted from adding estimates of all aggregated benefits and all aggregated costs and finding the difference between the two totals.

This conceptually simple approach was not feasible. First, few of the groups from whom benefit and cost data were solicited were able to furnish them. Second, the benefits and costs are not directly comparable, inasmuch as they would occur at different times. Virtually all the costs would be incurred during the transition period, at a time when benefits were just beginning. Most of the benefits would come after the transition. Third, the majority of benefit and cost items are basically elusive—perhaps even unknowable in dollar terms. As was pointed out above, some are intangible; others cannot be attributed purely to a metric change.

Comparative Analysis

The main objective, however, is not to arrive at absolute figures for benefits and costs. Rather, it is to determine which is more advantageous to the nation: deliberately going metric by plan, or eventually going metric without a plan. This requires a comparative analysis showing a clearcut differential between two aggregates whose values can be stated only in relative terms.

Manufacturing Industry Survey:
Allocation of Estimated Costs of Going Metric

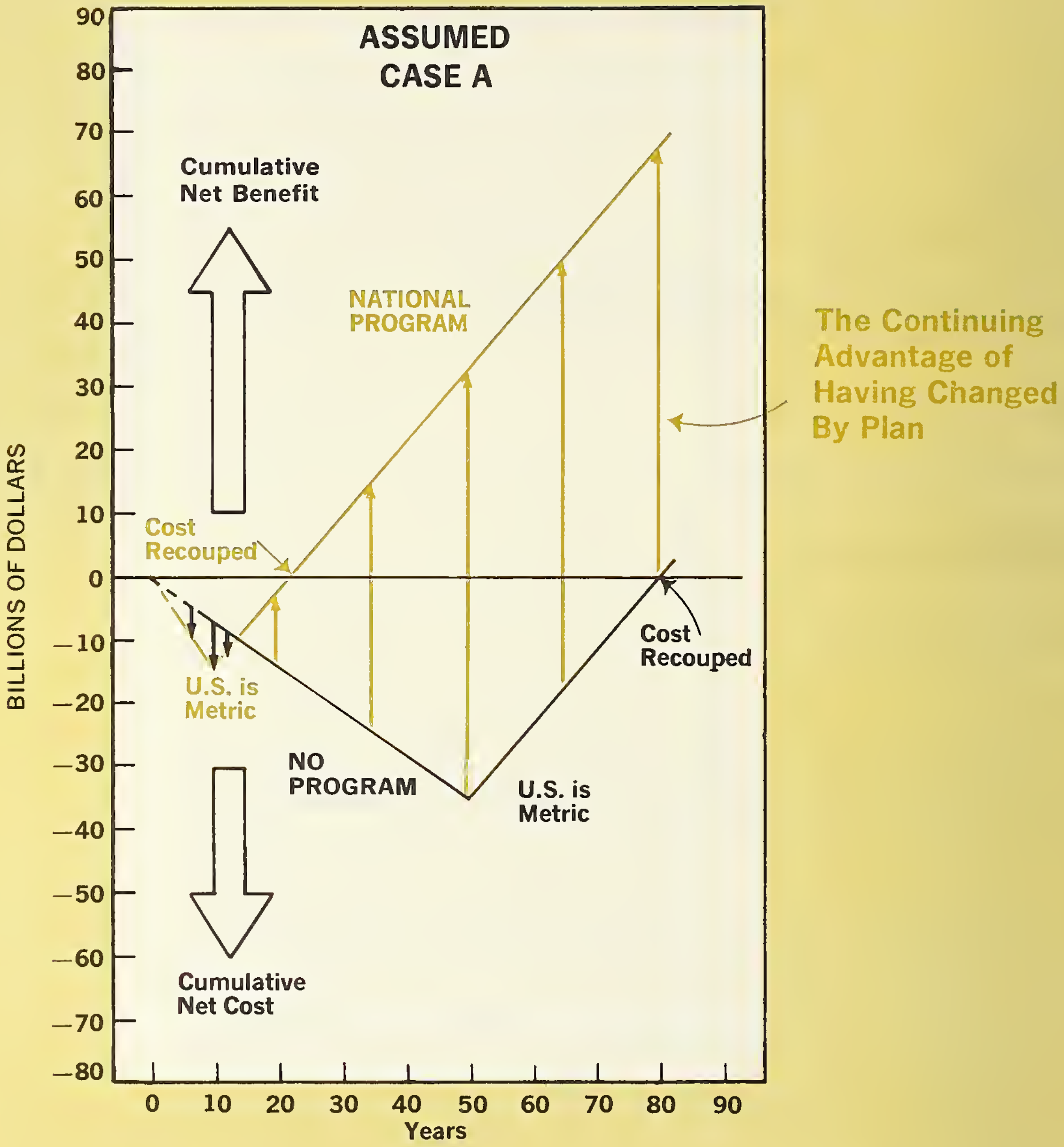



The data obtained in the manufacuring survey permit a comparative analysis.

The responses in the surveys of the manufacturing industry and of international trade permit such a comparative analysis. The manufacturing survey itemizes costs in such a form that it is possible to derive what the costs would be if the change were made without a plan. Moreover, the data provide a way of deriving benefits from estimates of the time required to recoup costs. In addition, exporters and importers in the international trade survey estimate a modest but favorable increase in the nation's trade balance following conversion to metric, and this can be translated in terms of an economic benefit. These derived economic benefits are applied in the analysis to both the changeover by plan and the changeover without a plan.

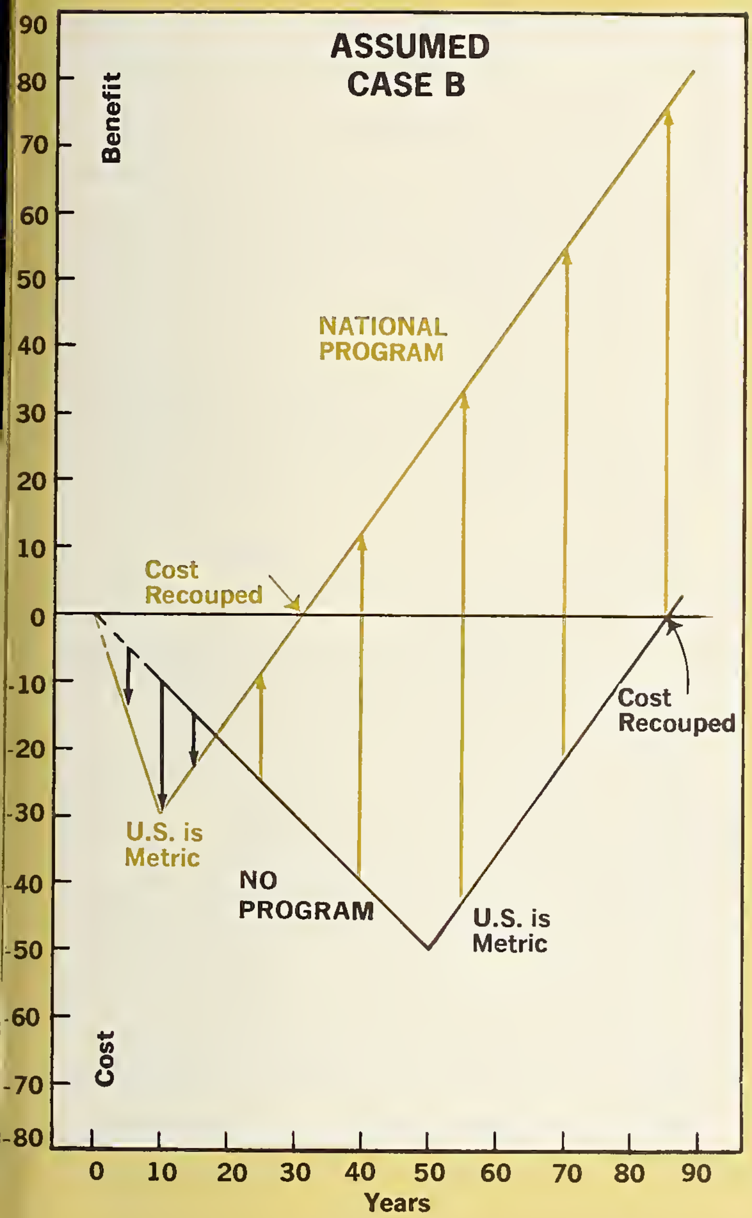
The diagrams on the next two pages illustrate the advantages to the manufacturing industry of changing to metric through a coordinated national program rather than changing without one.

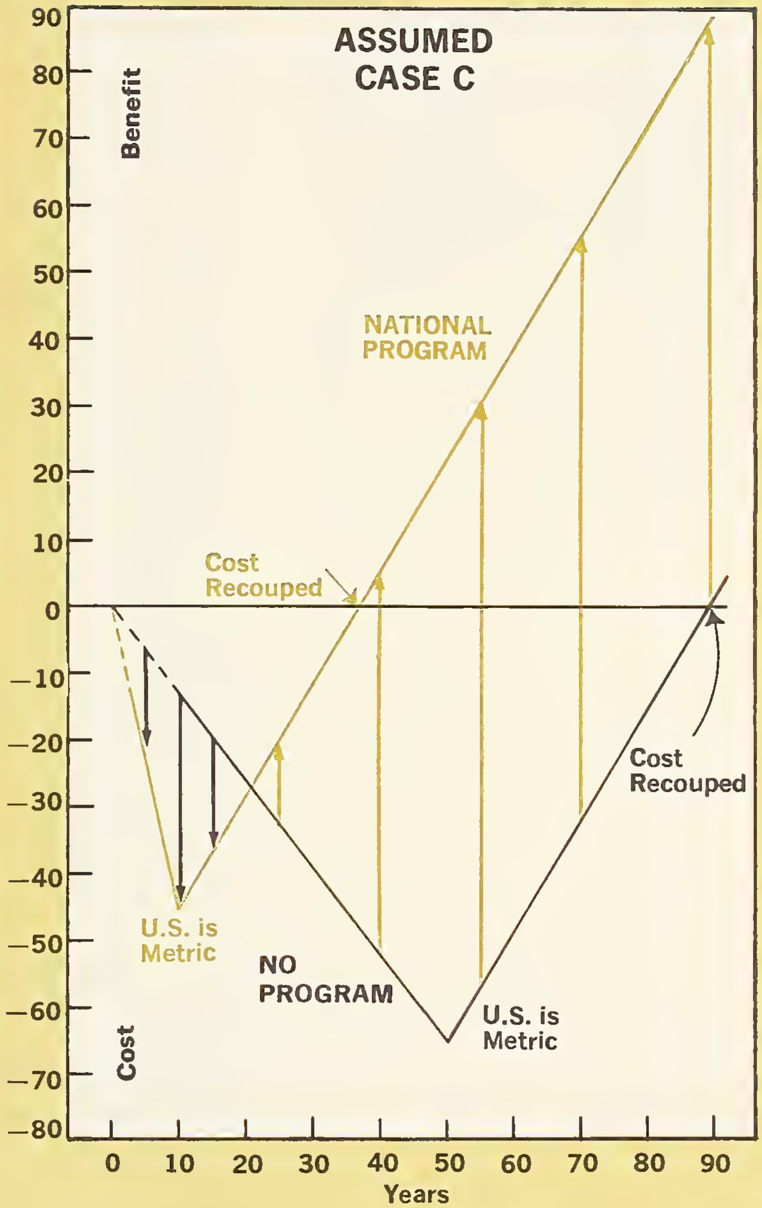
The Economic Advantage of Going Metric by Plan—Manufacturing Sector



These three diagrams illustrate the advantage to the manufacturing industry of a change to metric under a coordinated national program. The basic data and the assumptions used to construct the diagrams are explained on the following pages.

Case A assumes a total "Base" cost of $10 billion; Case B, $25 billion; and Case C, $40 billion. Lower and higher costs can also be assumed; but no matter what figure is used, there is a clear-cut advantage (the length of the colored arrows) in changing to metric by plan rather than drifting without one.





Assumed Average Annual Costs (Billions of Dollars)

	Case A		Case B		Case C	
	Program	No Program	Program	No Program	Program	No Program
"Base" Cost	1.0	0.2	2.5	0.5	4.0	0.8
Dual Capability Cost	0.5	0.5	0.5	0.5	0.5	0.5
Combined Cost	1.5	0.7	3.0	1.0	4.5	1.3

Annually averaged benefits and costs were used in order to simplify the diagrams by making all lines straight. But a more complex model would not change the relative advantages and disadvantages illustrated in the three cases shown above.

Basic Data and Assumptions used in Constructing the Benefit-Cost Diagrams on the Two Preceding Pages

Information about benefits and costs comes from two of the special investigations conducted in connection with the U.S. Metric Study: the surveys of manufacturing industry and of international trade. Certain of the data that were collected have been augmented by a limited number of conservative assumptions in order to construct the illustrative model discussed below. It identifies benefits and costs, cumulative with time, that might be expected by the manufacturing segment of society during a changeover to metric, carried out according to a national plan, and it compares them with corresponding benefits and costs during a metric changeover proceeding without plan.

There are two assumptions as to time. The period of transition to metric under a planned changeover is taken as 10 years, a period that most participants in the manufacturing survey found close to optimum for their own firms. The transition period for changeover without plan is taken as 50 years. This is an arbitrary choice, but at the rate that the use of the metric system is now increasing, it may be said to be roughly the time that will elapse before the nation becomes predominantly metric without any concerted program. The actual period might be longer or shorter; there is no way of knowing. The important point, however, is that the assumption of the 50-year period is not critical to the outcome of the analysis. As the reader can discover by redrawing the diagrams, using any other period greater than 10 years, the sign (positive or negative) of the benefit-cost differentials between plan and no plan will not be changed and the advantage of plan over no plan will still hold.

Benefit-Cost Assumptions

The assumptions as to benefits and costs were made on a "worst-case" basis. That is to say, when a choice was possible, it was made so that the no-plan mode of changeover was put in the best light.

The manufacturing survey identified two kinds of costs for a planned changeover: the average annual cost of maintaining dual capability for the manufacture of standard parts and materials (i.e., about $0.5 billion per year); and the total cost for all other manufacturing. *Any value can be assumed for the second kind of cost,* which in this analysis (and in the diagrams) is called the "Base" cost (p. 101).

For the purpose of this comparative analysis between plan and no-plan, it is assumed that the average annual cost of maintaining dual capability for the manufacture of standard parts and materials is the same in both cases. Yet an important reason for having a planned program is to reduce the period during which such duality would be necessary. Consequently, it would be reasonable to assume a higher average annual cost for duality under a no-plan approach. The assumption that this cost would not be higher is an element in the worst-case approach.

An important reason for having a planned program is to reduce the period of having to cope with two systems

It is also assumed that as to all other manufacturing the "Base" cost under the no-plan mode would be the same as that under a planned program. Yet the main purpose for having a planned program is to minimize breakdowns in cooperation and coordination during a changeover, so that metric parts are available when needed, metric products are in demand when they are made, new employees have been appropriately trained by the educational system. The assumption that costs due to mismatches would be no higher in the no-plan mode is another element in the worst-case approach.

In the manufacturing survey, among the questions asked in the case studies of costs were two that provide a basis for estimating benefits. The first was whether tangible savings would result from a change to metric. The second was how long it would take for these savings to compensate for the costs of going metric.

About one-fourth of the companies said that tangible savings would result and that these savings would compensate for costs over a period of 12 to 15 years. For the purposes of the analysis, the period of recoupment of costs is assumed to be 15 years. Moreover, since only one-fourth of the companies anticipated recoupment, the annual rate


Changing patterns of World Trade

of recoupment through tangible savings was divided by four. For example, in Case A (p. 101) the "Base" cost is assumed to be $10 billion; the total anticipated tangible savings over the fifteen-year recoupment period would be ¼ of $10 billion, or $2.5 billion.

The international trade survey concluded with a projection that after transition to metric the U.S. balance of trade would benefit to the extent of $600 million a year. The companies who contributed to this estimate based their judgments on the export and import of measurement-sensitive manufactured products; thus any costs in the redesign of these products to metric are already accounted for in the above cost figures from the manufacturing survey. The benefit to the economy of a marginal improvement in the trade balance can be calculated by using a multiplier of between 2 and 3 (see, for example, Paul A. Samuelson's basic text, *Economics*). Thus, the benefit to the economy of a $600 million favorable increment in the trade balance would be between $1.2 billion and $1.8 billion. But for the analysis the benefit is assumed to be only $1 billion per year.

In addition to the benefits identified as tangible in the manufacturing survey report, it was indicated that "less tangible savings not covered by this estimate might be a more important factor." Therefore, these intangible savings could be taken as at least equal to the tangible savings; but for purposes of this analysis they are disregarded altogether.

The final assumption regarding benefits is that once metric predominance is achieved, the benefits to be derived after 50 years under the no-plan approach will be the same as those to be derived after 10 years of a planned program. Although a planned program would deliberately seek to exploit opportunities for recouping costs, and rapidly changing patterns of world trade and other relations suggest that a prolonged transition would result in foregoing some advantages, these considerations are disregarded in the worst-case analysis.

How the Diagrams Were Drawn

The key data and assumptions used to construct the diagrams on pages 100 and 101 have now been explained. The diagram labeled *Case A* can serve to show how this was done and how similar diagrams can be drawn using other assumptions as to the cost of a metric changeover under a planned national program. In *Case A* the "Base" cost of a planned metric changeover (colored line) is taken as $10 billion over the ten-year transition period ($1 billion per year), plus $5 billion ($0.5 billion per year) for maintaining dual capability for the manufacture of standard parts and materials. Thus the descending portion slopes downward at the rate of $1.5 billion per year. The ascending portion slopes upward at the rate of $7 billion every six years; this upward slope is a combination of tangible savings of $2.5 billion every 15 years and the $1 billion benefit per year from the enhancement of the balance of trade (explained above).

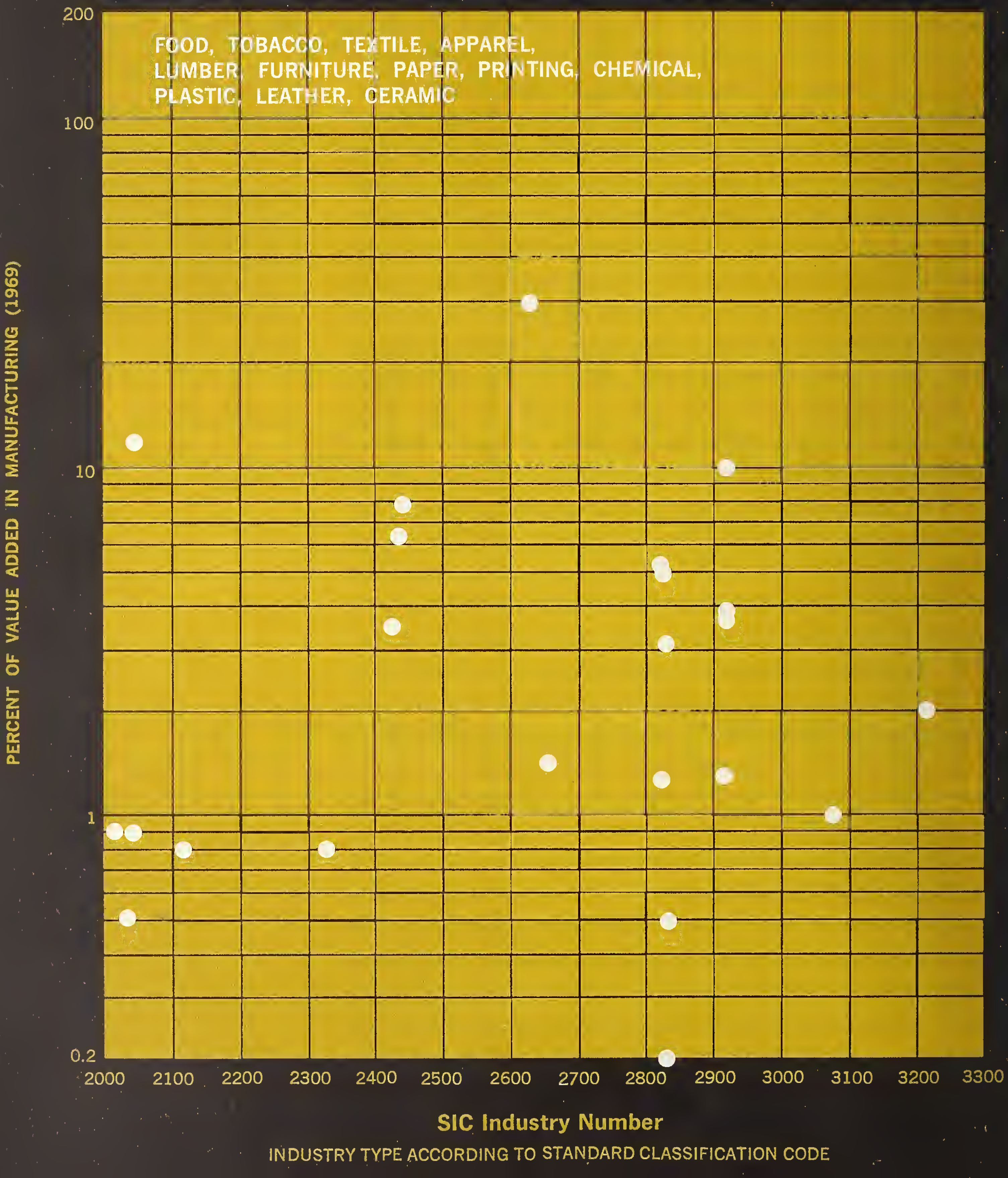
The black line in *Case A* represents a changeover without a national plan. The descending portion slopes downward at the rate of $7 billion every 10 years. This consists of $0.5 billion per year for the maintenance of dual capability plus $0.2 billion per year (the $10 billion "Base" cost of a metric changeover distributed over a period of 50 years). The ascending portion of the black line has the same slope as the ascending portion of the colored line, because both have identical components under the assumption that the benefits will be the same once metric status is achieved.

The Manufacturing Data

Estimates of benefits and costs were supplied by 126 manufacturing firms. This was by no means a random or representative sample of all U.S. manufacturing activities. Many companies, mainly manufacturers of measurement-sensitive products, were asked if they would make benefit-cost case studies of their own operations. Because of the considerable cost and effort required for such studies, in-

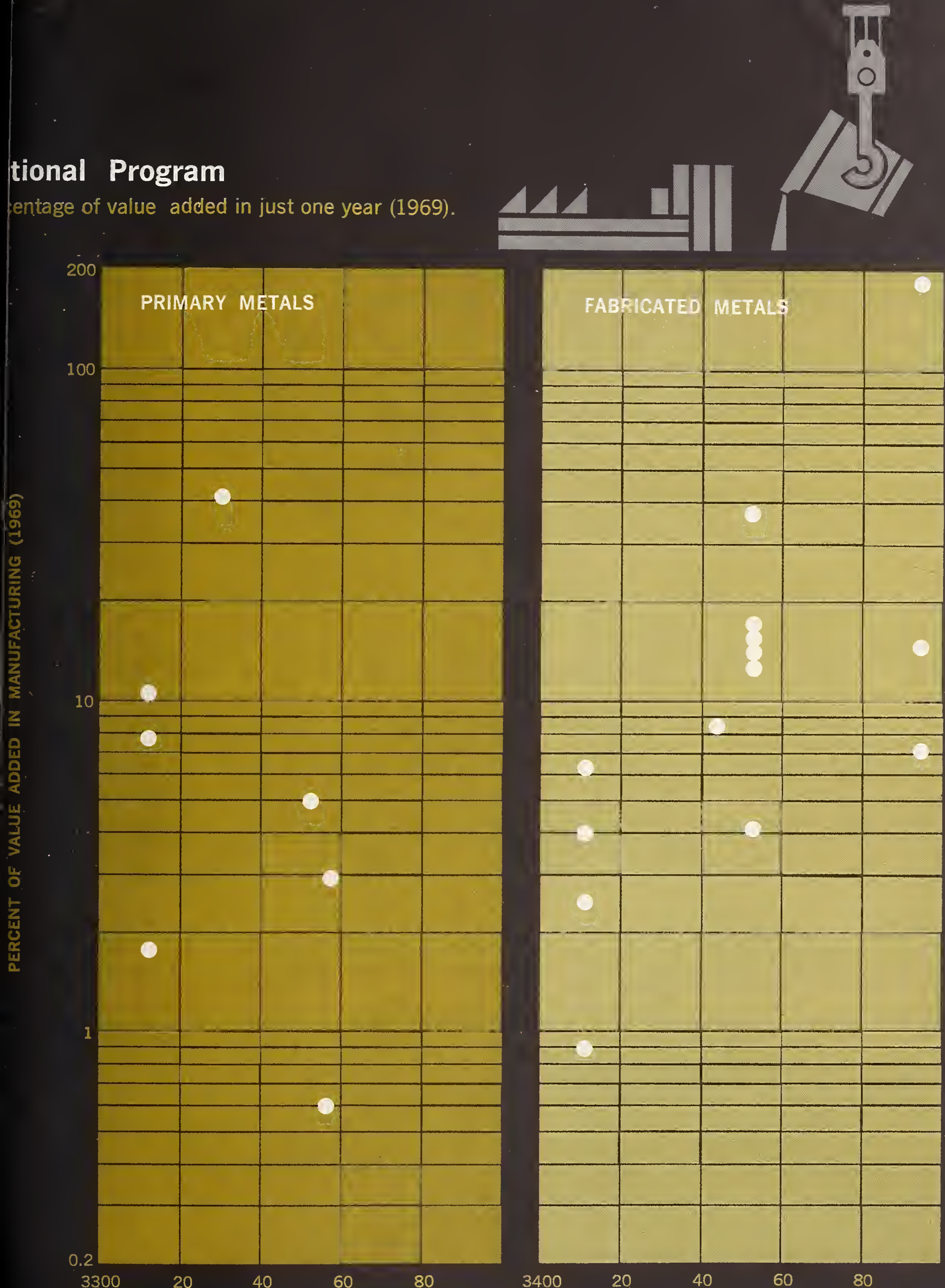
Manufacturers' Cost Estimates for Converting to Metric i

These estimates represent total costs of conversion, but are expressed



tional Program

centage of value added in just one year (1969).



SIC Industry Number

INDUSTRY TYPE ACCORDING TO STANDARD CLASSIFICATION CODE

Manufacturers' Cost Estimates for Converting to Metric i

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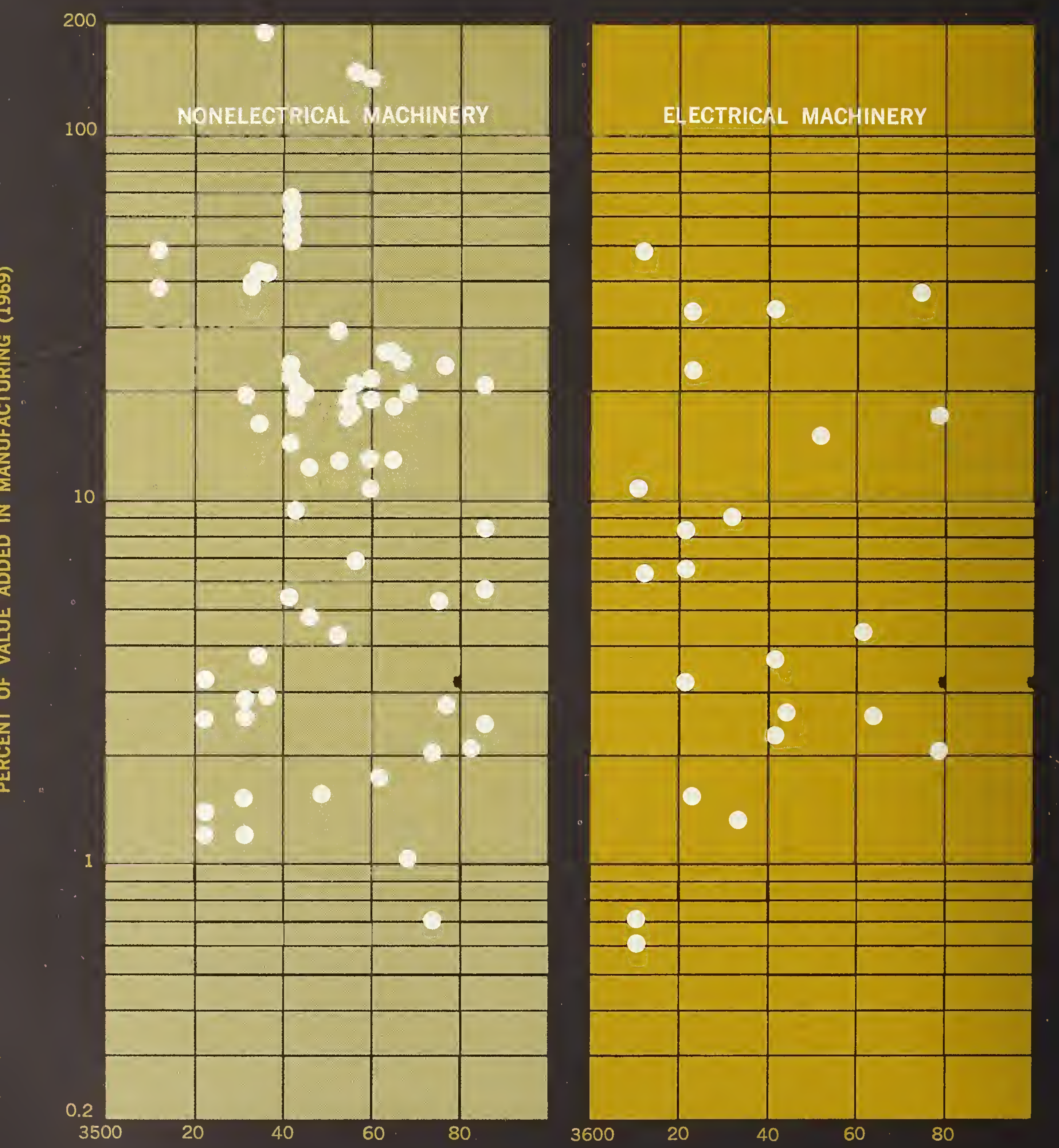

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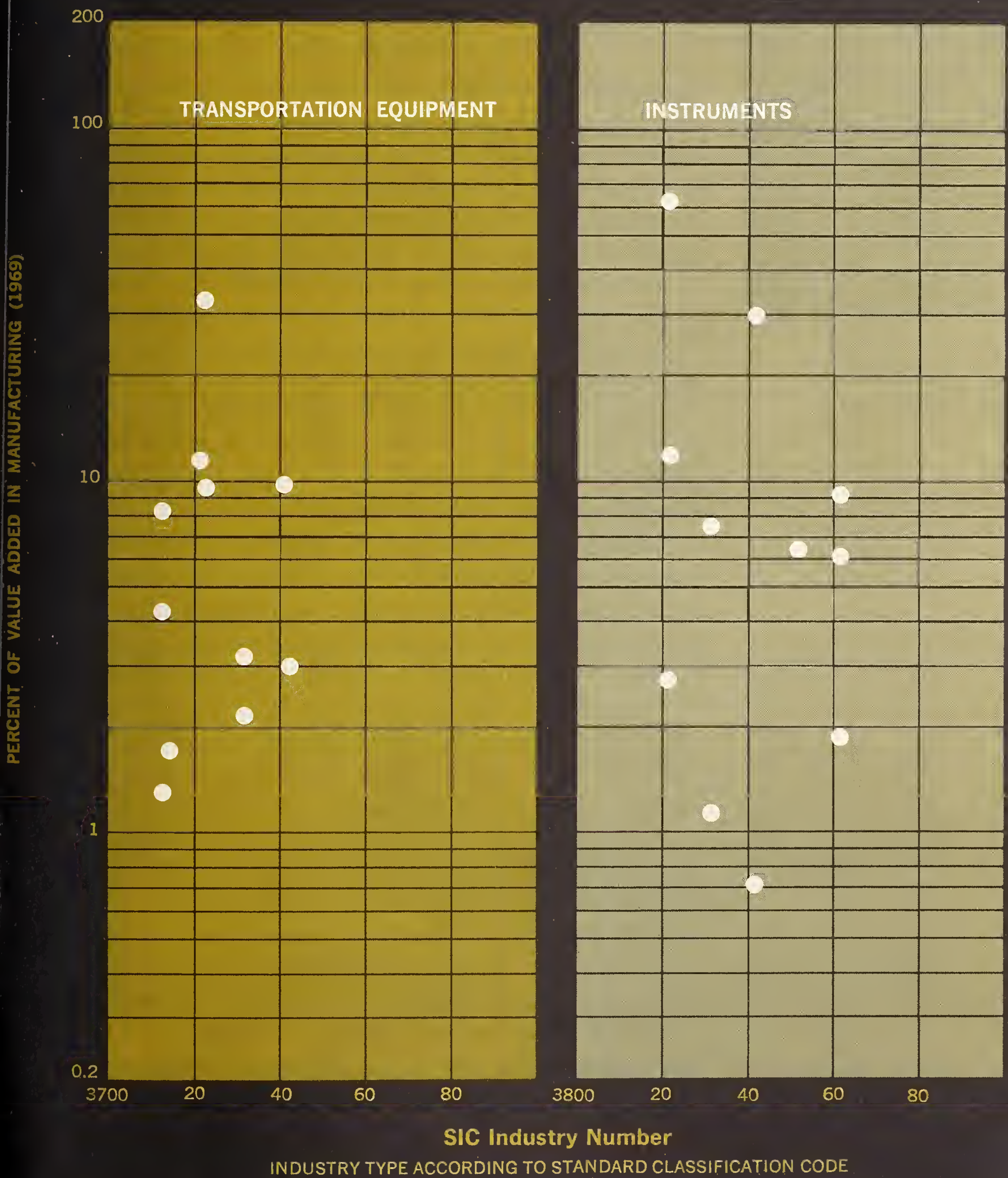
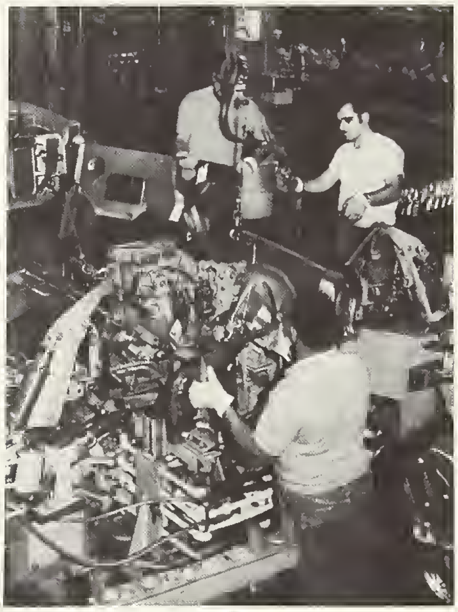



To project the estimates of measurement-sensitive firms to cover all manufacturing would result in an overestimate

formation was obtained from only 126 firms who were willing to participate in this phase of the Study. (See "Methodologies" section of Appendix One for details.)

By one method of extrapolation, which projected the cost estimates of these firms so as to represent the entire manufacturing industry, the total overall "Base" cost of going metric was calculated to be about $25 billion. This tentative aggregate cost for American manufacturing was subjected to further analysis, for two reasons. Experts on the manufacturing survey team judged that some of the reported cost estimates appeared unrealistically high, particularly in view of much lower estimates by companies making similar products (see the four preceding pages). Also, the firms who were asked to make the cost estimates were selected because they are engaged in the kind of manufacturing that would experience unusually high costs. It seemed to the experts that to project these costs without modification to cover the entire manufacturing industry would result in an overestimate.

The manufacturing survey team chose, therefore, to aggregate the estimated costs in the following manner. For each company, instead of gross costs, they considered cost as a percentage of value added in manufacture. Then they assembled the companies in groups that have common problems. Next, they assumed that in each group: (1) 1/4 of the companies overestimated costs and 3/4 of them underestimated, or (2) 1/2 overestimated and 1/2 underestimated, or (3) 3/4 overestimated and 1/4 underestimated.

These groupings and assumptions provided three possible cost aggregates for the manufacturing industry: (1) $32.6 billion, or (2) $14.3 billion, or (3) $6.2 billion. In their detailed analysis (published in a U.S. Metric Study special report: *The Manufacturing Industry*) the survey team concluded that the highest figure is excessive and that the actual figure probably lies somewhere between $6.2 billion and $14.3 billion. *In the final analysis, however, the important point is that it will be less costly and the benefits will come sooner, if the nation changes to metric by plan* *rather than leaving the change to chance.*

Cost Estimates From Other Sectors: Federal Government

Estimates for some other segments of society were provided in various ways (see "Methodologies" section of Appendix One, p. 139).

Estimates of metric conversion costs were made in two surveys of the Federal Government: one concerning the Department of Defense alone, the other concerning 55 other agencies. Similar estimates were sought from state and local government representatives. For the most part these representatives found it not feasible to make estimates, but some of their major costs are reflected in the surveys on education and on commercial weights and measures.

The 55 Federal civilian agencies contributed information that indicated costs attributable to extra efforts during a metric change in a national program would be about $60 million annually over a ten year period. There was no information as to the probable annual cost of changing to metric gradually, without a national program.

The Department of Defense Metric Study estimated conversion costs on the basis of maintaining national defense at a constant level during a conversion period assumed to begin in July 1972 and to be effectively completed ten years later. The cost items included in the estimate were based on a number of factors identified by the Defense study team. They foresaw extensive change orders in weapons systems already in the development stage. Men would have to be taken off the job and retrained. More lead time would be required for new weapons and for maintenance. Industry would suffer temporarily from a decrease in efficiency and the Defense Department would have to pay more for its purchases. Manuals, regulations, orders, and other documents would need rewriting in metric language. And the Armed Services would need more warehouse space for dual inventories.

For all these changes the Defense study team estimated that appropriations for the Department of Defense over a 30-year conversion period would have to be increased by a total of $18 billion, most of it (about 75%) during the first 10 years. The British military agencies, in contrast, intend to absorb the added costs of a metric changeover within their normal budgets.

The Department of Defense report also listed a number of long-term advantages. Going metric would contribute to a worldwide harmonization of measurements, and this would save the time now spent in converting from one system to the other. The compatibility and interchangeability of equipment between the U.S. and its allies would expedite repairs, make possible support in areas where support is now nonexistent, simplify procurement across national boundaries, and increase the communication of all data, including design, operations, and training. Use of the metric system would reduce the total training time of mechanics, engineers, and others. It would also reduce the chance for error in computations. Conversion would encourage a "general modernization and updating of individual plant equipment, ground equipment, and shop hand tools." And the need for fewer conversions and difficult programming would reduce computer time.

The Department of Defense estimated the cost of going metric as part of a national program. It did not estimate the cost of having to change to metric without a national program. A comparative analysis similar to that made for the manufacturing industry was not possible, because the Department of Defense data are not organized in such a way that permits derivations of the kind made earlier in this chapter.

However, the analysis of the manufacturing industry suggests that in the absence of a national program the Department of Defense could expect to incur greater costs than it would incur during a national program. Indeed, one conclusion of the Defense study is: "It is imperative that close coordination be maintained between DOD and industry. *Lack of such coordination will extend the conversion process and greatly increase the costs of conversion.*"


Nonmanufacturing businesses were surveyed by telephone

Nonmanufacturing Businesses

Nonmanufacturing businesses were asked to judge their costs on a different basis from that used by the manufacturing industry, because the problems of metric conversion are not the same. For nonmanufacturing businesses, metric conversion would in general require considerably fewer changes in machinery, tools, and other physical things, although they might translate Customary dimensions into metric dimensions. They would also incur costs in retraining employees, maintaining dual inventories, and modifying or replacing scales, gasoline pumps and other weighing and measuring devices.


Thinking in metric while shopping.

Nonmanufacturing companies were asked to indicate how greatly a metric change would affect their annual cost of doing business. They did not conduct formal benefit-cost studies like those in the manufacturing survey. Instead, representatives of nonmanufacturing businesses expressed their opinions in telephone interviews. Most of them foresaw no significant change in their annual costs. Of the minority who anticipated a change, about one-half expected an increase, and the remainder expected a decrease or could not say one way or the other. On the basis of these responses it was not possible to derive a firm estimate of benefits and costs for the nation's nonmanufacturing businesses. Nor was it possible to make a comparative analysis between a planned metric changeover and one without a plan, in terms of benefits and costs.

The costs of adapting or replacing weighing and measuring devices is treated in a U.S. Metric Study special report, *Commercial Weights and Measures,* which is cited in Appendix Two of this volume. The total cost, which would be borne largely by nonmanufacturing businesses, is estimated at about $340 million.

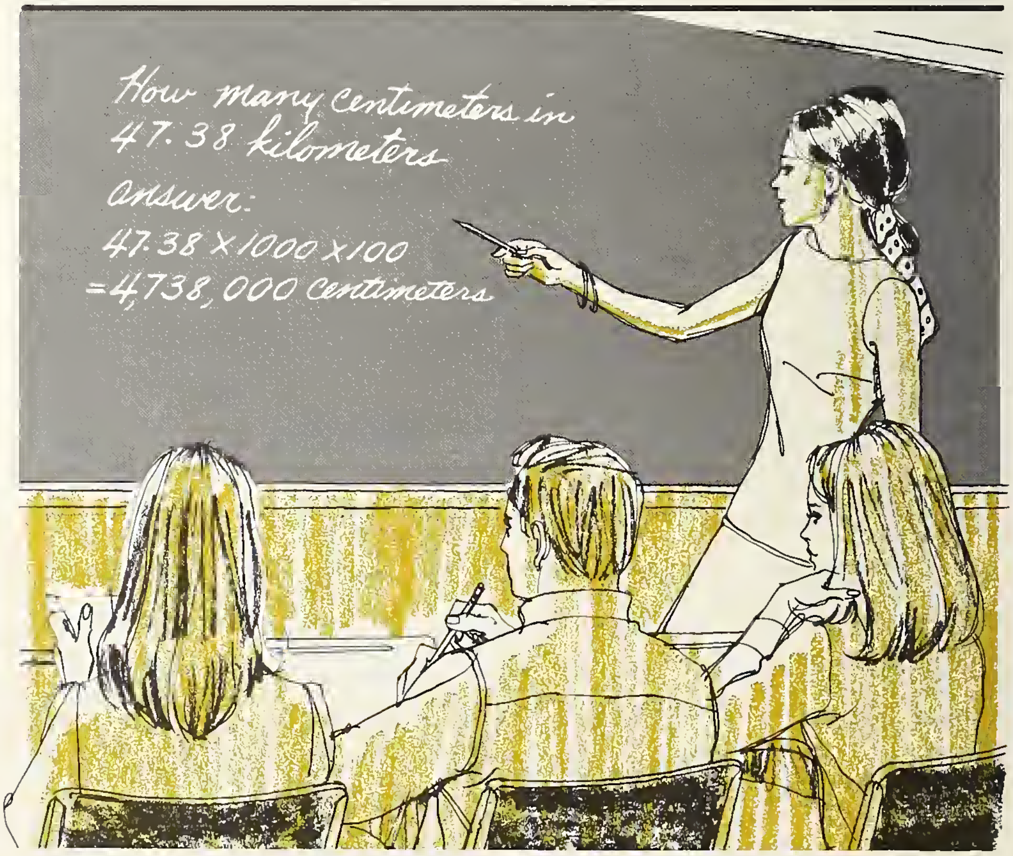
Almost 75 percent of the manufacturers of these devices and many weights and measures officials said there


So many meters high

would be benefits in using the metric system, chiefly because the metric system is more easily understood and thus, would help reduce time spent by employees in making calculations. The special report points out that "such a benefit, even if substantial, is difficult to express in quantitative terms, and no interviewee offered any analysis showing this benefit in dollars and cents."

Labor

Labor unions are concerned about possible costs to their members for new tools and also for retraining. They suggested that these expenses should be borne by employers. Employers did, indeed, view retraining and tool replacement as major cost items in their own estimates. On the other hand, some craftsmen are self-employed and might have to spend up to several hundred dollars for new

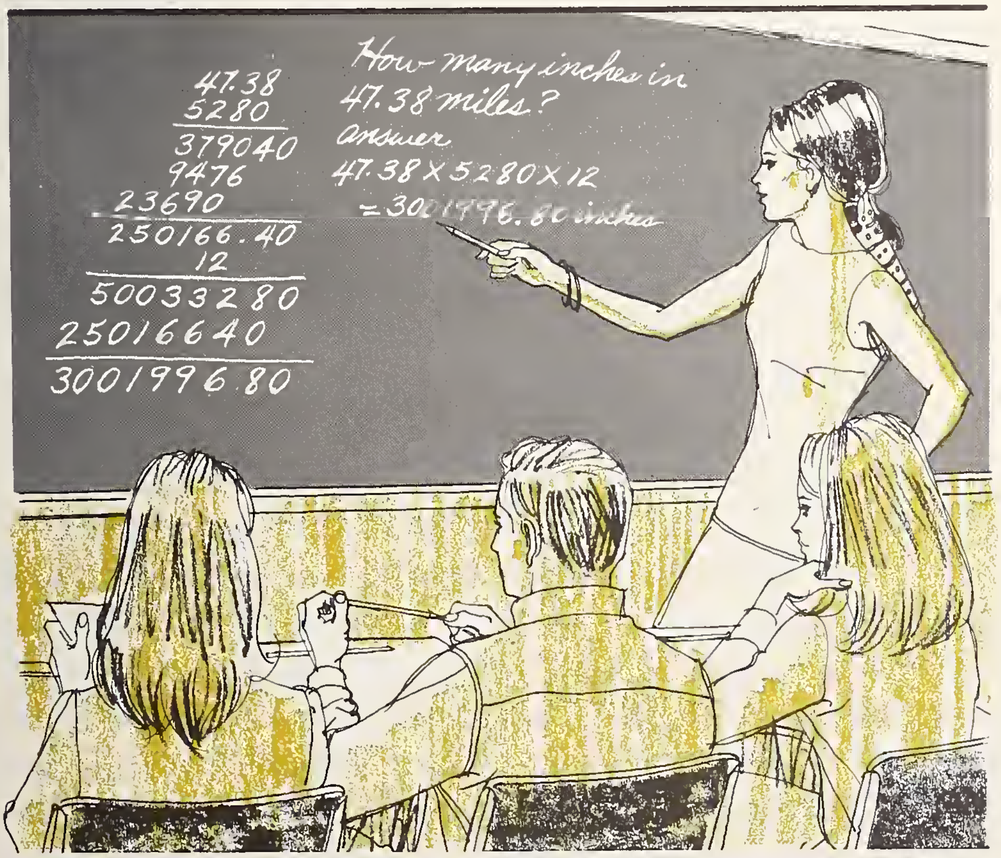


SIMPLIFIED METRIC EQUATION

tools as the nation changes to metric—regardless of whether there is a national program.

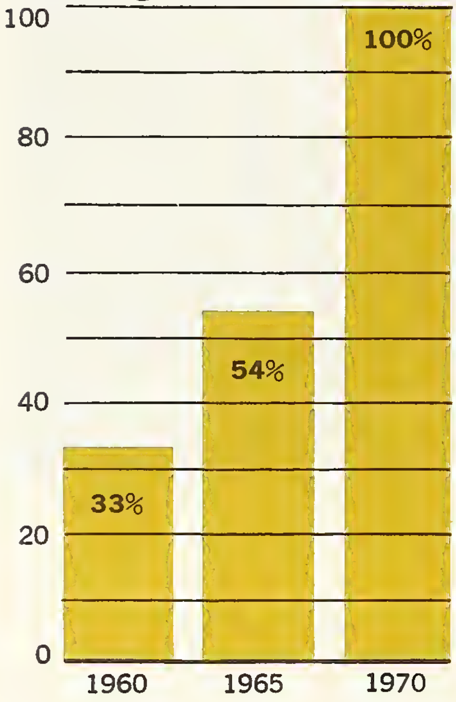
Some labor leaders are more deeply concerned about a more subtle cost, which can be termed "loss of experience." Take the automobile mechanic who, after years on the job, instinctively reaches for the right wrench to loosen a bolt. When working for the first time, or even the tenth time, on a metric engine, he cannot rely on his instinct. (This problem has already arisen owing to the increasing use of metric.) The mechanic unfamiliar with metric tools works slightly more slowly, less surely, and is therefore not quite so productive for a while. If he is a senior craftsman, he may even be at some disadvantage with respect to a metrically trained newcomer. Such examples are easy to envision for many other crafts and industries. No dollar estimate was given for this "loss of ex-

The problem is already with us



CUSTOMARY U.S. EQUATION

U.S. Grade School Mathematics Textbooks Using Some Metric



perience." In any case, however, it would be important to ensure that this problem is dealt with equitably in the design of a national plan.

Education

Educators and the firms that work with them see substantial benefits more than compensating for the costs of a metric changeover. The education survey, conducted as part of the U.S. Metric Study, indicated that changing textbooks and equipment would cost about $1 billion spread over three to five years. If they were changed for no other reason than going metric, the cost could be attributed to a metric changeover. *In fact, however, most textbooks are replaced anyway after a few years of use* and, thus, most of the $1 billion could be completely absorbed and would not appear as an extra item in school budgets. Indeed, new science curricula based on the metric system are already planned for schools.

Training teachers who are still not familiar with the metric system would represent another expense. But since most teachers these days pursue programs of continuing education, the cost would probably be inconsequential and could be absorbed if the conversion were made over a period of several years. It was suggested during the public hearings that much teacher instruction in metric could be done through programs on educational television.

The intangible benefits of going metric might well be substantial. Some teachers pointed out, for example, that it is very difficult for small children to learn to interpret the graduations on a Customary ruler; centimeters and millimeters are conceptually much simpler than small fractions of an inch.

Citing a study it had sponsored, the American Association for the Advancement of Science mentioned an additional intangible benefit. It has been found that slower children learn metric more readily than they do the Customary system—a factor that could not possibly be expressed in monetary terms.

Much more important, though, is the time that could be saved if students did not have to be drilled in the fractions necessary to cope with the Customary system. Estimates varied, but mathematics teachers said that in elementary school they spend from 15 to 25 percent of their class time driving home the details of adding, subtracting, multiplying, and dividing common fractions. They believe much of this is unnecessary. If the metric system, with its simpler decimal relationships, were taught, they could rapidly give their pupils the basic principles of fractions and then move on to other useful aspects of mathematics.


Extra time to teach and learn is an economic cost; time saved is an economic benefit

The Australian metric study (see Appendix Two) arrived at an almost identical conclusion: "There seems no question that considerable time would become available for valuable new work if metric units were taught in place of the Imperial. The arithmetical procedures required for use with the metric system would be no different from those of ordinary decimal work and money sums, which would give a unity to this phase of mathematical education . . . Various estimates have been made of the actual saving in time which would result from the adoption of the metric system. The British Association for the Advancement of Science and the Association of British Chambers of Commerce estimated in 1960 that there would be a saving of 20 percent in the teaching of arithmetic or 5 percent in the total school time for children between seven and eleven years."

* * * * *

The cost and inconvenience of a change to metric will be substantial, even if it is done carefully by plan. But the analysis of benefits and costs made in this chapter confirms the intuitive judgment of U.S. business and industry that increasing the use of the metric system is in the best interests of the country and that this should be done through a coordinated national program. There will be less cost and more reward than if the change is unplanned and occurs over a much longer period of time.

Two Paths to Metric: Britain and Japan

Of the countries that have changed to the metric system since World War II, or are now well under way, Japan and Britain are the largest industrial nations. Each approached conversion in its own way. Although neither program would serve as an exact model for the U.S., there are lessons to be learned from both in the event that this country decides to change to metric by plan, as recommended by this report.

"The educational effort . . . greatly facilitated the changeover. However, . . . educating just the children was not enough."

Japan's Zigzag Approach

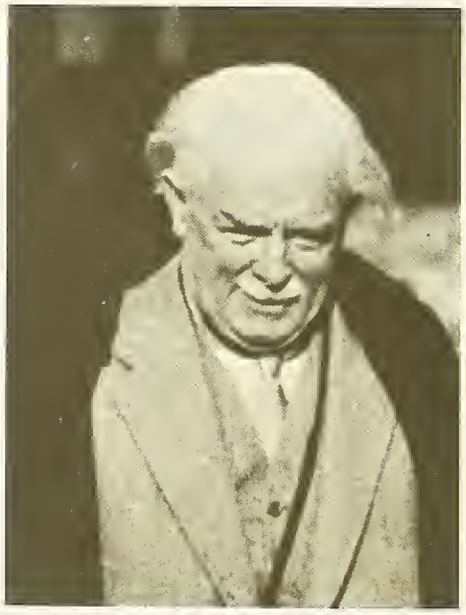
Japan began the approach to the metric system years before it had emerged as an industrial power. Interrupted first by the depression and then by the war, the program proceeded so haltingly that the goal was not reached for fully 40 years.

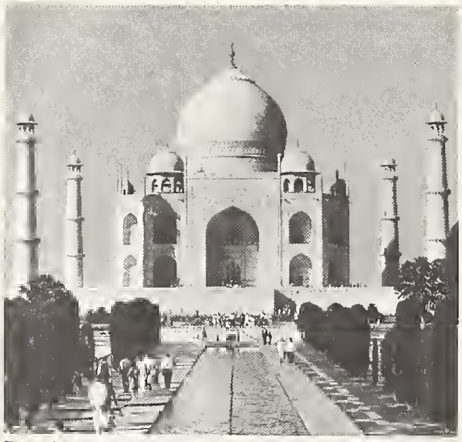
In 1921 Japan had three officially recognized measurement systems: metric, English, and a traditional system based on the *shaku* (11.930 inches) and the *kan* (8.267 pounds). In that year the use of the metric system was extended by law, at the expense of both other systems, and introduced into primary schooling. Plans were made for public utilities, government agencies, and a few industries to convert to metric over a ten-year period. Other sectors of the economy were allowed twenty years to make the change. But conversion progressed slowly and the periods were lengthened by 50 percent.

In 1939 a new law restored the *shaku-kan* system to equal footing with metric and also postponed final conversion to metric until 1958. Then at the end of the war, during the occupation, U.S. measurement units came into wide use. Finally, in 1951 still another law affirmed the 1958 target date for total metric conversion, and although the schedule was not met, the changeover was essentially completed in the early 1960's.

The Japanese made the metric system compulsory by edict of the Diet in the Measurement Law of 1951. Much of the final planning was directed by a Metric System


Parliament almost adopted metric in 1871


"Do you expect the British Workingman to . . . ask for .56825 litre of beer?"


In the 1950s India led the Commonwealth in the change to metric

Promotion Committee, a quasi-public agency, which worked closely with the Ministry of International Trade and Industry.

Two Lessons

If the U.S. decides to go metric by plan, what can be learned from Japan's experience? The educational effort begun in the schools more than a generation earlier greatly facilitated the final changeover. However, Japan's zigzag course to metric was largely due to the lack of a strong promotional effort in the initial stages; educating just the children was not enough. As Dr. Mitsuo Tamano, Director of Japan's National Research Laboratory of Metrology, said about the last stage of the changeover: "From the earlier bitter experiences, we felt the need of a strong campaign for the promotion of the metric system, lest we should repeat the same failure as before"—i.e., the repeated stalling of the program.

Britain's March to Metric

The British took much longer to make up their minds, but once they decided to go metric, they moved steadily forward. Oddly enough, a century ago Britain very nearly became one of the early metric nations. In 1871, Parliament considered making the metric system compulsory for all purposes after a two-year crash conversion program; the motion was defeated by only five votes.

There were a number of debates in Parliament between 1871 and 1907. In 1897 it was made lawful to use metric measurements for most purposes. In 1907 there was another effort to make the use of the metric system compulsory but this was defeated, and Mr. Lloyd George, then President of the Board of Trade, dismissed the proposal facetiously by commenting, "Do you expect the British workingman to go into a public house and ask for .56825 litre of beer?" Going metric or, as the British say, "metrication," was not seriously considered again until the middle of this century.

Renewed interest in metrication dates from a 1950 report of a departmental committee on weights and measures. After detailed study, the committee arrived unanimously at a number of conclusions. The metric system was inherently better than the Imperial system then in use. A change for all trade purposes was sooner or later inevitable. Meanwhile the dual use of both systems would in the long run cause extra inconvenience. The long-term advantages of an organized conversion would far outweigh the inconveniences of making the change. Besides, the committee made two important provisos: that change should be made in concert with the United States and British Commonwealth countries, and that prior to metrication British currency should be put on a decimal basis.

The report had little immediate impact. At that time British industry and commerce were against making a change while the U.S. and most of the Commonwealth, which were then Britain's main trading partners, still adhered to inches and pounds. Ten years later a committee of the British Association for the Advancement of Science and the Association of British Chambers of Commerce reported that a majority of industry still considered the time not ripe to make the change.

Industry Leads the Way

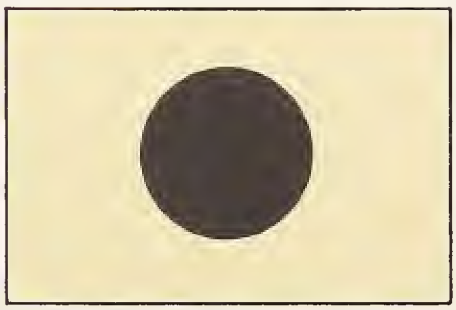
Then as more and more countries, including several members of the Commonwealth, shifted to the metric system and as the proportion of trade with metric countries increased, the balance of opinion shifted rapidly. In 1963 the British Standards Institution published a broad survey of industrial opinion which found a large majority of British firms in favor of starting metrication immediately, without waiting for the U.S. and the rest of the Commonwealth.

British industry itself took the initiative. In 1965 the president of the Federation of British Industries (roughly equivalent to our National Association of Manufacturers) informed the Government that a majority of firms favored adoption of the metric system as the primary and, ultimately,

UNITED KINGDOM
10 YEAR PROGRAM

AUSTRALIA
10 YEAR PROGRAM

NEW ZEALAND
7 YEAR PROGRAM



JAPAN
40 YEAR PROGRAM
(Interrupted)

Symbol for British Metrication.

the only method of measurement to be used. The Federation asked the Government to support the principle and to aid the scheduling of conversion.

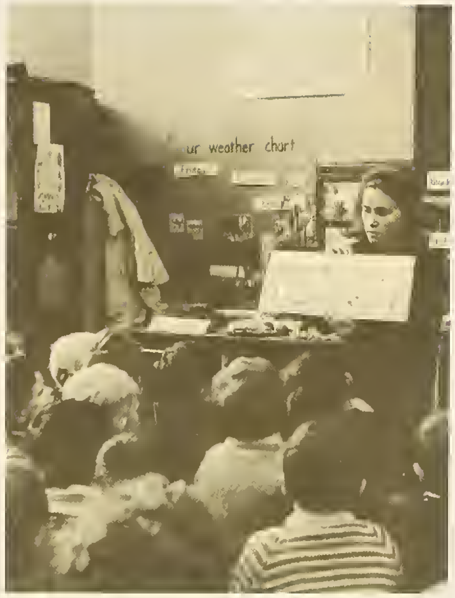
The Government's reply to this proposal was prompt and favorable, although it left most of the initiative with industry. It said in part: ". . . the Government considers it desirable that British industries on a broadening front should adopt metric units, sector by sector, until that system can become in time the primary system of weights and measures for the country as a whole . . . . We shall also encourage the change to the metric system as and when this becomes practicable for particular industries, by seeking to arrange that tenders for procurement by the Government and other public authorities shall be in terms of metric specifications."

Two Years for Planning

Britain had chosen the road to metrication, although more than two years of study were required before the program could be launched. In the summer of 1968 the Minister of Technology again reported on the subject. He made three major points: that manufacturing industry can make the change efficiently and economically only if the economy as a whole moves in the same direction on a broadly similar time-scale, and in an orderly way; that a Metrication Board should be established to guide, stimulate, and coordinate the planning for the transition; and that any legal barrier to the use of the metric system—e.g., tariff and other regulations written in Customary—should be removed. Every sector of the economy need not move at the same pace, he said, but central machinery—the Metrication Board—was needed to coordinate the change.

Thus, the stage was set for metric conversion. The Metrication Board was made a purely advisory body with representation reflecting the interests of industry, distributors and retailers, education, and the general public. No compulsory powers were sought or granted. As for the expense of conversion, the Minister stated: "There can be no question of compensation; the costs of adopting metric must lie where they fall." Finally he confirmed 1975 as a target date for conversion, with the possiblity that some sectors of the economy might aim at somewhat earlier or later dates.

The policy of the current (Conservative) Government toward metrication was expressed by the Minister for Industry, in the House of Commons in late 1970, when he said: "British industry has been moving steadily toward the adoption of the metric system. The previous Government indicated in 1965 that the process would be largely completed in ten years. That still seems to be the generally accepted view, and the Government acknowledges that it is a realistic forecast of the date by which the greater part of British industry will have adopted metric weights and measures." A White Paper detailing Britain's current policy toward metrication is expected to be issued soon.



"From the start the British have counted heavily on the educational system . . . "

As this report of the U.S. Metric Study goes to press, the British Metrication program is one year past the halfway point. Almost all the planning has been done, and in some sectors conversion is nearing completion. The chart on page 124 shows in some detail the scheduling for most of the major British industries. The remainder of this chapter summarizes accomplishments and problems in certain crucial areas.

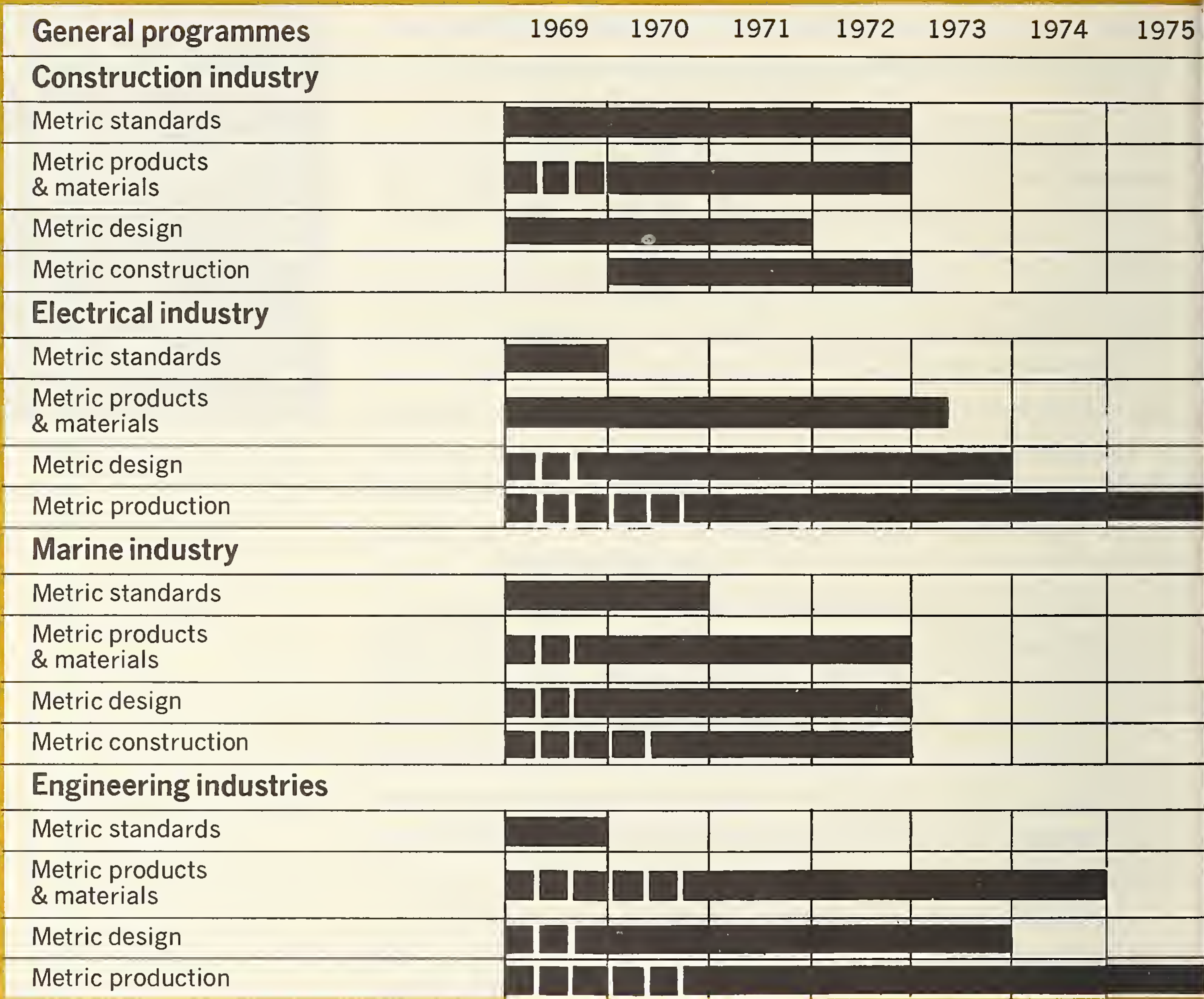
Education

From the start the British have counted heavily on the educational system to make metrication smoother and lasting. The children now entering primary schools are learning to think in metric terms, as naturally as their mothers and fathers thought in terms of inches and pounds. Those in higher education are breaking the habit of thinking in terms of the old units.

Teachers in primary schools are satisfied that the metric system will save time and effort. They will not have to spend valuable hours on the intricacies of the Imperial system, which generally makes arithmetic harder. British

BRITISH TIMETABLE FOR

Industrial metrication programmes



Legend

Build up

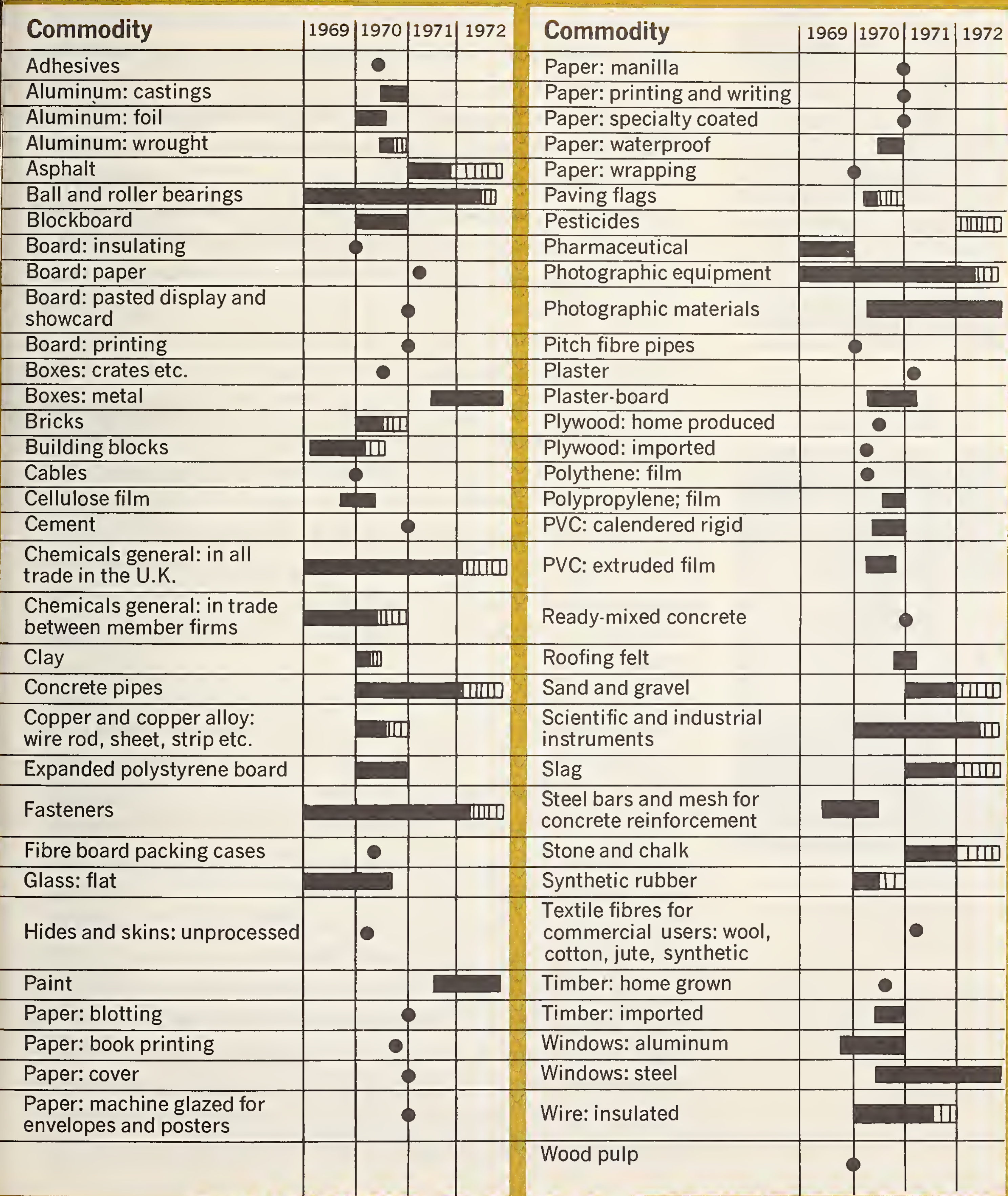
A planned changeover period during which both current imperial and new metric sizes/ quantities should be available.

Subsequently, only metric sizes/quantities will be available as standard.

A changeover period has been recommended but the precise timing and duration will be decided by individual companies.

The industry is planning to go metric on a particular date and no prolonged changeover period is foreseen.

Announced programmes for products and materials



Firms are finding that retraining for metrication is easier than was feared

schools are more independent in their choice of curricula than are U.S. schools. But regional and national examinations will by 1973 require the use of metric terminology. Headmasters who want their pupils to do well will train them in metric.

Publishers and makers of educational equipment are already well ahead in the production of texts and apparatus that conform to the metric system.

Future teachers now enrolled in colleges and schools of education are already being trained to teach in the metric system and should be familiar with it by the time they take their first jobs.

Vocational Training and Retraining

Here again, in this special area of education, the emphasis has been on teaching people to "think metric" on their own, rather than to rely on converting measurements from the more familiar inches and pounds. For the majority, the amount of new knowledge and reeducation needed has proved slight and easy to acquire on the job in a short time. Firms are finding that retraining for metrication is not the formidable obstacle it was feared to be at the outset of the program.

Vocational schools and technical institutes design their curricula to the needs of specific industries, and they are generally pacing their change to metric training according to the industries' metrication plans. The Council for Technical Examining Bodies, for example, has already published proposals for "metricating" examinations for trainees and workers in the leading industries: construction, industrial materials, engineering, mining, forestry, paper and printing, and shipbuilding.

The Industrial Training Boards have been active in preparing guidance for their industries on training needs. The Construction Industry Training Board, which has led the way in metric retraining, found itself with an exceptional problem. This stemmed partly from the decision of the industry to press forward with dimensional coordination and partly from the nature of the industry itself, with its large proportion of small firms.

For the most part, individual firms were not prepared to handle the necessary retraining as larger firms have generally been doing. Accordingly the Construction Industry Training Board has taken on a major role in providing training aids. In most other industries, the training boards are playing a more modest role in connection with metrication, and some have adapted to their own needs the training aids prepared for the construction industry.

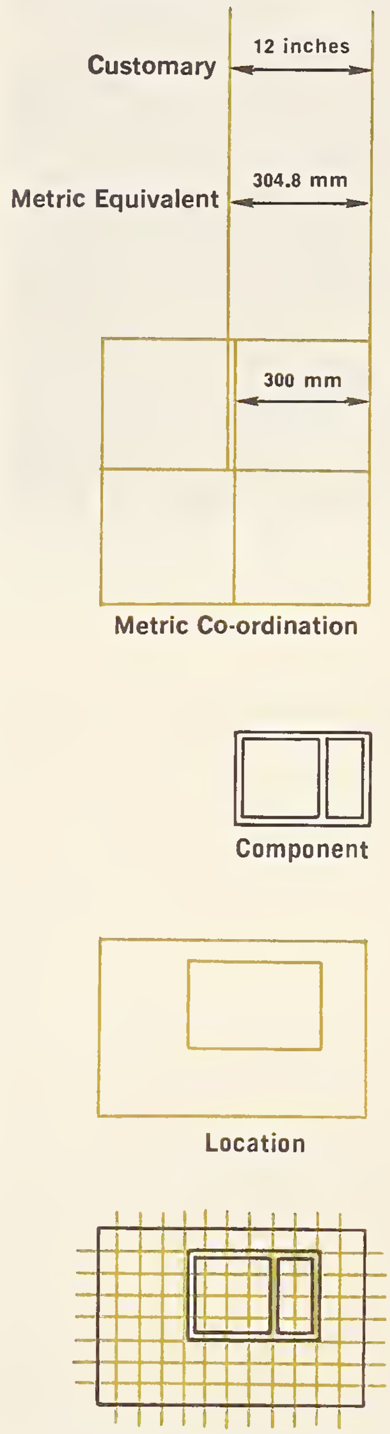
The Government Training Centers, a central government agency for retraining unemployed workers, planned for half the machine tools used in their programs to be metric by mid-1970. They also began revising documents to metric terms for trainees in bricklaying, carpentry, woodworking, plastering, and machine operating. All construction trades get some knowledge of metrication.

Construction

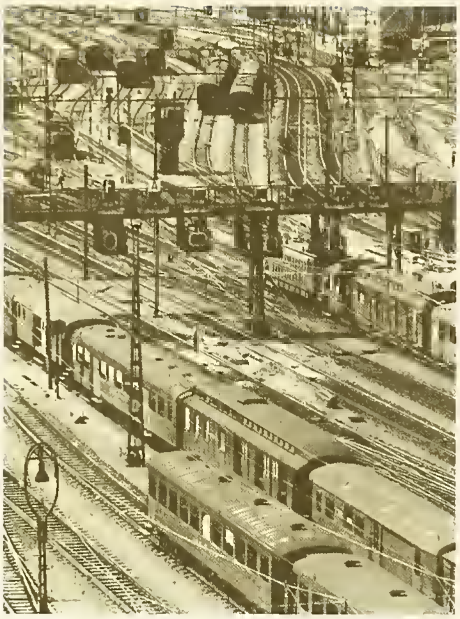
British metrication got off to an auspicious start when construction, one of the most complicated industries to change, led the way. Its activities are closely interlocked with those of a host of manufacturing industries—e.g., steel, glass, plastics, and timber. It employs a wide variety of skilled and professional people, including architects, civil engineers, electricians, steamfitters, and experts in heating and ventilation, and building maintenance. The conversion to metric materials and components, begun in January 1970, is expected to be substantially completed by December 1972. All the major materials manufacturers have now arranged their own metrication programs and these mesh with that of construction.

The construction industry decided from the outset to combine metrication with the adoption of a series of standardizing dimensions and thus to create new opportunities for modular design and building. Almost paradoxically, in rationalizing sizes the British construction industry has tended to favor a module of 300 millimeters. This is a

Coordination of Sizes in British Construction



Dimensional Framework Related to Component and Location


Railroads will have to become accustomed to new operating manuals

seemingly peculiar number, but it happens to be very close to the familiar length of one foot.

It was decided not to delay the metric design of buildings until new metric dimensions have been decided for all components. For a limited time some components made to Imperial standards will still be fitted into the new designs, in much the same ways that up to now most new buildings have had to make do with what was available. Old buildings have always been repaired with the materials available at the time.

By the end of 1972 the transition period will be virtually over, and Britain should be industrially capable of designing and constructing completely metric buildings. Meanwhile, most small private contractors have stuck to the old methods, except when they have found some cost advantage in changing or where their clients or their consultants require metric design. On the other hand, larger "systems" builders are having little difficulty in switching to metric, and their customers are benefiting from the advances in standardization.

Transportation and Communications

These industries, which affect the lives of almost everyone, are less commonly in private ownership than they are in the U.S. The British Government, for example, owns the electric power industry, the railroads, the major airlines, and, through the Post Office, the telephone and telegraph service. Whether publicly or privately controlled, most of these industries have had to face much the same problems, but each of them has had to work out its own timetable within the framework of the general target date of 1975.

Tariffs for delivering goods, people, and messages are generally based on combinations of weight, bulk, and distance. Thus, with little effort old tables can be converted to new ones that are almost exactly equivalent. The change will hardly affect the individual citizen.

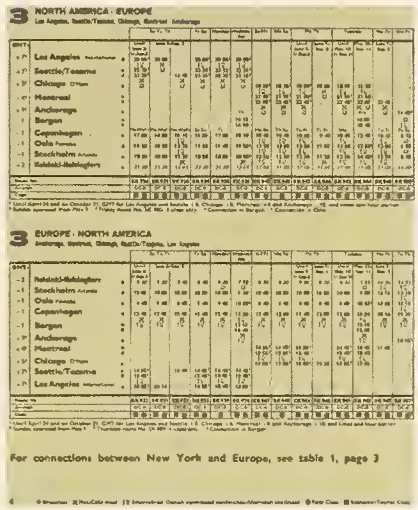
Many people, however, will have to adjust their thinking to revised traffic regulations, notably speed limits, when they are introduced. The Minister of Transport Industries decided against posting speed limits in both miles per hour and kilometers per hour during a transition period. In the interests of safety they recommended an abrupt switch. The timing of this change has not yet been decided, although there has been a good deal of preparatory work by the authorities.

So far as the traveler is concerned, metrication of the railroads will mean little, except that timetables including distances will be revised at some convenient time for reprinting. But the people who run the railroads will have to become accustomed to new operating manuals with speeds, distances, weights, pressures, and other dimensions expressed in metric terms when the change is made.

Metrication of shipping and navigation is primarily a matter of rewriting in new units various acts, rules, and regulations. This process is well advanced, as is the provision of metric training for mariners. However, the knot and the nautical mile are internationally recognized units and will continue in use. Revised metric charts for British waters will be available in 1972; the Navy Department will then begin issuing tide tables in metric units; and the port authorities will convert their tide gauges accordingly.

The airlines have long dealt with a mixture of metric and customary units and will continue to do so until there is a comprehensive international agreement to change. Since they already weigh freight and baggage in kilograms, conversion of customs and other regulations to metric will be an added convenience.

There is unlikely to be any early change in air navigation practices, particularly in units used for air-to-ground communications in traffic control or for the calibration of flight instruments. International civil aviation uses two different sets of standards; both include the knot and nautical mile, but one set measures speed and vertical distances in kilometers per hour and meters, the other in miles per hour and feet.


3 NORTH AMERICA · EUROPE

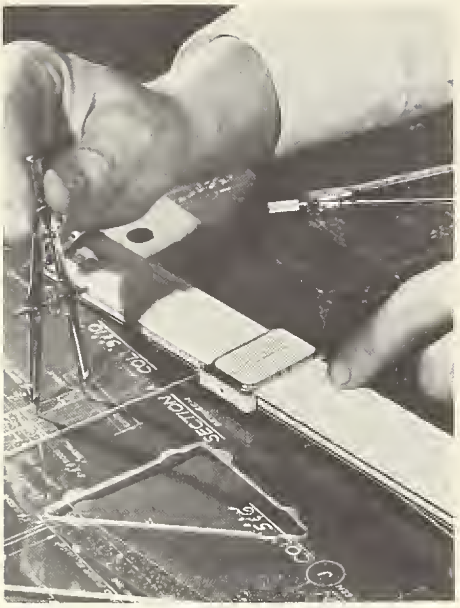
Los Angeles, Seattle/Tacoma, Chicago, Montreal, Anchorage, Bergen, Copenhagen, Oslo, Stockholm, Helsinki-Helsingfors

3 EUROPE · NORTH AMERICA

Helsinki-Helsingfors, Stockholm, Oslo, Copenhagen, Bergen, Anchorage, Montreal, Chicago, Seattle/Tacoma, Los Angeles

For connections between New York and Europe, see table 1, page 3

"The airlines have long dealt with a mixture of metric and customary units . . ."


"Precise measurement is a basic activity of engineering firms . . . "

In the transportation and communications industries, metrication seems to have assumed a definite pattern: only those things that need changing will be changed, and then only when the change becomes necessary.

Engineering

In no other group of industries does metrication represent so profound a change. Precise measurement is a basic activity of engineering firms, and the use of new units of measurement affects every aspect of the firm's business. To change in an orderly and efficient way, the British engineering industries have relied greatly on a metrication program and guide published in the summer of 1968 by the British Standards Institution—one of the first programs to be agreed upon.

For many products of the engineering industries the availability of metric standards has been an essential prerequisite of the changeover. These standards, prepared by the British Standards Institution, go far beyond a mere arithmetic translation from Imperial to metric dimensions. They have also eliminated unnecessary varieties of products and components and brought production into line with international standards where these exist. The task was imposing, but essential standards were made available in metric terms by the end of 1970.

While considering the changes dictated by metrication, engineering companies also linked these to still other and more far-reaching changes. According to the 1970 report of the Metrication Board: "All firms will, because of the metric change, be called upon sooner or later to review the design of their products. They have to consider whether it is timely to change the whole design or to change individual components of it. All this should be done in ways which will make possible the most economical use of materials to metric specifications and the incorporation of metric fasteners . . . . A firm's review of its activities should also cover purchasing policies for materials and components, the organization of production, stocking policy and control, and, not least, a critical examination of marketing policies."

In short, metrication gives such companies an unprecedented impetus to clean house.

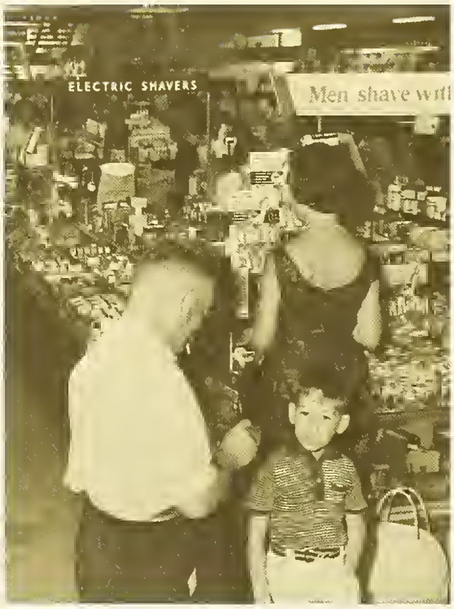
The effect of metrication on the engineering industries has been heightened by their customers who must themselves rely on engineering to further their own metrication. The Defence Department, in particular, has taken the lead in discussing the problems of metric change with its suppliers. In 1969 the Ministries of Defence and Technology jointly prepared an outline target program for the introduction of the metric system throughout the military procurement field, envisaging that all new designs should be metric. The completion of the changeover will depend, however, on the retirement of existing designs, some of which still have a long life.

Various segments of the engineering industries have responded to metrication in different ways. Aircraft manufacturers, for example, agreed to make every effort to comply with the Defence Ministry's program. But they pointed out that unless the U.S., the world's largest manufacturer and operator of civil aircraft, changes over to metric, two sets of units are likely to be current for some time to come.

"The Defence Department . . . has taken the lead in discussing the problems of metric change with its suppliers."

" . . . Britain is, like us, an advanced industrial nation and one with which we share many common traditions."

"Most machines can be readily converted . . . "



"Consumer trade and industry embrace such a wide variety of disparate products and problems . . . "

In the earliest days of metrication the Council of Machine Tool Trades Association accepted a recommendation that its members consider the metric system for new designs. This would not only familiarize designers and machine shop workers with the new units but would start a gradual decrease in the manufacture of strictly inch-based machine tools, thus reducing servicing problems when conversion was completed.

The British Bolt, Nut, Screw and Rivet Federation confirmed that it can meet the basic program of the British Standards Institution and began last year to produce preferred sizes of metric fasteners.

The automotive industry, on the other hand, while welcoming metrication in principle, has announced there will be no immediate and comprehensive change in the industry as a whole. Its plan is to continue conversion gradually as parts, components and new models are redesigned to metric specifications, a process which is now well advanced.

Many British engineering firms, especially those who export to the rest of Europe, are accustomed to producing to metric standards. Metrication has hardly taxed their technical ability, but it has challenged their planning skills. In fact, a number of the purely technical problems have proved less troublesome than had been anticipated.

The Metrication Board's 1970 report points out: "Although most inch-based machine tools can be used without modification to produce metricated components, some users will be faced with the need to convert their machines to a dual role or to metric working, and in some instances to replace them. Most machines can be readily converted, and conversion kits are now generally available . . . . Most firms will not be involved in major expenditures for reequipment and adaptation."

Industry, Trade, and the Consumer

Consumer trade and industry embrace such a wide variety of disparate products and problems that they have

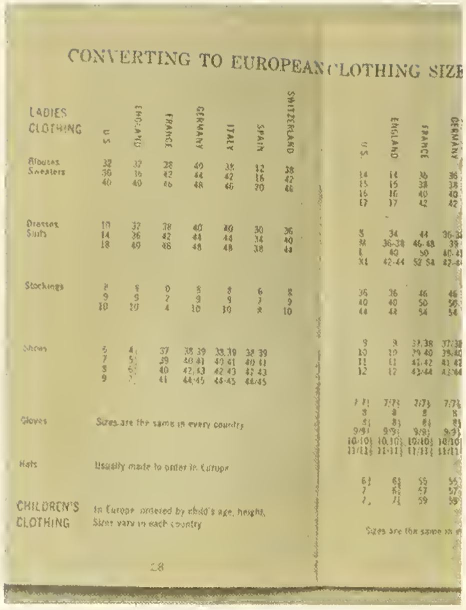
not been incorporated in any comprehensive plan or timetable for metrication. Nevertheless, some fragments of this sector have already worked out their programs, and in the pharmaceutical field British law now stipulates that all prescriptions be dispensed in metric units. Cosmetics, toothpaste, and similar drugstore items have followed suit.

In general, manufacturers in this area have the same metrication problems. Although they need not make elaborate technical changes in their production processes, they have to make timely adjustments in packaging, weighing, and labeling without disrupting their businesses. Throughout Britain many thousands of weighing machines will have to be converted and in some cases replaced. This alone is a complicated task, both for technical reasons and because the work cannot be done all at once.

As long as they are going metric, food manufacturers are considering changing the weights of the contents of packaged foods so as to provide a sensible series of quantities that will soon be familiar to the consumer, e.g., 125 grams as a close approximation of 1/4 pound; 250 grams for 1/2 pound; 500 grams for 1 pound; and 1 kilogram for 2 pounds.

For the most part, standardizing in ways such as this requires only that containers and filling machines be slightly modified. The cost is proving slight. The consumer will not have to contend with so many odd-sized packages and this, combined with Britain's new decimal currency, will make the calculation of unit prices much easier, the Metrication Board points out.

Other consumer-related industries, however, will have to make more sweeping technical production changes. Some carpet looms, for example, will require rebuilding, although there is no problem in supplying metric widths even now. The bedding industry also intends to become thoroughly metric this year, and to eliminate odd sizes. The single mattress has been standardized at 100 × 200 centimeters, and the double mattress at 150 × 200 centimeters. In scheduling this change, the mattress makers were helped



The confusion of clothing sizes

A strong argument for a coordinated national program is to ensure that small businesses are not left behind

by the fact that existing sheets, blankets, and quilt sizes will fit the new beds.

The British clothing industry also intends to clear up the long-standing confusion of sizes and to join other metric nations in international standardization based on the centimeter. An international scheme for the metric sizing of footwear has been agreed upon in principle.

In its dealing with these parts of trade and industry, the general public is being progressively confronted with the reality of metrication. To be sure, much retail trade involves measurement only incidentally. Many goods are sold by number or are pre-packed in familiar containers. Although packages generally are marked with metric as well as Imperial volumes or weights, few consumers habitually read quantities on the labels.

Still, the British anticipate complaints from customers who do not think they are getting their money's worth when, for example, they pay slightly more for 500 grams of butter than they did for one pound, which is only 454 grams. The problem would be simplified if retailers could convert for all commodities overnight, but this will be impossible since suppliers will change over at different times.

Small Business

The mixed situation that is likely to prevail for a time at the retail level points up in general the problems of small businessmen, many of whom are also retailers. Most large companies have adequate technical, financial, and managerial resources for planning their own metrication and dealing with it over a long period. Also, they purchase in such quantity that they can bring pressure on suppliers to meet their schedules.

The British Metrication Board has been studying companies that lack these resources and leverage, and it has expressed concern on two grounds. The small businessman is seldom in control over the decision of when to go metric; large companies tend to set the pace. Moreover, during the transition period some suppliers are reluctant to maintain full stocks of both metric and non-metric items, and if the small businessman runs short of some item his suppliers are unlikely to produce a special order of the limited quantity he may require; large companies are more likely to be able to get whatever they order.

These problems are of continuing concern. Nevertheless, they are not a burden peculiar to metrication; rather, they are the usual problems of most small businesses confronted by market and technical changes of any kind.

Still seeking for a workable solution, the Metrication Board states in its 1970 report: "Our present view is that a constructive attitude toward these problems by large firms is the main way of helping. Major producers and users can greatly ease the position by making their intentions widely known to those affected in good time." And this is a strong argument for carrying out metrication according to schedules carefully drawn up well in advance, with the government providing assurance that everyone gets a fair opportunity to participate.

Solving Problems

One of the most interesting aspects of the British metrication program is the ingenuity with which a number of minor but bothersome technical problems have been solved.

Even before metrication was well under way, the gasoline industry realized it was soon going to encounter a two-pronged problem: service stations were going to have to dispense gasoline by the liter and price it in the new decimal currency, which was due to be adopted in February 1971. They anticipated both difficulties by having designed a price-computing pump with an important new feature: a convertible head that could be easily adjusted for changes in both money and measurement. All gasoline pumps installed since October 1968 have been of this kind.

When pharmacy went metric there was some reason to worry about medicine to be taken in liquid doses. Few

Posters are widely used

consumers at that time had anything but the vaguest notion of the size of a milliliter. To avoid possibly disastrous confusion, drug manufacturers supplied pharmacists with quantities of cheap plastic spoons having a capacity of exactly five milliliters, one to be given away with each bottle of medicine.

Not all the knotty little problems of metrication have yet been solved. The dairy industry is still worried about the size of the metric milk bottle. The British householder is accustomed to having his milk delivered at the door every morning in one-pint bottles, and if milk is sold in the comparable metric size—500 milliliters—he is not likely to change the number of bottles he orders. Unfortunately, 500 milliliters is about 10 percent less than a British pint. Milk companies have reason to fear that consumption would slump, because this did in fact happen in Kenya, where the 500-milliliter milk bottle was adopted.

Fortunately, if the U.S. were to go metric, this would be no problem for our dairy industry, because the U.S. quart is about 5 percent smaller than one liter. Thus, if the same psychology were to apply, milk consumption would rise by roughly 5 percent should Americans begin buying their milk in liters.

Informing the Public

Throughout the metrication program a main goal has been to persuade the British people to "think metric," rather than to go through the tedious process of converting inches and pounds through arithmetic calculations. In addition to encouraging education and formal training, the Metrication Board has enlisted the cooperation of journalists and broadcasters to reach the general public. Posters, exhibitions, advertising campaigns, local meetings and study groups have also been encouraged.

How well has this extensive program worked? Generally, at this stage the British people have a pretty clear notion of metric lengths, a less clear one of weights and volumes.

The Board has no intention of trying to teach all the intricacies of the modern metric system to everyone. As one member has stated: "I would begin by crying halt to those enthusiasts who would wish every man, woman, and child drilled in all theory and detail." For most people it is enough to become accustomed to the gram, the kilogram, the meter, the liter and a few other units they need for everyday use.

Repeated surveys have indicated that the British public is becoming increasingly aware of metrication and more favorably disposed to it. The British decimal currency change has provided encouraging evidence of the readiness of people to accept such a change when the need arises.

According to a public survey completed early this year, public education has already been fairly successful. About 3/4 of the people questioned knew that a kilometer measures distance, and 2/3 of these knew it is less than a mile. Two-thirds knew that a liter is a measure of volume, and 2/3 of these knew that it is larger than a pint. About 2/3 knew that a kilogram is a measure of weight, but only 2/5 of these knew that it was more than a pound. More than 70 percent thought that metrication would be easy or fairly easy.

How much is a kilogram? 100 millimeters?

The Pilot Program

If the U.S. decides to go metric in a coordinated program, as the British are doing, what lessons can be gleaned from their progress? It is unrealistic to attempt fully to translate British experience directly to U.S. problems. The British economy is smaller and less complex. Moreover, we do not have under consideration joining a regional economic union such as the Common Market, which is wholly metric, although we do value trading with it.

On the other hand, Britain is, like us, an advanced industrial nation and one with which we share many common traditions. At least to this extent, their metrication effort serves as our pilot program.

How the U.S. Metric Study was Planned and Carried Out

Congress authorized the U.S. Metric Study in August of 1968 by the enactment of Public Law 90-472. This Act directed the Secretary of Commerce to provide for a broad inquiry and evaluation concerning the use of the metric system of measurement. Specifically, the Study was to:

- Determine the impact on the U.S. of the increasing worldwide use of the metric system.
- Consider both the desirability and the practicability of increasing the use of metric weights and measures in this country.
- Study the feasibility of international use of standards based on the Customary system.
- Examine the implications of the metric trend for international trade, national security, and other areas of foreign relations.
- Identify the practical difficulties that might be encountered should the metric system be used more widely in the U.S., and evaluate the costs and benefits of courses of action which the U.S. might realistically take.

On the basis of the findings and conclusions of the Study, the Secretary of Commerce was asked to make "such recommendations as he considers to be appropriate and in the best interests of the United States."

National Bureau of Standards

The Secretary delegated responsibility for the conduct of the Study to the National Bureau of Standards. The Bureau's report on the Study along with the Secretary's recommendations were to be presented to Congress in August of 1971.

The primary goal of the planning was to give every sector of society an opportunity to respond to the questions raised by Public Law 90-472 and to consult and cooperate with other government agencies, foreign governments, and international organizations.

Advisory Panel

As one means of furthering widespread participation, the Secretary of Commerce appointed a Metric System Study Advisory Panel. It consisted of almost 50 members from organizations representing a wide spectrum of interests. The chairman of the panel was Mr. Louis F. Polk, and its vice-chairman was Dr. Francis L. LaQue. The full membership of the panel is listed later in this appendix. The function of the Panel was to participate in the planning and conduct of the Study and to help ensure that an opportunity was provided for all sectors of the society to be heard.

The Plan

The blueprint for the Study was worked out by the National Bureau of Standards in close cooperation with the Panel and was completed in December of 1969. The plan provided for a series of hearings, called National Metric Study Conferences, supplemented by a number of special investigations. All of these were to be completed during 1970 so that the results could be evaluated and summarized early in 1971. Interim reports covering the special investigations and the results of the hearings were to be sent to the Congress. The National Bureau of Standards' comprehensive report of the entire U.S. Metric Study would lay the groundwork for the Secretary's recommendations to Congress in August of 1971.

The Hearings

Seven hearings were held during the late summer and fall of 1970—six of them in the Washington area. They were divided into separate categories as follows:

(1) Labor
(2) Consumer Affairs
(3) Education
(4) Construction
(5) Engineering-Oriented industry
(6) Consumer-Related Industry
(7) Small Business, State & Local Government, Natural Resources, Health, Transportation, and other services.

The categories were chosen so that there would be some overlapping of interests in order to ensure that all who wanted to participate could be heard.

The U.S. Metric Study invited contributions from more than 700 major groups, including labor unions, trade associations, professional societies, educational associations, consumer-related organizations, and others. The hearings were widely publicized in advance. Thus, in addition to those specifically invited to participate, there were many contributions from groups who submitted papers or took part in discussions.

The way in which the hearings were carried out is described in greater detail under "Methodologies" below. The groups invited to submit contributions are listed at the end of this appendix. The U.S. Metric Study interim report, *Testimony of Nationally Representative Groups*, which summarizes all the contributions, is cited in Appendix Two, page 164.

Supplementary Investigations

The investigations that supplemented the hearings covered the following subjects:

1. Manufacturing Industry
2. Nonmanufacturing Businesses
3. Education
4. Consumers
5. International Trade
6. Engineering Standards
7. International Standards
8. Department of Defense
9. Federal Civilian Agencies
10. Commercial Weights and Measures
11. History of the Metric System Controversy in the U.S.

The ways in which these investigations were conducted are described below under "Methodologies." The U.S. Metric Study reports covering these topics are cited in Appendix Two. In all, twelve reports, covering special topics in detail, have been published as part of the U.S. Metric Study record.

Methodologies

The Public Hearings

Section 2(5) of the Metric Study Act states, in part, that the Study should "permit appropriate participation by representatives of United States industry, science, engineering and labor and their associations . . . ." The purpose of the National Metric Study Conferences was to provide an opportunity for as many of such groups as possible to express the views of their constituent members, and to have those views heard and discussed in a public forum.

Contributions were sought from groups representing every sector of the society, and were obtained in several ways. More than 700 groups were invited by the Department of Commerce to participate in the Conferences or submit written views. Members of the Metric System Study Advisory Panel helped in the selection of the invitees. The Conferences were widely publicized in advance.

The meetings were, in effect, hearings. Any interested person could attend and participate in the discussions. A series of press releases was used to advertise the Conferences. Brochures announcing both the entire series and details of each individual conference were mailed to many thousands of potentially interested parties.

In order that the spokesmen invited could address themselves to the specific questions posed by the Metric Study Act, they were given guidelines and pertinent background material. Each spokesman was asked for a brief description of the nature of his organization, including a description of its membership, and an indication of the extent to which the membership was consulted in the preparation of the testimony.

Members of the Metric System Study Advisory Panel and other individuals participated in discussion panels, which commented on the presentations. They also asked questions to elicit further information.

There were 20 full days of hearings, in all, spread out over the latter half of 1970. These meetings were held in the Washington, D.C. area, with the exception of one set of hearings which was held at the Deerfield Academy in Massachusetts. Altogether, some 200 presentations were heard, and they were interspersed with extensive discussions. The organizations that were invited to contribute to the record of the hearings are listed at the end of this appendix.

Labor.—Questions concerning employees were answered by employers in the Manufacturing Industry Survey and the Survey of Nonmanufacturing Business. The Labor Conference was intended to give the labor unions an opportunity to speak directly for their members.

The Metric Study Group consulted with representatives of the AFL-CIO, and invited them to participate in the planning and conduct of the Labor Conference. For the conference, labor unions affiliated with the AFL-CIO were grouped as follows:

—Chemical, Oil, Mining, Pharmaceutical
—Construction
—Textile, Garment
—Transportation, Maritime
—Arts, Communications, Printing
—Metals
—Service
—Glass, Ceramic and Other.

Special guidelines were prepared for the labor participants. These were oriented to the particular relationship of workers to measurement usage, including questions related to prior experience in adapting to increased metric use: effects with regard to worker-owned tools; training programs offered and their effectiveness; and significant effects on the nature of jobs. Some AFL-CIO unions declined to participate because they believed their members would not be affected by increasing metric usage.

In addition to inviting AFL-CIO affiliates, the Metric Study sent letters to all independent unions inviting them to submit written views. Any independent union that wanted to give an oral summary at the Labor Conference was given the opportunity.

Consumer Affairs.—A Conference devoted to the effects of growing metric usage on the activities of the consumer was organized in cooperation with the American Home Economics Association. (The findings of the Consumer Conference were supplemented by a survey of the public's knowledge of metric, described later in this appendix under Supplementary Investigations.) Representatives of some 20 consumer organizations and college and university home economics departments presented reports in sessions concerned with: clothing, food and food services, the home, and transportation services (i.e., automobile purchase, use, and repair). The Conference also heard and discussed reports on consumer attitudes toward the metric system, as well as a report by a staff member of the Consumer Council of Great Britain concerning consumer experiences under that nation's metric conversion effort.

Education.—At the Education Conference, papers were presented by representatives of 30 organizations concerned with: elementary and secondary education, higher education, vocational and technical education, curriculum development, and support activities. (These contributions to the Education Conference were complemented by a special study, described later in this appendix.) For the invitees to this conference, the Metric Study modified the National Conference Guidelines to relate them to the particular effects of increasing metric use on teaching and educational support activities. These guidelines sought information as to effects on classroom activities and on items directly involved in the educational process (e.g., textbooks, instructional materials and teaching aids, shop and laboratory equipment).

Construction.—This Conference assessed the special benefits and problems of increasing metric usage on all aspects of the construction industry. Spokesmen presented reports in sessions devoted to: building design, building codes and standards, building materials production and sales, general contractors and subcontractors, building core (basic structure and utilities) construction, home builders and home manufacturers, and land services and heavy construction.

Engineering-Oriented Industries.—This Conference was cosponsored by the Engineering Foundation and was held at the Deerfield Academy, Deerfield, Massachusetts. Although the industries represented were covered at the company level by the Manufacturing Industry Survey, the Conference provided an opportunity for consideration and discussion at the industry association and professional society level of the opportunities and problems which increasing metric usage brings to industries heavily dependent on engineering activities.

Eight sessions were devoted to various industry groupings, and participants heard reports from 30 industry association representatives and 10 spokesmen for professional societies. One additional session considered broad national engineering and standards problems and another was devoted to the effects on consulting and professional engineers. Two European authorities reported on activities of the International Standards Organization with regard to the incorporation of metric units into engineering practice, and the degree of acceptance of metric units by European industry as a basis for current and future engineering standards and practices.

Consumer-Related Industry.—This Conference, again overlapping several of the Supplementary Investigations, covered those industries which produce primarily for or provide services primarily to the private consumer. Some 35 trade association representatives presented reports in sessions concerned with: wholesale and general retail trade, automatic merchandising, appliance sales and service, toy manufacturing, printing and publishing, book manufacturing, quality control, food processing, food sales, scale manufacturing, paper manufacturing, amusements, motels, textile mill products, apparel manufacturing, automobile sales and service, and car and truck renting. Also, a special foreign trade report was presented by the Commerce and Industry Association of New York.

General.—The final conference covered services, agriculture and natural resources, small business, and state and local government. Twenty-three trade association and professional representatives spoke on metric usage as it affects legal services, communications, finance, transportation and related services, accounting, and medical services. Eight association spokesmen discussed the metric questions as they relate to farming, forestry, fisheries, and mining. The two major associations of small businessmen presented reports.

The State-County-City Service Center reported on its study of the present and potential effects of metric usage on the activities of governments at the state and local level. (The Center was established to improve coordination among the Council of State Governments, the National Governors Conference, the National Association of Counties, the International City Management Association, the National League of Cities, and the United States Conference of Mayors.)

The Metric Study Act directed that the Study "consult and cooperate with other government agencies, Federal, state, and local" in carrying out its investigation. The Metric Study Team contracted with the Service Center to survey a sample of states, counties and cities. Two states (California and Kentucky), two counties (New Castle, Delaware and San Mateo, California) and five cities (Bangor, Maine; Grand Prairie, Texas; Kansas City, Missouri; San Jose, California; and Savannah, Georgia) were selected by the Center, and their measurement-related activities were studied in depth. The particular opportunities and problems of state and local governments in the area of commercial weights and measures activities were treated in a Supplementary Investigation, described later in this appendix.

Finally, this Conference heard a report by the Director of the British Metrication Board, Mr. Gordon Bowen, on the experience of the United Kingdom in going metric.

Supplementary Investigations

Manufacturing Industry.—The Manufacturing Survey obtained information in three areas:

- —The present impact within United States manufacturing industry of increasing worldwide use of the metric system.
- —This impact in the future, assuming that use of the metric system continues as at present, with no coordination among the various sectors of the society.
- —Alternatively, the effects of a coordinated national program to increase metric usage.

The survey team determined that the best way to obtain this information was to conduct, by mailed questionnaires, a survey of two parts. Part A was designed to solicit from manufacturing companies general information concerning metric usage and attitudes toward the metric system. Part B was concerned with more difficult issues dealing with the benefits, costs and timing of metric conversion within the companies. A significant response to Part B could be obtained only if companies were willing to make an intensive study with qualified staff and at considerable cost to the company.

For Part A, the Manufacturing Survey team decided to direct the questionnaire to a representative sample of the 267,000 individual manufacturing firms which existed in the United States according to the 1967 Census of Manufactures. The most complete available file of companies from which to select the sample was a Dun and Bradstreet magnetic tape file of companies engaged primarily in manufacturing. The file included information on the principal SIC (Standard Industrial Classification, used by Census Bureau) product code and on number of employees for most of the companies in the file.

The sample was stratified in two ways:

– by number of employees
– by measurement sensitivity of products.

(There were three measurement sensitivity categories: Category I—industries whose products are most measurement sensitive, such as machinery and appliances; Category II—industries whose products are moderately measurement sensitive, such as metal cans and lumber; and Category III—industries whose products are least measurement sensitive, such as jewelry and cutlery.)

The universe of manufacturing companies sampled by Part A of the Manufacturing Survey consisted of all manufacturing companies with 50 or more employees (as classified by the Dun and Bradstreet file) plus those companies in the measurement sensitivity Category I with fewer than 50 employees.

About 80 percent of the manufacturing companies in the United States are companies in Categories II and III with fewer than 50 employees. These companies, however, account for only about 15 percent of the total U.S. manufacturing output. It was reasonable to assume, also, that most of them would not be as greatly affected as Category I companies, and would not have much information on the implications of a metric conversion program. Consequently, for the 1-49 size class a decision was made to exclude companies in Categories II and III from the Survey and to compensate for this exclusion by increasing the sample size of Category I. For the purpose of this Survey, this procedure was better than taking a strictly random sample of all manufacturing firms.

The employee size classes used in the sampling stratification were 1-49, 50-499, 500-2499, and 2,500 and over. Thus there was a total of 10 Category/size classifications. The original intent was to have a sample size of approximately 300 for each employee size class within each measurement sensitivity Category. It was found, however, that for the larger companies (2,500 employees and over) the number of companies in each Category/size class was less than 300 and, therefore, for these classes all companies were included in the sample. The sample for the 1-49 employee size class (limited to Category I) was larger than the other samples because a lower initial response rate was expected from small companies.

A first mailing to the 3,838 companies in the sample was followed by a second mailing to those who had not responded to the first mailing. A total response of 1,859 companies was received, leaving a total of 1,979 initial nonrespondents after the two requests by mail. A subsample of approximately 350 companies was drawn from the 1,979 initial nonrespondents for intensive follow-up by certified letter and telephone. On the basis of the initial responses and the intensive follow-up of the subsample respondents, an effective response coverage of 84 percent of the universe was obtained by the Survey.

While the sample for Part A could be very broadly based, the Part B sample had to be confined to those companies with enough interest in metric conversion to be willing to do the background work necessary to provide adequate responses to the benefit-cost questions. Thus, responses were solicited only from those companies which had agreed to carry out the necessary studies at their own considerable expense. The Part B sample included companies that have been opposed to a change in our measurement system, as well as companies that have been neutral or favorable toward increased U.S. metric usage.

Based on the returns of the Part B questionnaire, an estimate was made of the total cost of introducing the metric system for the manufacturing sector, under a program that assumes each company will adopt its optimum period for accomplishing metric conversion. Some of the companies also made observations on benefits to be expected.

Nonmanufacturing Businesses.—The Survey of Nonmanufacturing Businesses complements the Manufacturing Survey; similar information was sought in both of these surveys.

According to U.S. Internal Revenue Service figures, there are about 11 million nonmanufacturing businesses in the nation, of which some 9 million are sole proprietorships. The firms included in this total account for about 65 percent of total U.S. employment.

Nonmanufacturing industries represent a wide variety of economic activities. Many of them sell only services, some just sell goods, and many sell both. The original sampling plan identified 98 types of nonmanufacturing firms at the two- or three-digit SIC (Standard Industrial Classification) level. These firms were in the following major industry groups:

—Agriculture, Forestry, Fisheries
—Mining
—Construction
—Transportation and Utilities (Communication, Electric, Gas and Sanitary Services)
—Wholesale and Retail Trade
—Finance, Insurance, Real Estate Services
—Business and Personal Services.

By combining similar categories, the original 98 types of firms were reduced to 87 sample groups. An equal number of firms was to be surveyed within each sample group and within each of three size categories:

—1-19 employees
—20-249 employees
—250 or more employees.

Although a sample of 1,500 firms would have been sufficient to represent nonmanufacturing industry in the U.S., a much larger number was chosen to insure adequate representation in all 87 sample groups. In 84 of the sample groups a total of 30 firms was to be surveyed, 10 in each size category. The three exceptions were: Agricultural Production, in which 90 interviews were to be obtained; Building, in which there were to be 45 firms; and Electric and Gas Utilities, which was to sample 60 firms. Thus the total hypothetical sample consisted of 2,715 companies.

The master sample was drawn by the Social Security Administration (SSA) from its file of Social Security reporting units in the U.S. The SSA maintains on file all establishments that employ one person or more. This file was the most complete list of nonmanufacturers available to the Survey. However, the SSA file does not include railroads.

A primary, stratified sample of 2,738 firms was randomly selected from the master file. To this list were added 90 farms and 40 railroads, for a total primary sample of 2,868 units. In addition, a secondary sample of 2,258 firms was randomly selected as a source of replacements for refusals, firms which had gone out of business, and other nonrespondents. In the case of multiple-unit organizations, a representative in the central office of the firm was asked to supply the information for the entire firm.

The wide variation in the types of business activities covered made the use of a standard mailed questionnaire format inadvisable. It was decided to obtain the information through telephone interviews, guided by questionnaires. The actual telephoning was conducted under contract by a private research organization. Each company was interviewed twice: an initial contact, to determine willingness to participate in the Survey and to obtain offhand background information as to knowledge of the metric system and experience with its use, followed by mailing of guideline-type information and questionnaires, and a final, detailed telephone interview, with a designated spokesman, to elicit the desired information. In many cases the person interviewed was the president of the firm; in other cases technical specialists were selected by the company to respond for it.

Contacts were attempted with 3,559 firms. The final number of full interviews obtained represented 90 percent of the primary sample of 2,868 firms. In each of the 87 Standard Industrial Classification groups, at least 57 percent of the sample responded; and in 72 of the 87 groups, more than 80 percent representation was obtained.

Education.—A contract was made with the Education Development Center for a study of the effects of metric usage on U.S. education. Located in Newton, Massachusetts, the Center has available for consulting purposes the staff and facilities of the Massachusetts Institute of Technology and Harvard University.

The contract called for a broad analysis and study of the total education system, including elementary and secondary, college and university, vocational, and adult education. Specifically, the aims of the study were: (1) to assess the educational advantages and disadvantages of both the metric and Customary systems of units, (2) to determine the current usage of metric measures in U.S. schools and trends in that usage, (3) to find the ways in which education would have to change as the U.S. accommodates to increased worldwide use of the metric system, under a planned or unplanned approach, and estimate the benefits and costs of the changes, and (4) to make recommendations of ways in which to take best advantage of the changes. The study also discusses and suggests ways of achieving curriculum changes needed in view of increasing metric usage.

Consumers.—A contract was arranged with the Survey Research Center (SRC) at the University of Michigan to measure consumers' knowledge of the metric system and attitudes toward its use. For some 20 years the Center has been studying consumers' level of knowledge and attitudes in many areas. Professor George Katona of SRC afforded the opportunity for a metric survey to be conducted subsidiary to SRC's on-going, quarterly consumer economic survey.

This personal interview survey used a sample of approximately 1,400 family units representative of all family units living in private dwellings in the continental United States. Twenty-two questions, about one quarter of the total survey, were devoted to the metric issues. They explored the respondent's level of knowledge of the Customary system and the metric system and familiarity with relationships between units in the two systems. Respondents indicating that they had used another measuring system, while living or traveling abroad, were queried concerning their experience.

Six questions asked opinions concerning the respondents' ability to adjust to metric units. Then they were asked whether it would be a good or a bad idea for the United States to change to the metric system, and why. Finally, respondents were asked to agree or disagree with six statements presented as arguments either in favor of or opposed to conversion.

International Trade.—The International Trade Survey was designed to evaluate the potential effects that U.S. conversion to metric measurements and standards may have on U.S. foreign trade. The National Bureau of Standards engaged the Business and Defense Services Administration (now called the Bureau of Domestic Commerce, or BDC) in the U.S. Department of Commerce to undertake this part of the Metric Study.

Accordingly, BDC conducted a survey of exporters and importers of commodities which would be affected by a conversion to the metric system. Questionnaires were sent to 510 U.S. exporting and importing firms in order to collect three broad classes of information:

—General information about the firms' foreign trade operations.
—Information about those factors which affect the respondents' trade.
—Projections of the respondents' trade to 1975.

The firms were asked to specify the magnitude of their foreign trade for the years 1967-69 and to estimate the amount of trade in Customary units and engineering standards and the amount in metric units and engineering standards.

Each respondent was asked to rank the five most important factors (out of a list of factors) either promoting or deterring foreign trade with the nine countries which are the most important U.S. trading partners. One factor was the measurement system used in order to determine how important the measurement factor is regarded in relation to other factors affecting the respondent's trade.

The third category of information collected was the respondent's estimate of the percentage change in his 1975 exports or imports over 1970 based on two assumptions: (1) the U.S. and his firm maintained the Customary measurement system, and (2) the U.S. and his firm had converted to the metric system. The net difference between the two estimates would provide data as to how the Nation's trade surplus would be affected by the general use of the metric system vis-a-vis continued use of our Customary system.

The Survey was restricted to those (five-digit Standard Industrial Classification) product classes which were identified as being measurement sensitive. These are classes covering products in which physical changes would most likely occur because of changes to metric measurements and engineering standards.

Product classes which had trade volumes of less than $10 million were not surveyed. Out of the 1,166 five-digit SIC product classes, 188 were selected for export products and 155 for import products.

The American Industrial Trader's Index (AITI) was used to select firms. The AITI is a computerized compilation of U.S. exporting and importing firms registered with the Department of Commerce. The list provides names and addresses as well as a substantial amount of other information on each firm, including product classes each firm exports and imports.

The group of firms selected for the Survey was not a scientific or probability sample of the total trade in each product class identified as being measurement sensitive. Although the AITI identifies product classes in which many firms export and import, it does not provide information on a firm's trade volume in each product class, and this would be necessary for an analysis based on a random sample survey. Instead, the number of respondents selected for each product class was based on the total trade volume of the product class. The larger the trade volume in the product class, the larger the number of firms selected. For each product class having a trade volume of $10 million to $49.9 million, five firms were drawn; for product classes with trade volume of $50.0 million to $99.9 million, seven firms were drawn; and for product classes with a trade volume of $100.0 million and over, 10 firms were chosen. Thus, the sample, while not random, would reflect the effects of metric change on foreign trade.

Most of the 510 firms involved in the Survey were asked to report for more than one product class. Nearly 74 percent of the firms canvassed responded. About 45 percent of the total 1969 export volume of the product classes identified as measurement sensitive was covered in the Survey. For imports, the percentage was nearly 37.

Engineering Standards.—The Engineering Standards Survey was designed to provide answers to the following questions:

- —To what extent are U.S. standards incompatible with international standards because of the differences in measurement units?
- —Is it feasible to retain and promote U.S. standards internationally without a change in our measurement units?
- —Is the nature of our measurement units a significant factor influencing U.S. effectiveness in international standards negotiations?

In order to obtain useful answers to these questions, the first task was to determine the role of measurement units in engineering standards. Next it was necessary to determine the compatibility of U.S. standards with corresponding international standards and the extent to which differences in measurement units contribute to the incompatibilities.

The international standards compared in the Survey were the international recommendations issued by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), the two standardization organizations that have worldwide membership.

These recommendations are indicators of current trends toward harmonization of national standards. The Survey made a comparison of the ISO and IEC recommendations for the following industrial materials and products, which were selected to be representative of the status of international standardization and the role of measurement units in such standardization:

- —Steel (70 Recommendations)
- —Non-Ferrous Metals (61 Recommendations)
- —Plastics (69 Recommendations)
- —Rubber (35 Recommendations)
- —Pipe and Tubing (25 Recommendations)
- —Antifriction Bearings (30 Recommendations)
- —Threaded Fasteners (9 Recommendations)
- —Electrical and Electronic Components and Equipment (158 Recommendations)
- —Building Construction and Materials (60 Recommendations).

The Survey consisted of a comparison of ISO and IEC Recommendations with corresponding national standards of the U.S. and six other countries: France, the United Kingdom, Germany, Italy, India and Japan.

International Standards.—Early in the course of the U.S. Metric Study it was recognized that the nation was faced with increasingly important issues in international agreements on engineering standards—issues which strongly interact with the questions regarding metric usage. Consequently, an interim report was forwarded to the Congress in December of 1970 in order to:

Call attention to the development in Europe of international product certification schemes.

Urge early attention to this and other problems concerning international standards, without awaiting the outcome of the U.S. Metric Study.

Report on the status of the Study at that time.

Department of Defense.—The purpose of the Department of Defense Study was to determine and evaluate the impact on operational capability, the advantages and disadvantages, and the benefits and costs of adopting the metric system for use in the Department of Defense.

The Air Force was assigned the leadership in undertaking the metric study within the Department of Defense. Representatives of the other Services and Defense agencies participated with the Air Force in developing guidelines for the conduct of the Study. These guidelines were to provide a consistent basis for estimating impact on each Defense agency.

More than 125 elements of the Joint Chiefs of Staff, Army, Navy, Air Force, Defense Supply Agency, National Security Agency, Defense Communications Agency, Defense Atomic Support Agency, and Defense Intelligence Agency participated in the Defense study. About 50 representatives of various Defense organizations were brought together into nine subcommittees: Operations, Logistics (Production and Procurement, Supply Support, and Technical Data), Research and Development, Construction, Personnel and Training, Legal, and Financial. These subcommittees prepared study assumptions and guidelines. The Department of Defense Steering Committee, with representation from the various Defense activities, monitored the effort and evaluated all inputs to the study.

Information was sought in the following areas:

- —Extent of present metric usage.
- —Percentage increase in resources necessary to maintain constant mission capability based on a 10-year transition period for metric changeover.
- —Practical difficulties expected from increasing metric usage and what should be done about meeting these difficulties.
- —Contingency plans for metric conversion.
- —Long-term advantages and disadvantages after the 10-year transition.

In addition to providing data according to the guidelines, narrative comments regarding the effect of metric transition upon command mission capability were invited.

The Department promulgated a policy, in connection with this Study, of not taking a position either for or against adoption of the metric system.

Federal Civilian Agencies.—Since the Metric Study Act directed that the Study "consult and cooperate with other government agencies, Federal, state and local," a Survey of Federal Civilian Agencies was established to assess the effects of increasing metric usage on Federal Government functions other than the Department of Defense.

This Survey ascertained the effects of metric usage and its increase on the internal operations of the participating agencies and the areas of national responsibility of these agencies.

The first aim of the Survey, the effects of metric changeover on the internal operations of agencies, was to determine:

- —The extent of present metric usage in government agencies.
- —The impact of increasing worldwide use of the metric system on U.S. government programs.
- —The extent to which Federal agencies plan to increase metric usage.
- —The possible impacts of a metric changeover under alternative programs.
- —How the agencies would introduce the metric system.
- —Whether the agencies favor a coordinated metric conversion program.

The second aim of the Survey, the impact of metric change on agency areas of national responsibility, was to seek estimates of the effects on:

- —National activities in the society at large over which Federal agencies have responsibility (for example, transportation, communications).
- —The ability of the Federal agencies to perform their missions with respect to those areas of national responsibility.

Here the Survey evaluated the effects of increased metric usage on the interfaces between the Government and the areas of national responsibility over which it has cognizance.

The Federal Survey team selected for participation in the Survey those civilian agencies which would probably be significantly affected by increased metric usage. With this in mind, 35 departments and independent agencies were chosen. With the subagencies in some Departments (e.g., Maritime Administration in Commerce; Office of Education in Health, Education and Welfare; or U.S. Coast Guard in Transportation), the total number of survey agencies came to 55. The agencies surveyed are listed at the end of this appendix.

It was decided that the questionnaire method was the best approach to getting the needed information. Knowledgeable respondents within the agencies were to provide answers on the basis of "best judgment." The agencies were asked to provide lists of those agency subdivisions which would likely be affected by metric usage. Questionnaires were then distributed to these subdivisions—amounting to some 450 Government offices and units in all. Based on the agency responses to the two sets of questionnaires (the internal operations and the area of national responsibility questionnaires), the Survey team wrote a summary of the effects on each agency's internal operations and its areas of national responsibility.

The results of the internal operations part of the Survey were based on 394 responding subdivisions spread through 50 Federal departments and agencies. In the area of national responsibility part, there were 57 agency responses scattered over 33 departments and agencies. The areas of national responsibility covered were:

- —Energy
- —Food and Fibre
- —Communications
- —Transportation
- —Transportation Safety
- —Science and Technology, including the National Measurement System
- —Education
- —Health
- —Labor Affairs
- —Trade Practices
- —Small Businesses
- —Consumer Affairs
- —Environmental Pollution Control
- —International Affairs and Trade
- —Economic Affairs: Taxation.

Commercial Weights and Measures.—The purposes of this Survey were to:

- —Identify and describe the impacts of changing selected commercial weighing and measuring devices to record and indicate in metric units, a process called adaptation.
- —Analyze the effects that increased metric usage would have on state and local weights and measures jurisdictions—in the areas of laws and regulations, testing equipment, and training programs.

In order to satisfy the first purpose of the Survey, the following types of equipment were considered: weighing devices, metering devices, taximeters, and cordage and wire measuring devices.

Information about the adaptation of weighing and metering devices was needed from both manufacturers and users. Some information was obtained from questionnaires, the rest by interviews and letters requesting information. The sample to be surveyed consisted of 20 companies suggested by the Scale Manufacturers Association and the Office of Weights and Measures in the National Bureau of Standards. These companies included nine scale and balance manufacturers, 10 meter manufacturers, and one fabric measuring device manufacturer.

There was a 75 percent return of the questionnaires sent to these 20 manufacturers. The questionnaires sent to each of the three industries surveyed (scale, meter, and fabric measuring) varied somewhat because of the different nature of the data sought. The respondents to the questionnaires represented about 50 percent of the annual value of shipments in the weighing and metering industries; the sole manufacturer of fabric measuring devices responded, also.

Additional information concerning adaptation of scale and metering devices was obtained from trade associations, including the Scale Manufacturers Association, the National Scale Men's Association, and the Gasoline Pump Manufacturers Association.

Another study was made of the costs and time periods involved in adaptation of taximeters, and cordage and wire measuring devices. The information for this study was derived from (1) responses from manufacturers of these devices to letters of request for information; (2) telephone interviews with trade associations, such as the International Taxicab Association; and (3) discussions with experts on the staff of the Office of Weights and Measures of the National Bureau of Standards.

In order to obtain information for the second purpose of the Survey (impacts of increased metric usage on weights and measures jurisdictions), questionnaires were sent to the weights and measures officials of: (1) all States, (2) the District of Columbia, (3) Puerto Rico, and (4) 16 major urban areas. A 93 percent return of the questionnaires was obtained.

The results of this part of the Survey were published in the report of the Task Force on Metrication of the National Conference on Weights and Measures dated December 17, 1970. (This Task Force report is published as part of the report on Commercial Weights and Measures, cited in Appendix Two.) The National Conference, which is sponsored by the National Bureau of Standards, is an organization of approximately 500 members. The membership comprises state and local weights and measures officers, Federal officials, and representatives of business, industry, and consumer organizations.

History of the Metric System Controversy in the United States.—The objectives of this study were to document earlier actions affecting the weights and measures used by the United States and to chronicle previous investigations into the feasibility and desirability of increasing U.S. use of the metric system of weights and measures. Particular attention was paid to the many activities of the Congress relevant to this subject and to the campaigns that were waged, both for and against adoption of the system, on a number of occasions.

Although a history of the issue was not specifically required under the provisions of the Metric Study Act, it was felt that a review of the vast amount of earlier material would be useful in placing the current study in its proper historical perspective.

A wide range of investigations on the subject of metric adoption has been conducted in and out of government. Those of major significance are highlighted in this report. Six special interest groups have existed, at one time or another, whose principal preoccupation was with the metric system. The published material issued by such groups was examined and unpublished records were utilized where available in summarizing the groups' activities and strategies. In addition, the report includes a selection of typical articles from technical and trade journals and newspapers as evidence of the great deal of interest in the question exhibited by the nation's press.

Throughout the work on this history, the issue was treated as a social, political and economic problem rather than as a scientific or technological one, and a special effort was made to show the relationship of other contemporary issues to the question of whether or not the U.S. should increase its use of the metric system of weights and measures.

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The principal agencies that participated in the U.S. Metric Study were the National Bureau of Standards and the Bureau of Domestic Commerce in the Department of Commerce, and a special study team in the Department of Defense. Other federal agencies that contributed to the Study are listed at the end of this appendix.

In addition, hundreds of individuals and organizations participated in the planning and conduct of the Study or were consulted. A list of the major groups follows.

This report does not necessarily represent the views of any of these groups, its individual members, or the organizations with which they are associated.

*Other individuals from other organizations that contributed to the Study are identified in the 12 volumes of Metric Study supplemental reports cited in Appendix Two.

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National Association of Bedding Manufacturers

National Association of Biology Teachers

National Association of Broadcast Employees and Technicians

National Association of Broadcasters

National Association of Building Manufacturers

National Association of Casualty and Surety Executives

National Association of Chain Drug Stores
National Association of Chain Manufacturers
National Association of Colleges and Teachers of Agriculture
National Association of Colored Women's Clubs
National Association of Counties
National Association of County Agricultural Agents
National Association of Credit Management
National Association of Electric Companies
National Association of Elementary School Principals
National Association of Engineering Companies
National Association of Extension Home Economists
National Association of Federal Veterinarians
National Association of Food Chains
National Association of Furniture Manufacturers
National Association of Glove Manufacturers, Inc.
National Association of Government Employees
National Association of Government Inspectors
National Association of Greeting Card Publishers
National Association of Home Builders
National Association of Hosiery Manufacturers
National Association of Housing and Redevelopment Officials
National Association of Independent Food Retailers
National Association of Independent Schools
National Association of Letter Carriers
National Association of Life Underwriters
National Association of Manufacturers
National Association of Margarine Manufacturers
National Association of Mens' and Boys' Apparel Clubs
National Association of Motor Bus Owners
National Association of Mutual Insurance Companies
National Association of Mutual Savings Banks
National Association of Negro Business and Professional Women's Clubs, Inc.
National Association of Photographic Manufacturers
National Association of Planners-Estimators, and Progressmen
National Association of Plumbing-Heating-Cooling Contractors
National Association of Postal Supervisors
National Association of Postmasters of the U.S.
National Association of Post Office and General Services Maintenance Employees
National Association of Power Engineers, Inc.
National Association of Purchasing Agents
National Association of Real Estate Boards
National Association of Refrigerated Warehouses
National Association of Retail Druggists
National Association of Retail Grocers of the U.S.
National Association of Secondary School Principals
National Association of Securities Dealers, Inc.
National Association of Service Managers
National Association of Small Business Investment Companies
National Association of Special Delivery Messengers
National Association of State Universities and Land Grant Colleges
National Association of Textile and Apparel Wholesalers
National Association of Theatre Owners
National Association of Trade and Technical Schools
National Association of Variety Stores
National Association of Wheat Growers
National Association of Wholesaler-Distributors
National Association of Wool Manufacturers
National Automatic Merchandising Association
National Automobile Dealers Association
National Band Association
National Bankers Association
National Bar Association
National Brotherhood of Packinghouse and Dairy Workers
National Building Material Distributors Association
National Business Education Association
National Canners Association
National Coal Association
National Coffee Association of the U.S.A.
National Collegiate Athletic Association
National Commission on Accrediting
National Concrete Masonry Association
National Confectioners Association of the United States, Inc.
National Conference of Standards Laboratories
National Conference of States on Building Codes and Standards
National Congress of Parents and Teachers
National Constructors Association
National Consumer Finance Association
National Consumers League
National Cotton Council of America

National Council for Geographic Education
National Council for the Social Studies
National Council of Catholic Men
National Council of Catholic Women
National Council of Farmer Cooperatives
National Council of Jewish Women
National Council of Negro Women
National Council of Senior Citizens
National Council of Teachers of English
National Council of Teachers of Mathematics
National Council of the Churches of Christ in the U.S.A.
National Council of the Young Men's Christian Associations of the United States of America
National Crushed Stone Association
National Customs Brokers and Forwarders Association of America
National Dental Association
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National Education Association Division of Adult Education Service
Home Economics Education Association
National Electrical Contractors Association, Inc.
National Electrical Manufacturers Association
National Elevator Industry, Inc.
National Environmental Systems Contractors Association
National Executive Housekeepers Association
National Farm and Power Equipment Dealers Association
National Farmers Union
National Federation of Federal Employees
National Federation of Grain Cooperatives
National Federation of Independent Business
National Federation of Licensed Practical Nurses
National Federation of Post Office Motor Vehicle Employees
National Federation of Settlements and Neighborhood Centers
National Fluid Power Association
National Fire Protection Association
National Fisheries Institute
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National Furniture Warehousemen's Association
National Governors Conference
National Grange
National Hairdressers and Cosmetologists Association, Inc.
National Hand Knitting Yarn Association
National Higher Education Association
National Home Furnishing Association
National Home Study Council
National Housewares Manufacturers Association
National Housewives' League of America, Inc.
National Independent Automobile Dealers Association
National Independent Dairies Association
National Industrial Traffic League
National Industrial Workers Union
National Industries for the Blind
National Institute of Diaper Services, Inc.
National Institute of Drycleaning
National Institute of Governmental Purchasing, Inc.
National Institute of Municipal Law Officers
National Institute of Packaging, Handling and Logistic Engineers
National Institute of Real Estate Brokers
National Institute of Rug Cleaning, Inc.
National Knitted Outerwear Association
National Knitwear Manufacturers Association
National League of Cities
National League of Postmasters of the U.S.
National Licensed Beverage Association
National Lime Association
National Limestone Association
National Liquor Stores Association
National LP-Gas Association
National Lumber and Building Material Dealers Association
National Macaroni Manufacturers Association
National Machine Tool Builders' Association
National Management Association
National Marine Engineers' Beneficial Associatior
National Maritime Union of America
National Medical Association
National Milk Producers Federation
National Newspaper Association
National Notion Association

National Oil Fuel Institute

National Outerwear and Sportswear Association, Inc.

National Paint, Varnish and Lacquer Association

National Paper Box Association

National Pest Control Association, Inc.

National Petroleum Refiners Association

National Postal Union

National Ready Mixed Concrete Association

National Restaurant Association

National Retail Hardware Association

National Retail Merchants Association

National Rural Electric Cooperative Association

National Rural Letter Carriers' Association

National Sand and Gravel Association

National Scale Men's Association

National School Boards Association

National Science Teachers Association

National Screw Machine Products Association

National Secretaries Association

National Security Industrial Association

National Shoe Retailers Association

National Small Business Association

National Society of Professional Engineers

National Soft Drink Association

National Sporting Goods Association

National Tool, Die, and Precision Machinery Association

National University Extension Association

National Urban League

National Vocational Agricultural Teachers Association

National Warm Air Heating and Air Conditioning Association

National Waterways Conference, Inc.

National Wholesale Druggists Association

National Wooden Pallet and Container Association

Negro College Committee on Adult Education

Newspaper and Mail Deliverers' Union of New York and Vicinity

North Carolina Consumers Council

Northern Textile Association

Office and Professional Employees International Union

Ohio Consumers Association

Oil, Chemical and Atomic Workers International Union

Operations Research Society of America

Operative Plasterers' and Cement Masons' International Association of the United States and Canada

Optical Manufacturers Association

Order of Railway Conductors and Brakemen

Oregon Consumers League

Packaging Institute, Inc.

Packaging Machinery Manufacturers Institute

Paper Bag Institute, Inc.

Paper Shipping Sack Manufacturers Association

Paper Stationery and Tablet Manufacturers Association

Patent Office Professional Association

Pattern Makers League of North America

Peninsula Consumer League, Inc.

Pennsylvania League for Consumer Protection

Pharmaceutical Manufacturers Association

Pickle Packers International, Inc.

Plastic Products Manufacturers Association, Inc.

Plate, Cup, and Container Institute, Inc.

Portland Cement Association

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Printing Industries of America

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Producers' Council, Inc.

Professional Photographers of America

Radio-Television News Directors Association

Railroad Yardmasters of America

Railroad Yardmasters of North America, Inc.

Retail Clerks International Association

Retail, Wholesale and Department Store Union

Rhode Island Consumers' League

Rubber Manufacturers Association

St. Louis Consumer Federation

Sales and Marketing Executives – International

Salt Institute

Scale Manufacturers Association

Schiffli Lace and Embroidery Manufacturers Association

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Screen Manufacturers Association

Seafarers International Union of North America

Service Employees International Union, AFL-CIO

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Sheet Metal Workers International Association

Shipbuilders Council of America

Soap and Detergent Association

Society for Advancement of Management, Inc.

Society for Experimental Stress Analysis

Society for Industrial and Applied Mathematics

Society of Aerospace Material and Process Engineers

Society of American Florists

Society of American Foresters

Society of American Military Engineers

Society of Applied Medical Systems

Society of Automotive Engineers, Inc.

Society of Fire Protection Engineers

Society of Manufacturing Engineers

Society of Motion Picture and Television Engineers, Inc.

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Society of Photographic Scientists and Engineers

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Society of Real Estate Appraisers

Society of Soft Drink Technologists

Society of the Plastics Industry, Inc.

Society of Women Engineers

Society of Wood Science and Technology

South Dakota Consumers League

Southern Building Code Conference

Southern Furniture Manufacturers Association

Southern Labor Union

Sporting Arms and Ammunition Manufacturers Institute

Steel Founder's Society of America

Stove, Furnace and Allied Appliance Workers' of Nortl America

Structural Clay Products Institute

Sulphur Institute

Super Market Institute

Surety Association of America

Tanners Council of America

Technical Association of the Pulp and Paper Industry

Theater Equipment and Supply Manufacturers Association

Texas Consumers Association

Textile Distributors Association, Inc.

Textile Foremen's Guild, Inc.

Textile Workers Union of America

Tobacco Associates, Inc.

Tobacco Institute

Tobacco Workers International Union

Toilet Goods Association, Inc.

Tool and Die Institute

Toy Manufacturers of America

Transport Workers Union of America

Tricot Institute of America, Inc.

Truck Body and Equipment Association, Inc.

United Allied Workers International Union

United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States and Canada

United Brick and Clay Workers of America

United Brotherhood of Carpenters and Joiners of America

United Business Schools Association

United Cement, Lime and Gypsum Workers International Union

United Church Women of the National Council of Churches

United Electrical, Radio and Machine Workers of America

United Federation of Postal Clerks

United Fresh Fruit and Vegetable Association

United Furniture Workers of America

United Garment Workers of America

United Glass and Ceramic Workers of North America

United Hatters, Cap and Millinery Workers International Union

United International Union of Welders

United Mine Workers of America

United Papermakers and Paperworkers

United Rubber, Cork, Linoleum and Plastic Workers of America

United Shoe Workers of America

United Slate, Tile and Composition Roofers, Damp and Waterproof Workers Association

United States Beet Sugar Association

U.S. Brewers Association, Inc.

U.S. Conference of Mayors

United States Independent Telephone Association

United States Savings and Loan League

U.S. Screw Service Bureau, representing
- Aerospace Precision Fastener Association
- Aircraft Locknut Manufacturers Association
- Precision Aerospace Rivet Association
- Sockets Group Products Bureau
- Tapping Screw Service Bureau
- Tubular and Split Rivet Council
- U.S. Cap, Screw and Special Threaded Products Bureau
- U.S. Machine Screw Service Bureau
- U.S. Wood Service Bureau

United Steelworkers of America

United Stone and Allied Products Workers of America

United Telegraph Workers

United Textile Workers of America

United Transportation Union

United Transport Service Employees of America

University Photographers Association of America

Upholstered Furniture Manufacturers Association

Upholsterers' International Union of North America

Utility Workers Union of America

Valve Manufacturers Association

Vinyl Fabrics Institute

Virginia Citizens Consumer Council

Washington Committee on Consumer Interests

Washington Society of Engineers

Water Pollution Control Federation

Window Glass Cutters League of America

Wire Association, Inc.

Wisconsin Consumers League

Woodworking Machinery Manufacturers Association

Work Glove Manufacturers Association, Inc.

Writers Guild of America, Inc.

Writing Instrument Manufacturers Association, Inc.

Young Women's Christian Association of the U.S.A.

Zinc Institute, Inc.

Zirconium Association

FEDERAL AGENCIES THAT PARTICIPATED IN THE U.S. METRIC STUDY

Department of State
Department of the Treasury
Department of Defense
- Department of the Army
- Department of the Navy
- Department of the Air Force
- Defense Atomic Support Agency
- Defense Communications Agency
- Defense Intelligence Agency
- Defense Supply Agency
- National Security Agency

Department of Justice
Department of the Interior
Department of Agriculture
Department of Commerce
- Environmental Science Services Administration
- Bureau of International Commerce
- Maritime Administration
- Patent Office
- National Bureau of Standards
- U.S. Travel Service
- Office of Product Standards
- Office of Telecommunications

Department of Labor

Department of Health, Education and Welfare
- Environmental Health Service
- Food and Drug Administration
- Health Services & Mental Health Administration
- National Institutes of Health
- Office of Education
- Social Security Administration
- Social & Rehabilitation Service

Department of Housing and Urban Development

Department of Transportation
- Office of Secretary of Transportation
- U.S. Coast Guard
- Federal Aviation Administration
- Federal Highway Administration
- Federal Railroad Administration
- Urban Mass Transportation Administration
- National Highway Safety Bureau
- National Transportation Safety Board

Atomic Energy Commission
Civil Aeronautics Board
Federal Communications Commission
Federal Maritime Commission
Federal Power Commission
Federal Trade Commission
General Services Administration
Interstate Commerce Commission
National Aeronautics and Space Administration
National Science Foundation
Small Business Administration
Smithsonian Institution
Tennessee Valley Authority
U.S. Postal Service
U.S. Information Agency
U.S. Tariff Commission
Veterans Administration
Office of Management and Budget
Council of Economic Advisors
Office of Emergency Preparedness
Office of Science and Technology
Office of Telecommunications Policy
President's Committee on Consumer Interests
Government Printing Office
Library of Congress

APPENDIX TWO:

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(Hearings on Bills to provide that the National Bureau of Standards conduct a study to determine the practicability of the adoption by the United States of the metric system of weights and measures.)

[2] "Providing for a Survey To Determine the Practicability of Adopting the Metric System of Weights and Measures," H.R. Report No. 785 (to accompany H.R. 2049), 87th Congress, 1st Session, 1961.

[3] "Conversion to Metric System," Hearing Before the Committee on Commerce, United States Senate, 88th Congress, 2nd Session, on S. 1278, January 7, 1964.

(Hearings on a Bill to provide that the National Bureau of Standards shall conduct a program of investigation, research and survey to determine the practicability of the adoption by the United States of the metric system of weights and measures.)

[4] "Notes on Conversion to the Metric System," Report of the Committee on Science and Astronautics, U.S. House of Representatives, 89th Congress, 1st Session, 1965.

(Brings together representative information concerning the historical, technical, international, financial, industrial, and legislative aspects of the metric system and the types of problems involved in converting to it.)

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(to accompany H.R. 10329), 89th Congress, 1st Session, August 24, 1965.

(Incorporates language changes suggested by Department of Commerce. Contains additional views. Concurrent Resolution 458, by James G. Fulton, that U.S. adopt the metric system.)

[7] "Conversion to Metric System," Hearing Before the Committee on Commerce, United States Senate, 89th Congress, 1st Session on S. 774, July 14, 1965.

(Bill contains amendments suggested by Department of Commerce to focus study on impact of increasing worldwide use of metric system on United States.)

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(Testimony by Dr. J. Herbert Hollomon, Assistant Secretary for Science and Technology, Department of Commerce.)

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(S. 2356 intended to reflect industry concern with effect of metric usage on standards of size and shape, and to require more specific recommendations for meeting costs of conversion.)

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(H.R. 3136 modified to provide for study of engineering standards and recommendation as to means of meeting costs of conversion.)

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ISO/R 1000-1969(E)

ISO Recommendation	R 1000	February 1969

(Annex Omitted)

RULES FOR THE USE OF UNITS OF THE INTERNATIONAL SYSTEM OF UNITS AND A SELECTION OF THE DECIMAL MULTIPLES AND SUB-MULTIPLES OF THE SI UNITS

1. SCOPE

This ISO Recommendation gives rules for the use of units of the International System of Units and for forming and selecting decimal multiples and sub-multiples of the SI units for application in the various fields of technology

2. GENERAL

2.1 The name Système International d'Unités (International System of Units), with the abbreviation SI, was adopted by the 11th Conférence Générale des Poids et Mesures in 1960.

The coherent units are designated "SI units".

2.2 The International System of Units is based on the following six base-units :

metre (m)	ampere (A)
kilogramme (kg)	kelvin (K)
second (s)	candela (cd)

as units for the base-quantities : length, mass, time, electric current, thermodynamic temperature, and luminous intensity.

2.3 The SI units for plane angle and solid angle, the radian (rad) and the steradian (sr) respectively, are called supplementary units in the International System of Units.

2.4 The expressions for the derived SI units are stated in terms of base-units; for example, the SI unit for velocity is metre per second (m/s).

For some of the derived SI units special names and symbols exist; those approved by the Conférence Générale des Poids et Mesures are listed below :

Quantity	Name of SI unit	Symbol	Expressed in terms of basic or derived SI units
frequency	hertz	Hz	$1\ Hz = 1\ s^{-1}$
force	newton	N	$1\ N = 1\ kg{\cdot}m/s^2$
work, energy, quantity of heat	joule	J	1 J = 1 N.m
power	watt	W	1 W = 1 J/s
quantity of electricity	coulomb	C	1 C = 1 A·s
electric potential, potential difference, tension, electromotive force	volt	V	1 V = 1 W/A
electric capacitance	farad	F	1 F = 1 A.s/V
electric resistance	ohm	Ω	1 Ω = 1 V/A
flux of magnetic induction, magnetic flux	weber	Wb	1 Wb = 1 V·s
magnetic flux density, magnetic induction	tesla	T	$1\ T = 1\ Wb/m^2$
inductance	henry	H	1 H = 1 V·s/A
luminous flux	lumen	lm	1 lm = 1 cd·sr
illumination	lux	lx	$1\ lx = 1\ lm/m^2$

It may sometimes be advantageous to express derived units in terms of other derived units having special names; for example, the SI unit of electric dipole moment (A·s·m) is usually expressed as C·m.

2.5 Decimal multiples and sub-multiples of the SI units are formed by means of the prefixes given below :

Factor by which the unit is multiplied	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

The symbol of a prefix is considered to be combined with the unit symbol to which it is directly attached, forming with it a new unit symbol which can be raised to a positive or negative power and which can be combined with other unit symbols to form symbols for compound units.

Examples

$$1\ \mathrm{cm}^3 = (10^{-2}\,\mathrm{m})^3 = 10^{-6}\,\mathrm{m}^3$$

$$1\ \mu\mathrm{s}^{-1} = (10^{-6}\,\mathrm{s})^{-1} = 10^{6}\,\mathrm{s}^{-1}$$

$$1\ \mathrm{mm}^2/\mathrm{s} = (10^{-3}\,\mathrm{m})^2/\mathrm{s} = 10^{-6}\,\mathrm{m}^2/\mathrm{s}$$

Compound prefixes should not be used; for example, write nm (nanometre) instead of mμm.

3. RULES FOR THE USE OF SI UNITS AND THEIR DECIMAL MULTIPLES AND SUB-MULTIPLES

3.1 The SI units are *preferred*, but it will not be practical to limit usage to these; in addition, therefore, their decimal multiples and sub-multiples, formed by using the prefixes, are required.

In order to avoid errors in calculations it is essential to use coherent units. Therefore, it is strongly recommended that in calculations only SI units themselves be used, and not their decimal multiples and sub-multiples.

3.2 The use of prefixes representing 10 raised to a power which is a multiple of 3 is especially recommended.

NOTE. – In certain cases, to ensure convenience in the use of the units, this recommendation cannot be followed; column 5 of the tables in the Annex gives examples of these exceptions.

3.3 It is recommended that only one prefix be used in forming the decimal multiples or sub-multiples of a derived SI unit, and that this prefix be attached to a unit in the numerator.

NOTE. – In certain cases convenience in the use requires attachment of a prefix to both the numerator and the denominator at the same time, and sometimes only to the denominator. Column 5 of the tables in the Annex gives examples of these exceptions.

4. NUMERICAL VALUES

4.1 When expressing a quantity by a numerical value and a certain unit it has been found suitable in most applications to use units resulting in numerical values between 0.1 and 1000.

The units which are decimal multiples and sub-multiples of the SI units should therefore be chosen to provide values in this range; for example,

observed or calculated values	can be expressed as
12 000 N	12 kN
0.003 94 m	3.94 mm
14 010 N/m²	14.01 kN/m²
0.0003 s	0.3 ms

4.2 The rule according to clause 4.1 cannot, however, be consistently applied. In one and the same context the numerical values expressed in a certain unit can extend over a considerable range; this applies especially to tabulated numerical values. In such cases it is often appropriate to use the same unit, even when this means exceeding the preferred value range 0.1 to 1000.

4.3 Rules for writing symbols for units are given in ISO Recommendation R 31, Part . . . * : *General principles concerning quantities, units and symbols.*

5. LIST OF UNITS

For a number of commonly used quantities, examples of decimal multiples and sub-multiples of SI units, as well as of some other units which may be used, are given in the Annex to this document.

* At present at the stage of draft proposal.

(Annex Omitted)

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FEDERAL REFERENCE DATA

Title—A Metric America: A Decision Whose Time Has Come

NBS Special Publication 345

Author—Daniel V. De Simone, *National Bureau of Standards*

Key words—Business and industry; economy; education; international relations; international standards; international trade; metric; technology assessment.

Abstract—This report evaluates and distills the findings of the U.S. Metric Study in which thousands of individuals, firms and organized groups, representative of our society, participated. On the basis of all the evidence marshalled in the Study, the report concludes that the United States should change to the metric system through a coordinated national program. The chapter headings are: I. Perspective, II. Two Centuries of Debate, III. Measurement Systems, IV. Arguments That Have Been Made for Metric and for Customary, V. Going Metric: What Would It Really Mean? VI. The Metric Question in the Context of the Future World, VII. Going Metric: The Broad Consensus, VIII. Recommendation and Problems Needing Early Attention, IX. Benefits and Costs, X. Two Paths to Metric: Britain and Japan. The report includes a bibliography of 12 supplemental reports authored by members of the U.S. Metric Study Group.

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NASA

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and other private sources.

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U.S. METRIC STUDY

The U.S. Metric Study emblem uses the American Shield in a special way: The stripes represent the six base units of the International Metric System and the dot its decimal ratios.