NBSIR 83-2729

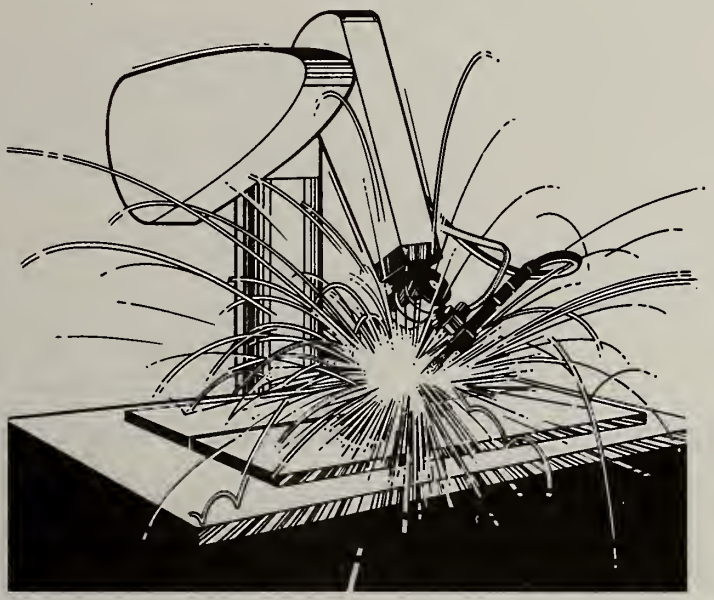
NATIONAL NEEDS IN WELDING TECHNOLOGY

PROCEEDINGS OF A CONFERENCE

April 28, 1983
Philadelphia, Pennsylvania

Sponsored by:

American Welding Society
Welding Research Council
The American Society for Metals
Federal Committee on Materials (COMAT)



Hosted by:

The American Welding Society

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Federal Committee on Materials

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, Secretary
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CONTENTS

INTRODUCTION

These proceedings are part of an initiative--jointly supported by the private sector and the federal government to address the need for an improved and coordinated U.S. effort in welding research and technology. This is in response to national recognition of the importance of advances in welding technology to progress in critical industrial areas (aircraft, automobiles, defense systems, electric power, electronics, heavy construction, and shipbuilding). A coherent U.S. approach to a strengthened technical position in welding is seen as highly desirable in the face of very active, well coordinated, government supported, welding technology programs overseas.

In 1982 welding specialists from the private sector and federal agencies met together and recommended that "business as usual" in welding was not an acceptable U.S. approach, and that an assessment be made of approaches to improve the U.S. competitive position. The recommendations were forwarded to the Office of Science and Technology Policy (OSTP). The Interagency Committee on Material (COMAT), reporting to OSTP, identified welding as one of three priority areas for attention. COMAT established a Task Group on Welding Technology which met early in 1983 with the American Welding Society (AWS), the Welding Research Council (WRC), the American Society for Metals (ASM), and university representatives.

The Conference described herein was organized by these groups to identify needs for welding research and technology, and to develop cooperative strategies that will provide a coordinated implementation mechanism. It was hosted by the American Welding Society and scheduled to coincide with the Society's 1983 National Convention in Philadelphia.

EXECUTIVE SUMMARY

The following preliminary work was done prior to the April 28, 1983 Conference. Technical representatives from industries, government, and universities submitted more than a hundred suggestions for needed research, development, engineering and technology transfer. A survey of welding equipment and consumable suppliers, base-metal suppliers, and weldment fabricators indicated that industry places principal emphasis on the need for development and dissemination of information on design, materials, selection, fabrication practices, and inspection procedures. Current federal research related to welding was compiled and reviewed. Primary objectives of the federal programs are (1) to improve weld processes to achieve productivity increases and cost reduction and (2) to assess the fitness-for-service of welded structures to ensure structural integrity.

At the Conference, 88 invited technical experts, corporate executives, and government managers met to identify implementation strategies to improve welding technology in the U.S. The morning session was devoted to a series of background presentations on the status and needs of welding technology as seen by private sector and government specialists. These papers are listed in the Agenda. In the afternoon two panels were convened in parallel and agreed on the following conclusions and recommendations by:

Panel I:

Strategies for Near Term and Long Term Improvement of U.S. Welding Technology

- CONCLUSIONS
  - Remedial action is necessary considering the lagging U.S. effort with respect to welding technology.

- It is unrealistic to just depend on existing government and industry laboratories, WRC/AWS, or foreign welding institutes or to increase support of welding technology at any of these existing facilities for the purpose of beginning a Welding Institute

- RECOMMENDATIONS

  Listed in order of priority but not mutually exclusive (votes pro-con as recorded)

  - Develop a strategy to:

    - Establish an American Welding Technology Applications Center (27-2)

    - Expand support for existing U.S. welding research at universities (16-5)

    - Establish an American Welding Institute similar to The Welding Institute in England (12-8)

  - Establish an eight-man Welding Technology Action Committee chaired by industry to address the three approaches and draft an action plan within 90 days.

Panel II:

Priority Needs and Opportunities in Welding Research, Development, Engineering, and Technology Transfer

Panel evaluated 114 research suggestions received prior to the Conference. First, priorities were established on the basis of scientific opportunity and needs of welding technology. Second, opportunities/needs were prioritized for coordination of ongoing activities.

- PRIORITY CATEGORIES OF NEEDS/OPPORTUNITIES

1. Productivity, Automation, Process Control
2. Microstructure Evolution and Solidification
3. Advanced Processes Development
4. Transport Processes, Measurement, and Modeling
5. Fitness for Purpose

- PRIORITY CATEGORIES FOR COORDINATED ACTIVITIES

1. Fitness for purpose
2. Productivity, Automation, Process Control
3. Codes, Standards, Specifications, and Regulations
4. Advanced Processes Development
5. NDE, Quality Control, and Inspection

CONFERENCE AGENDA

NATIONAL NEEDS IN WELDING TECHNOLOGY

Bellevue-Stratford Hotel, Red Room
Philadelphia, PA

April 28, 1983

A JOINT CONFERENCE OF THE AMERICAN WELDING SOCIETY, WELDING RESEARCH COUNCIL, AMERICAN SOCIETY FOR METALS, COMAT WELDING TASK GROUP

9:00 AM	Word of Welcome, AWS	Mr. Paul Ramsey
9:05 AM	Introduction	Dr. Robert Mehrabian
9:15 AM	The National Needs: Industry Summary*	Dr. John H. Gross
9:45 AM	The National Needs: Government Summary*	Dr. Hans Vanderveldt
10:20 AM	Coffee	
10:40 AM	Research Opportunities*	Dr. Bruce MacDonald
11:00 AM	Current Status: Industry Summary*	Mr. William T. DeLong
11:30 AM	Current Status: Government Summary*	Dr. Louis C. Ianniello
12:00 PM	Lunch	Tecumseh Room

1:00 PM Conference Participants will meet separately in two Workshop Panels

Workshop Panel I. Strategies for Near Term and Long Term Improvement of U.S. Welding Technology

Co-Moderators: J. Gross
H. Vanderveldt
D. Olson

Workshop Panel II. Priority Needs and Opportunities in Welding Research, Development, Engineering, and Technology Transfer

Co-Moderators:	Topic Areas:
R. Stout	- Metallurgy
J. Key	- Processes
G. Oyler	- Manufacturing and Technology Transfer

4:00 PM Coffee

4:15 PM Joint Session: Panel Moderators Report to Plenary Session

4:45 PM Discussion

5:30 PM Adjourn

*Copies of the Background Presentations and/or Visuals distributed by the speakers are available from Dr. J. D. McKinley, Center for Materials Science, National Bureau of Standards, Washington, DC 20234

Panel I:

STRATEGIES FOR NEAR TERM AND LONG TERM IMPROVEMENT OF U.S. WELDING TECHNOLOGY

The panel meeting was opened by Dr. Robert Mehrabian of NBS at 1:00 pm and was moderated by Dr. John Gross (U.S. Steel), Dr. David Olson (Colorado School of Mines), and Dr. Hans Vanderveldt (Naval Sea Systems Command). Mr. Robert Hardy (David Taylor Naval Ship R&D Center), and Mr. B. Joseph Werner (Airco, Inc.) acted as co-recorders. The panel members are identified in the List of Participants.

- **PRESENTATIONS**

- A presentation was made by Dr. Alan Wells of The Welding Institute (TWI)(Abington, England). He described its history, structure, and role in the U.K. He stated that TWI had no interest in making a capital investment in the U.S. to extend its position or role, but it would think favorably about temporary assignment of its personnel to the U.S. both to assist in the formation of an American Welding Technology Applications Center and to benefit the development of its personnel.

- A second presentation was made by Dr. Norman Eaton of the Welding Institute of Canada to inform the panel about the Institute's history and current activity. Key points in his talk relating to the successful formation and growth of a "welding institute" or "applications center" were:

  - Need for industrial champions

- Staffing implies continuity which requires stable funding

- Collaborative approach is essential

- Organization to be separate from government control

- Recognize that each component of the welding community (Government, Industry, University) has its strengths and weaknesses, but the linkages formed in an institute or center environment help to reinforce the strengths and overcome the weaknesses.

- Seed money (in this case the source was the Canadian Government) was essential to provide for the start-up expenses and permit the WIC to establish its credibility as an on-going organization.

DISCUSSION

- The Panel addressed the question "What are viable approaches to solving the problem?" and reached the following consensus:

  - Problem in U.S. Welding Technology is lack of: Communication, Coordination, and Collaboration.

  - Basic research is experiencing continued growth. Applied research and technology transfer are problem areas.

- Approaches considered to resolve the U.S. problem were based on 12 alternatives listed below. These were voted on by the Panel I attendees. The three approaches receiving favorable votes are listed in the RECOMMENDATIONS below.

- Do nothing beyond normal practice.

- Establish blue-ribbon panel to examine issues.

- Establish an American Welding Institute similar to The Welding Institute in England

- Expand support for existing U.S. welding research at universities.

- Establish an American Welding Technology Applications Center.

- Utilize The Welding Institute in England.

- Utilize The Welding Institute in Canada.

- Utilize the Welding Research Council and the American Welding Society.

- Utilize DOD and/or Government Laboratories.

- Utilize facilities at Industry Installations.

- Consider forming a "Technical Management Center"

- Consider mix of several viable approaches

● RECOMMENDATIONS

Favorable consensus in order of voting priority but not mutually exclusive (votes pro-con as recorded)

- Establish an American Welding Technology Applications Center (27-2)
- Expand Support for Existing Welding Research at U.S. Universities (16-5)
- Establish an American Welding Institute Similar to the Welding Institute in England (12-8)

Further Recommendations:

- Appoint an Action Committee of 6-8 members chaired by industry to develop an action plan within 90 days, incorporating the three recommended approaches and in the process:
  - Emphasize industry initiative
  - Consider the budget requirements of the proposed action plan
  - Consider possible government assistance
  - Consider as a model the EPRI NDE Center in Charlotte, NC
  - Consider as a model the approach used by the Welding Institute of Canada
- Refer Action Committee plan to Panel members for comment prior to publication or implementation

Panel II

PRIORITY NEEDS AND OPPORTUNITIES IN WELDING RESEARCH, DEVELOPMENT, ENGINEERING, AND TECHNOLOGY TRANSFER

Workshop Panel II was subdivided into three Subpanels as follows:

Subpanel A--Welding Metallurgy:
Dr. Stout, Moderator
Dr. Wolf, Recorder

Subpanel B--Welding Processes:
Dr. Key, Moderator
Dr. Reed, Recorder

Subpanel C--Manufacturing and Technology Transfer:
Dr. Oyler, Moderator
Dr. Hauser, Recorder

Forty-six individuals participated in the three Subpanels. Each Subpanel met for approximately two hours to:

- Prioritize needs and opportunities in R, D, and E, and Technology Transfer for increased support by industry and government
- Prioritize needs/opportunities for coordination of ongoing activities
- Identify unique facilities in the U.S.

Each Subpanel selected by ballot the five highest priority categories of needs/opportunities in their respective topic areas. The separate reports of the Subpanels are presented in Exhibits 2, 3, and 4.

The three Subpanels then convened as one Panel for approximately one hour to compile their highest priorities into one listing. There was some duplication in the categories so that a combination resulting in 12 categories was made. All members of the Panel voted to select the top 1/3, middle 1/3, and bottom 1/3 priority ratings for the categories.

● **RECOMMENDATIONS**(Full Panel II)

Exhibit 1 presents the 12 categories, the weighted rating results, and the order of priority which resulted from the balloting. Following are the five highest priority research categories.

- PRIORITY CATEGORIES OF NEEDS/OPPORTUNITIES

1. Productivity, Automation, Process Control

   Intelligent, closed-loop automation of welding processes requires diagnostic real-time information from the arc and weld pool and feedback control through computer interfacing. Sensors characterizing the dynamics of the weld pool, arc parameters, location and character of the weld groove, coupled with the development of models and with signal analysis for integrating such information into overall system control are research priorities.

2. Microstructure Evolution and Solidification

   The requirements for use of higher strength alloys with adequate toughness places emphasis on the development of matching

weldments. The control of microstructural evolution and solidification offers promise for improved weldability and improved weld-metal and heat-affected-zone toughness. The study of microalloying, solute distribution modeling, thermal cycle vs phase stability relationships, and enhanced grain refinement will contribute to better weldment mechanical performance.

3. Advanced Processes Development

The development of advanced weld processes promises to conserve energy, conserve materials, increase productivity, join advanced materials, and produce better weld quality. Research on narrow-gap weld design, high-energy-density beam and high-deposition rate processes, and development of improved power-supplies, and solid-state and flux-cored processes offer major opportunities.

4. Transport Processes, Measurement, and Modeling

Better information about the transport processes of the arc, weld pool, and surrounding solid is essential for welding process model development. Critical areas for research leading to control of microstructure, defects, and bead penetration and contour are experiments and modeling of heat and fluid flow and gas-metal and slag-metal interactions for which accurate measurement of the physical and chemical properties of liquid metals and slags is necessary.

5. Fitness for Purpose

The development of fitness-for-service methodology will lead to rational standards for weld quality, allowable stress levels, and material toughness. To produce reliable fracture mechanics models, research on nondestructive inspection for weld-defect sizing, in-service stress measurement, and development and verification of relationships among defect size, toughness, and strain need to be developed.

- PRIORITY CATEGORIES FOR COORDINATED ACTIVITIES

1. Fitness for purpose

2. Productivity, Automation, Process Control

3. Codes, Standards, Specifications, and Regulations: Standardization of requirements in all required documents

4. Advanced Processes Development

5. NDE, Quality Control, and Inspection: Post weld inspection, ultrasonic techniques, acoustic emission, eddy current, acceptance criteria for above, defect characterization.

• FACILITIES LIST

Panel II presented the following list of unique welding facilities in the U.S.

Laser Welder, 20 KW; Brown & Root, Houston, TX

Flash Upset Butt Welder for Pipe; McDermott, New Orleans, LA

Electron Beam Welder, 100 KW; Chicago Bridge, Chicago, IL

Phase Transformation Apparatus; University of Tennessee, Knoxville, TN

Full Size Environmental-type Test Facility for Corrosion; General Electric, San Jose, CA

Robotics Test Laboratory; General Electric, Schenectady, NY

In his morning presentation Dr. L. C. Ianniello listed the following outstanding federal facilities:

DOE

Diagnostics and modelling for arc/plasma/weld pool; computer controlled gas tungsten arc welder; NDE; Idaho National Engineering Lab.

Robotics for arc welding; explosive welding and modelling; precision welding with lasers/electron beam; Los Alamos National Lab.

Electron beam diagnostics/computer control/controlled environment; Lawrence Livermore National Lab.

	Continuous CO_2 laser, 9 KW; large diameter pipe weld test facility; Oak Ridge National Lab.
	Laser and resistance welding--process diagnostics/modelling; Sandia National Lab.
NASA	Variable polarity plasma arc welding; Marshall Space Flight Center
DOD	Arc/plasma diagnostics; Army Materials & Mechanics Research Center
	Experimental laser welding facility; Tank Automotive Command
	Arc/plasma diagnostics; Construction Engineering Research Lab.
	Inertial welding for dissimilar metals joining; Armament R&D Command
	Automated plasma arc facility for turbine repair; Oklahoma City Air Logis. Center
	Pulsed arc with waveform control; magnetic control of arc, infrared process monitor; hot cracking test facility; David Taylor NSRDC
	Continuous CO_2 laser, 15 KW; Naval Research Lab.

Panel II--Exhibit 1

PRIORITY CATEGORIES OF OPPORTUNITES/NEEDS

Category	Weighted Rating By Ballot	Priority
A-1 Specific Alloys	76	9
A-2 Microstructure Evolution and Solidification	91	2
A-3 Consumables	81	8
A-4 Fitness-for-Purpose	84	5
A-5 Thermal Physical Properties	54	12
B-1 (C-1) Productivity/Automation/ Process Control	116	1
B-2 Transport Processes--Measurement and Modeling	85	4
B-3 (C-2) Advanced Processes Development	90	3
B-4 (C-3) NDE, Quality Control, and Inspection	83	6
B-5 Process Effects on Metallurgical Structure and Properties	83	7
C-4 Welding Procedures and Parameter Development	67	10
C-5 Codes, Standards, Specifications, and Regulations	65	11

Panel II--Exhibit 2

REPORT OF SUBPANEL A, WELDING METALLURGY

Dr. Robert D. Stout, Moderator
Dr. Stanley M. Wolf, Recorder

The Welding Metallurgy Subpanel consisted of 14 members (see 29). The Subpanel identified five high priority generic topics and appropriate subtopics. The discussion identified the high-priority, near-term, quasi-specific areas, as well but recognized that an overall program in R, D, and E for Welding Metallurgy must be broad based, including both specific and generic efforts. The selection criteria for the near-term areas were: (1) bounded definition of the problem area, and (2) likelihood of meaningful technical results emanating in three to five years.

The generic areas representing highest priority needs/opportunities are listed below. Asterisks denote topics identified as high priority near term items; these are listed in the next paragraph in more detail.

A-1 Specific Alloys

- Steels, HSLA*, Stainless
- Aluminum alloys*
- Titanium alloys
- High temperature; nickel, cobalt alloys; advanced materials; dissimilar metals

A-2 Microstructural Evolution

- Hydrogen effects*
- Grain refinement*
- Segregation*
- Transformations; impurity effects; HAZ

A-3 Consumables

- Flux *
- Filler metals

A-4 Fitness-for-Purpose

- Defect detection, sizing, evaluation, and codification
- Residual stress; mechanical properties

A-5 Thermophysical Properties

High priority near term RD&E areas within the framework outlined above are:

A-1 Specific Alloys

- HSLA steels

- Aluminum
  Control methods for minimizing porosity
  Weldable high-strength heat-treatable alloys

A-2 Microstructural Evolution and Solidification

- Development of HSLA steels with improved weldability, particularly with respect to resisting hydrogen cracking

- Development of procedures and compositions of parent metal and weld metal to enhance grain refinement

- Segregation, modeling of solute distribution in weld metal

A-3 Consumables

- Flux development, e.g., slag-metal reactions to provide impurity control
- Filler metals for HSLA steel for toughness-critical applications

A-4 Fitness-for-Purpose

- Defect detection, sizing, evaluation, and codification

Under Categories for Cooperative Efforts, Subpanel A recommended the distribution of quarterly reports and preprints to scientists/engineers in the same major topical areas.

Panel II--Exhibit 3

REPORT OF SUBPANEL B, WELDING PROCESSES

Dr. James F. Key, Moderator
Dr. Richard P. Reed, Recorder

Panel members (see page 29) represented university, government, laboratory, and industrial interests in welding process research and development. The Subpanel's mission was to (1) identify priority research, development, and engineering topics needing more work or initiation of new investigations in the near future; (2) identify programs amenable to cooperative (inter-institutional) programs; and (3) identify advanced facilities and capabilities that could contribute to welding technology research and development. Members submitted topical suggestions for welding process R&D which included ongoing work that requires additional funding and new programs that could be initiated in the near future. Topics submitted were divided into the following categories:

B-1 Process Control--Automation

For the purposes of this Panel, automated processes are distinguished from mechanized or semiautomatic processes and defined as processes under intelligent closed-loop control. Diagnostic real-time information from the weld pool is sensed, fed back to a computer with a process model in the software, and corrective action taken.

- Sensor development
- Control models--all fusion processes
- Signal analysis and system integration

B-2 Transport Processes--Measurement and Modeling

Transport processes generally refer to heat and mass transport in the arc, the liquid weld pool, and the surrounding solid. They also have strong effects on, and are affected by physical and chemical reactions in a process. These procedures generally determine the structure, properties, and defect characteristics in welds and are fundamental to process model development.

- Heat and fluid flow
- Gas-metal and slag-metal interactions
- Physical and chemical properties of slags and liquid metals

B-3 Advanced Process Development

Advanced process development addresses process and equipment improvements and adaptations to join advanced materials, increase productivity, and improve quality.

- Narrow-gap joint designs
- High-energy-density beam processes
- High-deposition rate processes
- Power supply development and analyses
- Solid-state process development
- Flux-cored process development

B-4 Nondestructive Evaluation (NDE)--Postweld Inspection

- Ultrasonic techniques
- Acoustic emission techniques
- Eddy-current techniques
- Acceptance criteria for the above
- Defect characterization

B-5 Process Effects on Metallurgical Structure and Properties

This topic bridges transport process investigations with solidification and microstructure evolution.

- Solidification, microstructure, and phase stability
- Flaw formation
- Multipass welds--microstructure and phase stability
- Heat-affected zone--microstructure and phase stability
- Heat-input effects

The five major topics listed above were discussed by Panel members in detail. A consensus was reached that these five topics, as stated here, were the most critical subjects requiring further research and development and are excellent candidates for near-term technology benefit, even though complete solutions may take years of concentrated work. Panel members voted and ranked these topics by priority as follows:

B-1 Process Control--Automation
B-2 Transport Processes--Measurement and Modeling
B-3 Advanced Process Development
B-4 Nondestructive Evaluation (NDE)--Postweld Inspection
B-5 Process Effects on Metallurgical Structure and Properties

These rankings should be viewed with some caution. Process Control--Automation was clearly judged most important. Transport Processes and Advanced Process Development had nearly equal priority and can be viewed as an integral part of Process Control--Automation. NDE and Process Effects on Metallurgical Structure and Properties had nearly equal priorities. These topics are also closely related to the others listed. All five are most important to advancement of welding technology.

The Processes Subpanel also evaluated these topics for Cooperative Research and Development. Three topics in order of priority were judged most suitable for cooperative (inter-institutional) programs:

B-2 Transport Processes--Measurement and Modeling
B-1 Process Control--Automation
B-5 Process Effect on Metallurgical Structure and Properties

The Subpanel did not address the special facility/capability issue because an adequate listing of these facilities was provided in the morning session by Dr. Louis Ianniello.

Panel II--Exhibit 4

REPORT OF SUBPANEL C, MANUFACTURING AND TECHNOLOGY TRANSFER

Dr. Glenn W. Oyler, Moderator
Dr. Daniel Hauser, Recorder

The Manufacturing and Technology Transfer Subpanel consisted of 15 members (see page 30). The Subpanel members had submitted 46 proposals prior to the meeting. These proposals were catalogued into 15 categories (see Enclosure 2). The Subpanel was divided into three groups of five individuals each. One group reviewed the ten 5-page submittals, which had been prepared by industry representatives for Panel I, to extract the needs/opportunities that were presented in those submittals and that were applicable to manufacturing and technology transfer. Another group reviewed the submittals from the various government agencies to extract the applicable needs/opportunities. The third group reviewed the submittals that were presented to the Conference held at MIT by the Office of Naval Research on March 24-25, 1983, and extracted the applicable needs/opportunities. The total number (214) of the applicable needs/opportunities from all of these sources is tabulated by category in Enclosure 2.

The three groups then recombined as the Subpanel and voted by secret ballot to determine the five highest priority categories, and the weighted results for each category are shown in Enclosure 2.

The five identified highest priority needs/ opportunities are:

C-1 Productivity

- Automation, robotics, feedback control, etc.

C-2 Process Development

- Refinement of processes for applications, such as, narrow-gap welding, etc.

C-3 Quality Control and Inspection

- Improvement in Quality Control procedures and NDE

C-4 Welding Procedures and Parameter Development

- Research needed to determine the limits of the ranges of the many parameters
- Effect of interaction of parameters on heat input

C-5 Codes, Standards, Specifications, and Regulations

- Standardization of requirements in all required documents

Under Categories for Cooperative Efforts, Subpanel C recommended: first, C-5 Codes, Standards, Specifications, and Regulations; second, C-3 Quality Control and Inspection; and third, C-1 Productivity.

PARTICIPANTS LIST

PANEL I

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

These proceedings are part of an initiative--jointly supported by the private sector and the federal government to address the need for an improved and coordinated U.S. effort in welding research and technology.

The Conference described herein was organized by the American Welding Society, the Welding Research Council, the American Society for Metals, university representatives and COMAT to identify needs for welding research and technology, and to develop cooperative strategies that will provide a coordinated implementation mechanism. It was hosted by the American Welding Society and scheduled to coincide with the Society's 1983 National Convention in PHiladelphia.

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