NSRP NO. 0364
December 1992

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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

WELDING RESEARCH FOR SHIPBUILDING SP-7 PANEL PROGRAM FROM 1972 TO 1992

MARITIME ADMINISTRATION OF
THE U.S. DEPARTMENT OF TRANSPORTATION IN
COOPERATION WITH INGALLS SHIPBUILDING, INC.

A word about the NSRP:

The National Shipbuilding Research Program (NSRP) has been engaged in research research related to improvements in shipbuilding in the U.S. since 1973. The program is a cooperative effort involving shipyards both commercial and Naval and related industries and educational institutions.

Since the inception of the program in 1973, R&D projects have been performed which have contributed significantly to shipbuilding in the areas of facilities, environmental issues, outfitting and production aids, design and production integration, human resource innovations, training, coatings and flexible automation. A library and bibliography of NSRP reports is maintained at the University of Michigan, Transportation Research Institute, Ann Arbor, Michigan.

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WELDING RESEARCH FOR SHIPBUILDING

THE SP-7 PANEL PROGRAM FROM 1972 TO 1992

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for

U.S.DEPARTMENT OF TRANSPORTATION

MARITIME ADMINISTRATION

WELDING RESEARCH FOR SHIPBUILDING

THE SP-7 PROGRAM FROM 1972 TO 1992

1.0 INTRODUCTION

The primary purpose of this report is to provide current and future members of SP-7 with a comprehensive overview of major SP-7 projects and activities. SP-7 is the Welding R&D panel of the National Shipbuilding Research Program (NSRP) and is a panel of the Ship Production Committee of the Society of Naval Architects and Marine Engineers. It is chartered "to perform research and development tasks for the advancement of shipbuilding technology and methodology". Its goal is to develop and implement materials and processes which will result in the improvement of the competitive position of U.S. shipbuilding in the world marketplace. A copy of the charter and statement of objectives of SP-7 is given in the Appendix.

Over 40 evaluations of technology and projects relating to welding and have been performed under SP-7. Prior to showing a complete listing of the projects since 1973, a brief description will be given of the structure and functions of the National Shipbuilding Research Program.

2.0 STRUCTURE AND FUNCTIONS OF NSRP

The NSRP is a cooperative R&D effort of the U.S. Shipbuilding Industry, the U.S. Navy, the U.S. Maritime Administration and the industries, universities and research organizations which actively participate in projects and meetings. The National Shipbuilding Research Program is conducted by the Ship Production Committee of the Society of Naval Architects and Marine Engineers. The Ship Production Committee consists of the Executive Control Board, the SPC Panel Chairpersons and the NSRP program managers. The Nine Ship Production Committee panels, which meet at regular intervals, and the NSRP table of organization is included in the appendix.

The Executive control board is made up of leaders in U.S. Shipbuilding, support industries, government, and educational institutions. Chairpersons of the panels are selected by the Panel membership. Program Managers are designated by the support contracts of the sponsoring agency, the U.S. Navy or the Maritime Administration. Program Management costs are provided under cost sharing contracts with the sponsoring shipyards. The program has received financial support from the Maritime Administration of the U.S. Department of Transportation and the U.S. Navy. The mandate for the program has its origins in the Merchant Marine Act of 1970, Section 212 Paragraph c. which provided for "collaboration with ...shipbuilders in developing plans for the economical construction of vessels"

3.0 SOURCES OF SUPPORT FOR THE SP-7 PROGRAM

Selection and prioritization of R&D projects to be performed is a function of the nine panels which make up the action arms of the NSRP. Members of the Ship Production Committee and members of the nine panels, including the Chairpersons, serve on a voluntary basis. Thus, in addition to Maritime Admistration and U.S. Navy funding, the entire program is dependent upon the voluntary support of the organizations which provide for their membership and time.

Prior to 1990 each panel was provided with separate funding for program management services. The program management functions include meeting arrangements, project subcontracting, report publication and distribution and technology transfer. These funds also provide for financial and some other support services of the sponsoring shipyards. In the case of SP-7, Program management from 1980 to 1982 was provided under contract with Sun Ship Inc., Chester, Pennsylvania. From 1983 to 1987 Program Management and the Chairmanship of SP-7 was sponsored by Newport News Shipbuilding Inc., Newport News, Virginia. The Chairmanship and Program Management transferred in 1986 and 1987 with two existing and one new cost sharing contract to Ingalls Shipbuilding Inc., Pascagoula, Mississippi.

In 1988 federal direction and support of the NSRP was changed from the Maritime Administration of the U.S. Department of Transportation to the U.S. Navy Research Center at Carderock, Maryland. Under the Navy program the nine panels of the NSRP are divided into three groups, Design Engineering, Industrial Processes, and Resource Management. Three full time program managers provide the support services, one to each of the three groups.

4.0 SP-7 CONTRACTS

Since 1980 four Maritime Administration contracts have provided support to the NSRP for SP-7, welding related projects:

MA 11989*	Program Management Support of Ship Production Panel SP-7
MA-80-SAC-01041	Research to Improve Welding Technology
DTMA-84-C-41028	Welding Improvement Program
MA-12122	Cooperative Agreement for SP-7 R&D Projects Program Management for NSRP

*In 1987 cooperative agreement MA 11989 between Ingalls

(* cont'd)
and the U.S. Maritime Administration was signed. It provided for Ingalls to maintain continuity of Program Management of SP-7 as the ...01041 and ...41028 contracts were being transferred from Newport News to Ingalls. MA 11989 did not fund any technical projects.

Prior to 1980 the SP-7 program was managed for the NSRP by Bethlehem Steel Shipyard at Sparrows Point, Maryland. In 1980 the 01041 contract was awarded to Sun Shipbuilding in Chester, Pennsylvania. The contract was moved to Newport News Shipbuilding, Newport News, Virginia in 1984. Newport News Shipbuilding supported Ben Howser as Chairman and Mark Tanner as program manager. At that time the 41028 contract was moved from Sun Shipbuilding to Newport News. In 1987 both the 01041 contract and the 41028 contract were moved to Ingalls Shipbuilding Inc in Pascagoula, Mississippi. Lee Kvidahl, Ingalls Chief Welding Engineer succeeded Howser as chairman of SP-7 and O.J. Davis of Ingalls was appointed as Program Manager. In 1989 cooperative agreement MA 12122 between Marad and Ingalls was signed to provide for Program Management and also for two technical SP-7 projects. The Ingalls contracts continued through November, 1992 and provided for subcontracting and completion of all projects funded by MARAD. In 1989 the funding of the SP-7 program was continued by the Manufacturing Systems Division of the U.S.Navy's David Taylor Research Center (now Naval Surface Warfare Center), Carderock, Maryland. The Program Management function for Navy work was contracted to Petersen Builders Shipyard, Sturgeon Bay, Wisconsin. James Rogness of Petersen Builders serves both SP-7 for welding and SP-3, the Surface Preparation and Coatings Panel

5.0 SELECTION OF PROJECTS

The technical objectives of the SP-7 program are met by projects which are proposed and submitted by panel members, associate members, and in many cases visitors to the meetings. The only requisite is that proposals be addressed to the improvement of productivity and quality of welding in shipbuilding. All project proposals submitted for consideration by SP-7 are studied by the membership and prioritized according to criteria of relevance, probability of technical success and potential impact on producibility, quality and cost effectiveness in shipbuilding. The projects deemed most needed by the industry are presented by the panel chairman to an annual meeting of the Ship Production Committee Executive Control Board. Efforts are then made by the Executive control board to allocate available funds for those projects judged most likely to produce the greatest benefits to shipbuilding productivity.

6.0 IMPACT OF SP-7 ON WELDING AND MATERIALS IN SHIPBUILDING

Over the past 20 years significant impacts on the materials and processes of shipbuilding have been made as a direct result of SP-7 projects. In some cases the project and its report merely provided the start that was needed to stimulate the follow on work which produced the most beneficial results apart from SP-7 support. Such is the nature of R&D. An abstract of each project report is beyond the scope of this report, however, a brief overview is given of some projects considered highly beneficial to welding in shipbuilding.

Each SP-7 project produces a detailed technical report. Some projects have produced first generation items of welding related hardware such as more efficient processes, improved filler materials, and more weldable alloys for better productivity in building ships. Prototype power supplies and wire feed mechanisms have been further developed and have found widespread use in shipyards. These are examples of win-win situations where not only the private and public shipyards have benefitted but also university researchers and suppliers in the commercial sector. In some cases projects have reduced the limitations which originally prevented application of a cost effective welding process for shipbuilding applications. Some projects have contributed simultaneously to quality and producibility, as well as to the metallurgy of steel, aluminum, filler metals and casting alloys. Examples of the latter are the High Yield Strength Weldable Casting and the HSLA filler metal projects.

6.1 DEVELOPMENT OF A FLEXIBLE WIRE GUIDE FOR MIG WELDING

An example of a hardware contribution is the development of a continuous weld wire feed system for MIG welding. An innovative wire drive design was developed and, in combination with a flexible delivery guide tube, the welder was enabled to perform work more than 200 feet from the power supply and wire feeder.(NSRP project report 0041, Development of Extended Length, Continuous Wire Feed System)

6.2 IMPROVEMENTS IN AUTOMATION AND POWER SUPPLIES

Development and implementation of automated and robotic welding systems is a longterm goal of U.S. Shipbuilding. To be functional and practical for shipbuilding in field and many shop applications, automatic welding equipment must be rugged and portable. In one SP-7 project a lightweight tractor was developed which was the basis for a series of improved and upgraded welding tractors. Another innovation was the development of prototype welding control circuitry which has led to great improvements in pulsed gas metal arc welding processes which are now widely and productively implemented throughout the industry.

6.3 THROUGH-THE-ARC SEAM TRACKERS FOR ROBOTIC WELDING

A significant advancement in automated welding technology resulted from the projects which applied computer technology to the development of automated, seam tracking welding. In these projects (Tracking System for Automatic Welding, Ph I and II) electrical information such as arc voltage, welding current and wire feed rate was controlled by a computer to programmed welding parameters. In this way the computer was able to perform real-time corrections to welding parameters as needed to control the width of oscillation, heat input (electrical parameters), and correct the path of the tractor about the centerline of the joint while welding.

This project provided the base for further development of through-the-arc sensing technology which is extensively used in robotic welding. Some of the problems encountered in developing this system lead directly to a follow on project which resulted in improvements in selection of GMAW torch tip materials. This in turn resulted in longer tip life and greater continuous use without down time to replace torch tips.

The technology of sensing and computer processing of real time welding arc parameters was subsequently adapted to quality control applications in that actual real time parameters used in welding can be sensed and stored in computer files. Such systems are now commercially available.

Prior to the robotic "thru-the-arc" seam tracking projects described above, several study projects on potential use of robots in U.S. Shipbuilding were undertaken. Two welding robots were the subject of project reports in the '80's, the Unimation "Apprentice" and the Cincinnati Milacron T-3 Robot. SP-7 project report, NSRP 0173, July 1983, NSRP 0182, December 1983 and NSRP 0183, March 1984 demonstrated clearly the need for simplicity and repetitiousness in fabricated component and structural details for advantageous use of robots in the state-of-the-art of that time. These projects did lead to implementation of robots in several shipyards especially in the manufacture of hatches and doors. Other applications such as fabrication of pipe and wireway hangers are in process.

6.4 ROBOTIC WELDING IN JAPAN

Visits were made to Japan in 1983 and 1991 to observe their activities in design and implementation of robots. These two visits showed how special purpose portable robots can be effectively used to make structural welds of bulkheads and panels and other applications. The most useful applications were found to be on long, flat position and vertical fillet welds. Success of these applications were found to be dependent on great similarity of work pieces, tightly integrated flow of work and just-in-time staging of materials. The visits also clearly showed that gantry mounted robots can be made cost effective for structural welding where commercial ships can be designed for repetitiousness of components and simplicity. It was noted that the principle of thru-the-arc sensing as in the SP-7 computer controlled tracking study was adapted for use in Japanese robotic welding in three shipyards visited.

6.5 LIGHTWEIGHT INVERTER WELDING POWER SUPPLIES

An SP-7 sponsored project which has continued to influence the welding industry is the development of a lightweight power supply based on solid-state inverter technology. The principal of using higher frequencies to reduce the weight requirements of power supplies which use transformers was well known. The objective of utilizing solid state switching devices to increase the frequency of available 60 Hertz was achieved and these advanced technology power supplies were demonstrated as applicable to Shielded Metal Arc, Gas Metal Arc and Gas Tungsten Arc welds. These project results were reported in NSRP 0041, Development of a Portable AC/DC Welding Power Supply Module, June 1974. As reported in a recent article of the Journal of the American Welding Society the technology developed from this project is now the basis for an entire family of modern lightweight welding power supplies.

6.6 HIGH HEAT INPUT WELDING

High strength steels with high toughness and tolerance to high heat input welding have been the subject of SP-7 welding and materials development projects. Retention of high toughness at low temperatures is an essential property of steels for ships which are expected to sail in all of the worlds oceans. High heat input welding can be highly productive in shipbuilding, however, high heat inputs can be destructive to toughness in some traditionally used high strength alloys. The properties of welding filler metals are of equal importance. In some ways improvements in filler metals are more difficult because, where steel plates can be controlled in thermal history and rolling conditions, filler metal properties are essentially the result of solidification in the weld joint. SP-7 projects have addressed this problem area and have produced useful information adding to the body of metallurgical knowledge of High Strength Low Alloy steels and the metallurgy of filler materials. Development work in these areas is continuing.

6.7 SUBMERGED ARC WELDING WITH BULK FILLER MATERIALS

In the project report, Automatic Submerged Arc Welding with Metal Powder Additions, NSRP 0253 June 1986 the basis for high heat input welding was developed with bulk additions to the flux and puddle. It was found that up to 60% increase over conventional sub-arc welding deposition could be achieved with heat inputs up to 85 Kilojoules/inch., The report shows positive findings on heat affected zone grain structures. This work also provided direction for further needed research.

6.8 TUBULAR ELECTRODES FOR SUB-ARC WELDING

In the project, Tubular Electrodes Designed for Submerged Arc Welding, NSRP 0241, July 1984, average improvements of 19% in deposition rates were demonstrated with commensurate increase in welding efficiency and no sacrifice in quality. The use of flux cored electrodes in shipbuilding has multiplied since that time.

6.9 IMPROVEMENTS IN MIG WELDING USING FLUX CORE ELECTRODES

In the project, Twist Wire GMAW and FCAW Narrow Gap Welding, NSRP 0261 March, 1988 good penetration of the side walls of narrow gap joints was shown using twisted wire electrodes. It was found that twisted wire for both the Gas Metal Arc and Flux Core Arc process produced the effect of an arc rotation with the arc directed first to one side of the joint then the other as the twisted wire melted back. The process has been used in production with beneficial cost reductions resulting from the decreased volume of weld metal required for welding thick wall steam pressure vessels.

Another filler metal project established useful baseline data on the longitudinal shear strength of new flux core filler wires, (see NSRP 0297). The absence of empirical data on these properties constrained designers to the dimensions of welds based on data of the much slower shielded metal arc process. The shear strength of Mil-101TC/TM electrode was found to be equivalent to coated electrodes but the Mil-71T1-HY was found to be 15% higher. Both weight savings and cost savings are expected to result from this work.

6.10 ELECTROSLAG WELDING OF LARGE CASTINGS

Large high yield strength castings have important uses in modern ships for shaft struts, propeller shaft housings, rudders, rudder stocks and other applications. Joining of large castings with efficient welding processes has always been a difficult problem. An SP-7 project reported in NSRP 0252, August 1986, "Consumable Guide Electroslag Welding of 4" to 24" Thick Carbon Steel Castings" studied the innovation of using multiple consumable guides to increase the efficiency of the metal deposition rate. Details of the test assemblies and equipment configuration successfully used are shown in that report.

6.11 A NEW HIGH YIELD STRENGTH CASTING ALLOY

The development of a new High Yield Strength Casting Alloy which can be welded without preheat was established as an objective of the SP-7 panel. Success in this effort will not only allow significant reductions in cost to weld but will also permit greater flexibility in design and use of high strength steel in large and small castings. Complex castings of high strength steel which require welding to make up the finished components will also be more economical to fabricate. The alloy development phase of this project was conducted jointly by Esco Corporation and Oregon Graduate Institute.

The project report, NSRP 0326 High Yield Strength Steel Casting for Improved Weldability, 1991, has placed this valuable metallurgical information in the public domain and has sufficient detail that any interested company or university can duplicate and continue the work. The best casting alloy which resulted from the iterations of chemistry in phase I has been demonstrated to be weldable without cracking under severe conditions of restraint and which consistently results in cracks to HY 80 steel castings. Toughness properties are equal to HY80 castings.

The next step in this development requires demonstration of producibility of this material in production size melts. Given the success of this alloy development task, SP-7 may find justification in revisiting some of the high heat input, high production rate welding projects which were only moderately successful with conventional alloys.

6.12 AIDS TO VISUAL INSPECTION OF WELDS

The investigation and development of improved methods of inspection of welds are included in the SP-7 charter. The most frequently used method of inspection of welds in shipbuilding is visual inspection. It is also the most common cause of rejection and costly rework of welds. Visual inspection is highly subjective and given to individual interpretation. In order to reduce this subjectivity and reduce unneeded rework of welds, the membership of SP-7 developed a set of butt welds and fillet welds with typical surface imperfections. These welds were carefully selected to show degrees of severity which could be correlated to acceptable and unacceptable requirements of the inspection standards most commonly used in U.S. Shipbuilding.

Selected samples of welds with imperfections, 32 in all, were molded and replicated by casting using durable plastic which preserved the fine details of the original welds. A total of 400 sets of plastic replicas and User's Manuals for each set were made in the three Phase project, Visual Reference Standards for Weld Surface Conditions (NSRP 0338, September 1991). These sets were distributed to all U.S. Shipyards, universities teaching welding science and technology, Maritime Schools, Navsea, Navy Research Centers, Coast Guard Safety Officers, American Bureau of Shipping, American Welding Society, American and Edison Welding Institutes and technical professional organizations.

6.13 DISTORTION CONTROL IN WELDING AND CUTTING

Precision and repeatability are recognized to be essential to extensive use of robotics in welding of ship structures. As an aid to that objective, and also to further the benefits of statistical process controls, an SP-7 Project was performed.

The project report NSRP 0314, September 1990 entitled Fabrication Accuracy Through Cutting and Welding Distortion Control and Flame Straightening, sought to document the improvements which can be made in fit-up accuracy using various straightening technologies together with statistical process control methods. These improvements are essential to implementation of more extensive use of robotics and automation for welding.

6.14 LINE HEATING APPLIED TO PIPE ALIGNMENT

In the early '80s the principles of line heating were shown in NSRP sponsored projects to be cost effective for accuracy in forming shaped parts. In the SP-7 Project report, Flame Bending of Pipe for Alignment Control, NSRP 0297, March 1990, the principles of line heating were shown to be applicable to alignment control of pipes in shipbuilding. The follow up project resulted in NSRP 0336, 1991, Practical Guide for Flame Bending of Pipe. These two reports may be now used by any shipyard to develop the procedures and training programs necessary to implement this technology.

6.15 DESIGN AND PLANNING FOR WELDING COST IMPROVEMENTS

The NSRP program has brought out in many ways the inseparable relationship between appropriate design and detailed planning in order to implement the most efficient cutting, fitting and welding programs in shipbuilding. Several starts were made in the 80's by SP-7 to deal with the producibility problems relating to design and planning. Finally a project with Puget Sound Naval Shipyard produced the report, NSRP 0339 Design and Planning Manual for Cost Effective Welding, October 1991. This document is more than a report of an investigation. It is rather a working document which provides fundamental guidance to design engineers, welding engineers, Production supervisors, welders and production planners.

It is not feasible for a single document to deal definitively with all of the subjects identified in the Design and Planning Manual which are essential to cost effective welding. However, the project and the report succeeded in integrating in one document the basic requirements of economy, design principles, metallurgy, fitting, welding and inspection applicable to welding in shipbuilding. It provides a basis for each shipyard to insert and to modify the Design and Planning Manual to suit the individual shipyards. In addition the manual sets forth the principles of statistical process control and thermal straightening which are aiding in the correction and control of distortion caused by welding. In addition to having use as a technical reference, this project document is also the basis for a training program in at least one shipyard.

7.0 AVAILABILITY OF SP-7 REPORTS

An effort has been made in this review of the SP-7 program to characterize what are considered to be some of the main project contributions of the SP-7 Panel of the NSRP. An overview of some but not all of the projects is included, however, all projects are listed below. It was not possible to provide separate abstracts of each of the projects performed under the auspices of the SP-7 panel and the National Shipbuilding Research Program. For a complete set of abstracts, use may be made of the Bibliography of the NSRP maintained at the the University of Michigan, Transportation Research Institute, 2901 Baxter Road, Ann Arbor, Michigan, 48109. The bibliography provides listings and abstracts of all SP-7 and other NSRP panel projects all of which are available as reprints or microfiche.

8.0 COMMUNICATION, A MAJOR BENEFIT OF THE NSRP PROGRAM

One of the greatest benefits of the NSRP program is the communication between leaders in shipbuilding welding and other disciplines provided by panel meetings, project reports and symposia. The consensus opinions reached by SP-7 members on the most productive areas in which to focus the available resources could hardly be achieved in any other way. The meetings keep lines of communication between shipyards open throughout each year. The result of this communication is technology transfer and incalculable cost savings and cost avoidances by essential technical exchanges.

9.0 LISTING OF SP-7 PROJECTS - 1973 to 1992

One of the objectives of this report is to briefly recount the SP-7 program and projects which have been supported by Marad contracts.

Some projects were discontinued because of shutdown of the sponsoring shipyard, in some cases the cause was loss of key personnel and in some it was recognized that the priority interests of the NSRP were not being served. Such projects were terminated and available funds were reassigned. In some cases terminated projects were restarted after rescoping and identification of suitable subcontractors. An example is the Design and Planning Manual for Cost Effective Welding project which was successfully completed by Puget Sound Naval Shipyard in 1991.

Listed below are all SP-7 projects which resulted in technical reports. In parentheses, following the Project report are the project identification number, the Project title if different from the report title, the date of the report, and the performer or subcontractor.

9.1 CONTRACT MA 11989 (program management contract - no technical projects)

9.2 PROJECTS OF MA 12122

Design and Planning Manual for Cost Effective Welding, NSRP #0339, October 1991 (Project 7-87-1, Puget Sound Naval Shipyard)

Fabrication Accuracy Through Cutting and Welding Distortion Control and Flame Straightening, NSRP #0314 September, 1990 (Project 7-87-2, Ingalls Shipbuilding,

9.3 PROJECTS OF DTMA-84-C-41028

Laser Cutting of Structural Members with High Powered Nd:YAG Laser System, NSRP #0363, November, 1992 (project 7-84-13, Pennsylvania State University)

High Yield Strength Steel Casting for Improved Weldability, NSRP #0326, May 1991, (project 7-84-12, Esco Corporation, Portland Oregon and Oregon Graduate Institute)

Visual Reference Standards for Weld Surface Conditions, and User Guide for Weld Replicas, Ph III, NSRP #0338, September, 1991,(Project 7-84-11, American Bureau of Shipping and subcontractor<Hellier Technical Training and consulting>)

Evaluation of the Benefits of HSLA Steels Ph IV, NSRP 0292, March 1989, combined reports for Phases I,II,III and IV), (Project 7-84-9 provided for Phase IV and report, Beaumont Shipyard of Bethlehem Steel Corporation)

Flame Bending of Pipe for Alignment Control, NSRP #0297, March, 1990, (Puget Sound Naval Shipyard)

Evaluation of the Benefits of HSLA Steel Ph II, combined report in #NSRP 0292, March 1989, (Project 7-84-5, Beaumont Shipyard of Bethlehem Steel Corporation)

<u>9.4 Projects deleted or discontinued from DTMA 84-C-41028:</u>

Design and Planning Manual, (was 7-84-01, Project was completed under contract MA 12122)

Robotic Arc Welding Technology, (was 7-84-02)

Automated Recordable Ultrasonic Inspection (7-84-03)

Substitute Eddy Current Inspection for Magnetic Particle Inspection (was 7-84-04)

Determination of Hydrogen in Weldments (was 7-84-06)

Development of Fitting and Fairing Aids for Curved and Non-Parallel Subassembly, (was 7-84-07)

Evaluate High Strength Steels by Advanced Metallurgical Processes (was 7-84-10)

<u>9.5 PROJECTS of MA-80-SAC-01041</u>

Practical Guide for Flame Bending of Pipe, NSRP 0336, 1991 (Substituted for Project 7-SP-7, Puget Sound Naval Shipyard)

Investigation of Tubular Electrodes Designed for Submerged Arc Welding Applications, NSRP 241, July 1986 (Project #7-83-1, also referred to as Cored Wire for Sub-Arc Welding project, Bay Shipbuilding, Wisconsin)

Evaluation of the Benefits of HSLA Steel Ph III, combined report NSRP 0292, March 1989, (Project 7-SP-9, Bethlehem Steel Beaumont Shipyard)

Evaluation of the Fillet Weld Shear Strength of Flux Core Welding Electrodes, NSRP 0297, September 1989,(Project 7-SP-8, titled Longitudinal Fillet Weld Shear Strength of Flux Core Electrodes, Ingalls Shipbuilding)

Evaluation of High Strength Steels Produced by Advanced Metallurgical Processes, NSRP 0262, Sept 1987 (Project 7-SP-6, titled Thermo-Mechanically Processed High Strength Steel, American Bureau of Shipping)

Higher Strength Steel Specially Processed for High Heat Input Welding, NSRP 0209, February 1985 (project 7-SP-5 titled Candidate Steels for High Heat Input Welding American Bureau of Shipping)

Study Mission to Japan Trip Report, NSRP 0173, July 1983 (project 7-SP-4, combined report Newport News, American Bureau of Shipping, NAVSEA, and NASSCO)

Evaluation of the Cincinnati Milacron T3 Robot for Shipbuilding Welding, NSRP 0183 March 1984 (Project 7-SP-3, Todd Shipyard)

Acceptance Standards for NonDestructive Test Not Required by Classification Ph II, NSRP 0215, Sept 1985 (Project 7-SP-2, American Bureau of Shipping)

Acceptance Standards for NonDestructive Test Not Required by Classification, Ph I`NSRP 0168, March 1983, (Project 7-80-3, American Bureau of Shipping)

Visual Reference Standards for Weld Surface Conditions, Ph II NSRP 0220, March 1986 (Project 7-SP-1, includes Photos of metal samples used for plastic replica sets, American Bureau of Shipping)

Automatic Submerged Arc Welding with Metal Powder Additions to Increase Productivity and Maintain Quality, NSRP 0253, June 1986 (project 7-83-2 titled Bulk Welding of High Strength Steels, Newport News Shipbuilding, Inc)

Out-of-Position Welding of 5000 Series Aluminum Alloys Using Pulse GMAW Power Sources, NSRP 0184, January 1984 (Project 7-82-5 titled, Aluminum Welding or Pulsed Gas Metal Arc Welding of Aluminum, Todd Pacific Shipyard, Seattle)

Evaluation of the Usability and Benefits of Twist Wire GMAW and FCAW Narrow Gap Welding, NSRP 0261, March 1988 (this project replaced 7-83-4 and was performed by Puget

Sound Naval Shipyard)

Tracking System for Automatic Welding, Ph II, Improvement of Contact Tip Life for Through-the-Arc Welding System, NSRP 0291, February 1989, (Project 7-SP-3, Electric Boat Division)

Tracking System for Automatic Welding, Ph I, NSRP 0211, (Project 7-83-3, Electric Boat Div.; used CRC M1000 through-the-arc sensing and computer control of arc path)

Consumable Guide Electroslag Welding of 4" to 24" Thick Carbon Steel Castings, NSRP 0252, August 1986, (project 7-82-2 titled Multi-Consumable Guide Electroslag Welding Newport News)

Evaluation of the Benefits of HSLA Steels Ph I, NSRP 0292 March 1989, combined report, (project 7-82-1, replaced project titled Ultrasonic Equipment Develop project, performed by Beaumont Shipyard of Bethlehem Steel Corp.)

SMAW Ceramic Weld Backing Evaluation, NSRP 0125 March 1982 (project 7-80-5, Performed by OffShore Power Systems, Jacksonville, Florida)

Study of Fitting and Fairing Aids of U.S. Shipyards, NSRP 0195, September 1984, (project 7-80-4, Todd Pacific Shipyard and National Steel and Shipbuilding, San Diego, California)

Visual Reference Standards for Weld Surface Conditions, Ph I NSRP 0168, April 1983 (project 7-80-3 American Bureau of Shipping)

Special Studies (project 7-80-2, reports resulting from special studies are listed as SP reports)

Unimation "Apprentice" Welding Robot for Shipyard Application NSRP 0182, December 1983, (project 7-80-1, titled Robot Welding, Todd Pacific Shipyard)

9.6 Deleted Projects From MA-80-SAC-01041

Ultrasonic Equipment Development (was 7-82-1)
Tubular Electrodes for Sub Arc Welding Ph II (was 7-SP-7)
Automated Portable Tack Welders for Shapes (was 7-83-4)
Low Hydrogen Welding Processes (also referred to as Low Moisture Electrode project, was 7-82-4)

9.7 PROJECTS OF THE SP-7 R&D PROGRAM UNDER U.S. NAVY FUNDING

Most of the SP-7 Projects started after 1990 under subcontract to Petersen Builders with Navy funding are underway at the time of preparation of this report. They include the following:

Development of a Portable Tackwelder -(Project 7-91-1) A carriage to perform automatic welding of tacks has been designed and is being built at Mare Island Naval Shipyard.

Advanced Cutting Technology - (7-89-2) Various state-of-the-art processes of cutting ship components are being evaluated at Ingalls Shipbuilding in this project. Processes include laser, waterjet and other methods. Photogrammetry is being used to measure distortion produced by the various methods.

Pulse Purge for Consumable Insert Welding - (7-90-2) Pressure pulses applied to purge gas in pipe welds allow a welder to see the precise point at which a consumable insert is properly fused. This project is developing those techniques in preparation for technology transfer to other shipyards.

Autogenous Pipe Welding - (7-90-3) Welding processes leading to elimination of need for filler metals in making pipe welds are being researched at Mare Island Naval Shipyard

Tee Beam Manufacturing Analysis - (7-91-4) Various approaches to production of Tee Beams in sizes which are not available from commercial sources are under study at Bath Iron Works.

Portable Laser Pipe Cutting/Welding System - (7-92-4) A Nd:YAG laser coupled to an optical fiber is being used to develop cutting and welding processes aboard ship. The expectation is that laser energy can be delivered over 100 meters through a flexible optical fiber to perform welding. Mare Island Naval Shipyard is task leader in the project.

Application of Hitachi-Zosen Portable Robots to Shipbuilding- This project involved visits to three shipyards and a robot manufacturer by a team from four U.S. Shipyards. Newport News organized the project and completed the report.

Simultaneous Three Edge Pre-weld Cleaning - (7-92-2) This project, at Bath Iron Works, has the objective of improving productivity in fit up and welding of panels and structural components.

Thick Section Welding With Fiber Optic/Nd:YAG Laser (7-93-5) This project at Mare Island Naval Shipyard is expected to demonstrate feasibility of the laser/fiber optic welding to Narrow Gap Welding.

Producibility of High Yield Strength Casting With Improved Weldability - (7-91-2) This is a high priority project to follow up the successful development of a crack resistant casting alloy. At the time of this report it is in need of funding.

Development of Shielded Metal Arc Electrodes for HSLA-100 - (7-90-1) This project is nearing completion at the time of this report. A new metallurgical approach was taken to develop a shielded metal arc electrode specific for the new HSLA steels. The use of titanium and other microalloy additives are used to produce desirable fine grain ferritic structure to modify the basic martensitic/bainitic metallurgy. This approach is expected to meet yield strength and toughness requirements, preserve base metal properties adjacent to the welds and have better resistance to hydrogen assisted cracking than the conventional weld metals. This project is being performed at Colorado School of Mines.

Square Butt Pipe Welding - (7-92-5) The objective is to develop pipe welding processes without bevel preps.

Manual for Thermal Spray of Machinery Components - (7-92-3) The objective is to apply thermal spray to preventive and corrective maintenance to costly machine components.

Optimization of Small Size Fillet Welds - (7-93-4) The objective is to develop automatic and semiautomatic processes for 1/8" fillet welds.

Ultrasonic Testing Criteria on Thin Weldments - (7-89-1) The objective is to extend applicability of UT to thin section structural welds.

9.8 Projects of SP-7 Prior To Contracts Reported Above

Technical reports resulting from SP-7 projects between 1974 and the first project report of contract DTMA-80-SAC-01041 are listed below starting with the earliest. All of those listed below were performed under subcontract with the Sparrows Point Shipyard of Bethlehem Steel Corporation except for the Fitness-For-Service reports by Dr.Leslie Sandor.

One Side Welding - Flux Development and Study of Multiple Arc Behavior, NSRP 0039, 1974 (Linde Division of Union Carbide)

Development of Extended Length Continuous Wire Feed System
NSRP 0040, May 1974 (Performed by Hobart Brothers Corp)

Development of a Portable AC/DC Welding Power Supply Module
NSRP 0041, June 1974 (performed by Celesco Industries)

Applicability of Laser Welding to Ship Production, Volume I
NSRP 0044 (United Aircraft Research Laboratories)

Toughness Evaluation of Electrogas and Electroslag Weldments
NSRP 0048, March 1975 (American Bureau of Shipping)

Applicability of Firecracker Welding to Ship Production,
NSRP 0051, July 1975 (Battelle-Columbus)

Plasma Processes of Cutting and Welding, NSRP 0054,
February 1976 (Linde Division of Union Carbide)

Development of an All Position Welding Machine, NSRP 0062
December 1976 (M.T. Gilliland Company)

High Metal Deposition per Ampere, NSRP 0063 (Linde Division of Union Carbide Corporation), and
High Metal Deposition Welding, Vol I and II, NSRP 0072,
December, 1978 (Expansion of NSRP 0063, TAPCO, Intl)

Dynamic Tear Test Correlation with Explosion Bulge Test at the Same Temperature, NSRP 0080 January 1989 (American Bureau of Shipping)

Investigation of Welding Processes for Low Temperature Applications, NSRP 0083, January 1979 (American Bureau of Shipping)

Applications of Plasma Arc to Bevel Cutting, NSRP 0085, 1979
Hypertherm, Inc)

Mechanized Gas Metal Arc Welding of Light Plate, NSRP 0086,
February 1979 (M.T. Gilliland Co.)

Applicability of Laser Welding to Ship Production, Vol II,
NSRP 0095, December 1979 (United Aircraft Research Laboratories)

Property and Productivity Improvements in Electroslag and Electrogas Welding, NSRP 0099 (Material Sciences Northwest, Inc.)

Ceramic Weld Backing Evaluation, NSRP 0110 June 1980
(Offshore Power Systems)

Development of a Composite Consumable Insert for Submerged Arc Welding, NSRP 0112, August 1980 (IIT Research)

Extension of E7024 Electrode Application in Shipbuilding in Shipbuilding, NSRP 0113, August 1980 (American Bureau of Shipping)

Self-Shielded Flux-Cored Wire Evaluation, NSRP 0118, December 1980 (Offshore Power Systems)

Proceedings of First Conference on Fitness-For-Service in Shipbuilding, NSRP 0121 (Leslie W. Sandor/ Bath Shipyard)

High Metal Deposition per Ampere, NSRP 0063 (Linde Division of Union Carbide Corporation) and

High Metal Deposition Welding, Vol I and II, NSRP 0072, December, 1978 (Expansion of NSRP 0063, TAPCO, Intl)

Dynamic Tear Test Correlation with Explosion Bulge Test at the Same Temperature, NSRP 0080 January 1989 (American Bureau of Shipping)

Investigation of Welding Processes for Low Temperature Applications, NSRP 0083, January 1979 (American Bureau of Shipping)

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Self-Shielded Flux-Cored Wire Evaluation, NSRP 0118, December 1980 (Offshore Power Systems)

10.0 CONCLUSION

The development of materials and processes related to fabrication and welding of ships which have come out of the SP-7 contribution to the National Shipbuilding Research Program have produced great technological improvements and cost savings for U.S. Shipbuilding. In many cases the scientific and engineering project results have moved the state-of-the-art very quickly. In some cases trends have been started which required many years to reach full development and implementation. Without question the investments in the NSRP program in R&D are returned in cost savings many times over. In many cases the projects are seminal in that a needed start is provided which only later results in significant advancements in cost effectiveness.

All SP-7 projects authorized and funded by Marad contracts have been completed and all projects and the resulting project reports since 1973 are described above.

DISCLAIMER

This report was prepared as an account of government sponsored work. Neither the United States, nor the Maritime Administration, nor any person acting on behalf of the Maritime Administration (A) makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness or usefulness of the information contained in this report/manual, or that the use of anyh information, apparatus, methnod, or process disclosed in this report may not infringe privately owned rights; or (B) assumes any liabilities with respect to the use of or for damages resulting from the use of any information, apparatus, methods, or process disclosed in this report . As used in the above , "Persons acting on behalf of the Maritime Administration" includes any employee, contractor, or subcontractor to the contractor of the Maritime Administration to the extent that such employee, contractor, or subcontractor to the contractor prepares, handles, or distributes or provides access to any information pursuant to his employment or contract or subcontract to the contractor with the Maritime Administration. Any possible implied warrantees or merchantability and/or fitness for purpose is specifically disclaimed.

CHARTER
PANEL SP-7
WELDING

Panel SP-7 of the Ship Production Committee of the Society of Naval Architects and Marine Engineers is chartered to plan, oversee the performance of, and facilitate the implementation of the result of research and development projects to advance shipbuilding processes and methodologies. Its goal is to develop and initiate implementation of equipment, procedures, and processes which will result in reducing the cost and improving the competitiveness of American shipbuilding, ship repair, and overhaul.

Panel SP-7 will take its general guidance from the Executive Control Board of the Ship Production Committee, and will augment its efforts through information obtained from the Panel members, based on individual experiences and knowledge.

Panel SP-7 will, when appropriate, join efforts with other panels to produce a common project product.

Panel SP-7 is, by its charter, challenged to perform tasks including, but not limited to, the following areas:

- investigate methods and processes to improve the technology of welding, cutting, forming, and burning as it pertains to and is applied to shipyards in the United States. The scope of involvement of Panel SP-7 includes, but is not limited to:
  - welding procedures and their qualification.
  - application of automated devices to welding.
  - effects of the various welding processes on materials distortion, shrinkage and metallurgy, and the prediction of these effects.
  - cost effectiveness of the various welding processes, both as related to the welding process itself and to the effect of the process on the overall ship production effort.
  - development, in concert with the supplier industry, of filler materials and base metals properly suitable to ship manufacture and its environment.
  - development of, or improvement of, non-destructive test methods capable of definitely accelerating in process quality control.
  - design of welded structure to improve adaptability to new welding processes.
  - in correlation with Panel SP-9, develop training syllabi for welders, designers and managers to provide them with the required background to improve weld-related functions.
- Panel SP-7 shall perform its duties and responsibilities by:
  - conducting a program to improve welding technology by promoting production-effective short term and intermediate term projects for the greatest benefit to the industry.
  - constantly monitoring the active projects of the program and continually and critically assessing their development as to meeting their stated objectives and their continuing potential to benefit the shipbuilding welding industry. If, for any reason, a project looses its potential for benefit, to recommend that the project be terminated.
  - provide accurate, descriptive and timely reports of all active projects and distribute final reports to the greatest number of people who will derive benefit from the project.
  - encourage and promote implementation of the results of completed projects.
  - collaborate and cooperate as necessary and as requested with other panels in the development and implementation of their programs.
  - request collaboration and cooperation from other panels as necessary to accomplish the objectives and programs of the SP-7 Welding Panel.
- develop an annual plan of projects related to the improvement of application of welding to the shipbuilding industry.
- coordinate the project plan and results thereof with other panels.

Panel SP-7 shall compose itself of individuals with ship production, shipyard management, shipyard labor and crafts, ship design and academic expertise who are versed in current and future concepts of shipbuilding. Members should be selected that are knowledgeable of problems of shipbuilding and have a role in the implementation of the solutions to these problems.

Selection of projects shall be by consensus of active shipbuilding and government members of the panel.

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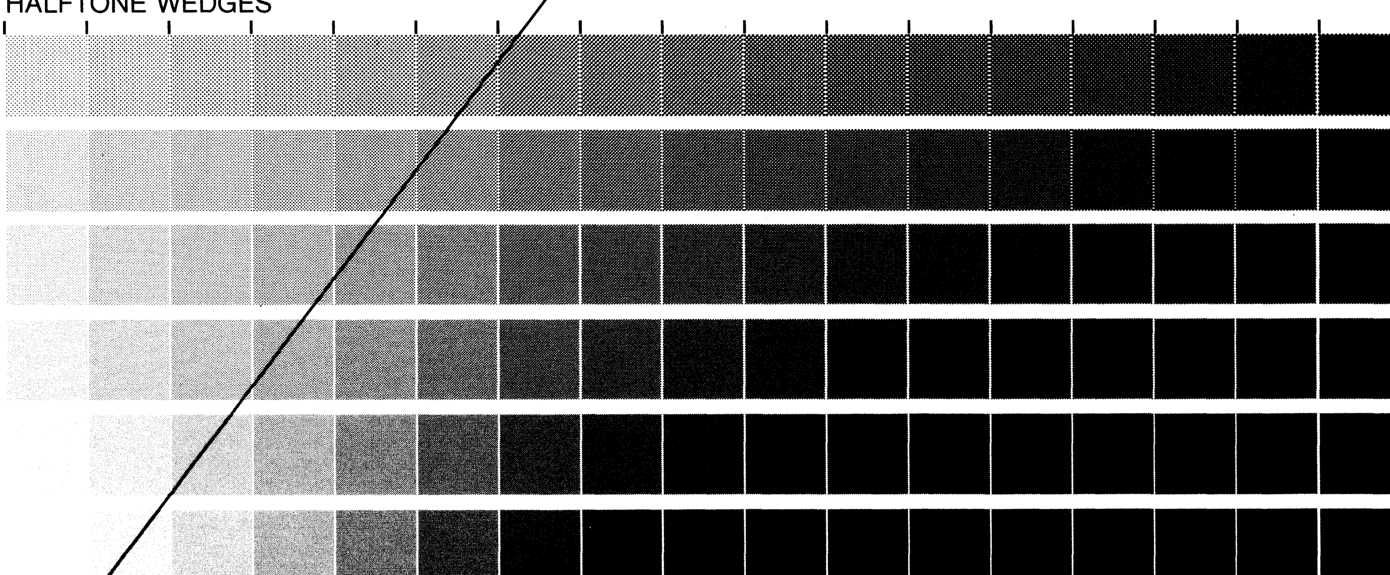

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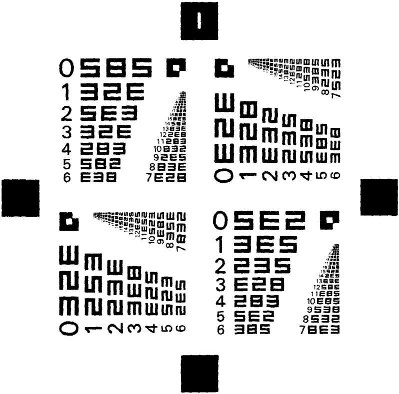
RIT ALPHANUMERIC RESOLUTION TEST OBJECT, RT-1-71



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