UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of:	§	
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HOUSTON LIGHTING & POWER COMPANY, ET AL.	§	Docket Nos. 50-498OL
	§	50-499OL
	§	
(South Texas Project, Units 1 & 2)	§	
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TESTIMONY ON BEHALF OF HOUSTON LIGHTING & POWER COMPANY, ET AL.

OF

MR. EUGENE A. SALTARELLI
MR. MATTHEW D. MUSCENTE
MR. GORDON R. PURDY
MR. J. RODOLFO MOLLEDA
MR. LOGAN D. WILSON
MR. MICHAEL D. SULLIVAN
DR. DANIEL HAUSER

ON

THE WELDING PROGRAM AT STP

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THE STP WELDING PROGRAM

Q. 1 Please state your names.

A. 1 Eugene A. Saltarelli, Matthew D. Muscente, Gordon R. Purdy, J. Rodolfo Molleda, Logan D. Wilson, Michael Sullivan, and Daniel Hauser.

Q. 2 Mr. Molleda and Mr. Wilson, by whom are you employed?

A. 2 (JRM, LDW): Houston Lighting & Power Company (HL&P).

Q. 3 Mr. Saltarelli, Mr. Muscente, and Mr. Purdy, by whom are you employed?

A. 3 (EAS, MDM, GRP): Brown & Root, Inc. (B&R).

Q. 4 Mr. Sullivan, by whom are you employed?

A. 4 (MS): Nuclear Technology, Inc. (NUTECH), a consulting firm specializing in nuclear plant analysis and design, with particular expertise in American Society of Mechanical Engineers (ASME) Code applications.

Q. 5 Dr. Hauser, by whom are you employed?

A. 5 (DH): Battelle Columbus Laboratories (Battelle), a research and development firm which performs, among other things, studies of welding procedures, inspection processes and metallurgy.

Q. 6 Mr. Saltarelli, what is your position and what are your current responsibilities?

A. 6 (EAS): I am Senior Vice President and Chief Engineer of the B&R Power Group. I am responsible for the engineering of all fossil and nuclear power plants in the Power Group, including South Texas Project (STP). Since April 1980 when I joined B&R, one of my responsibilities has been to help develop plans for the STP welding reexamination, repair, and restart programs. In addition, I have closely followed the Welding Task Force activities through regular meetings with the Task Force Chairman who reports directly to me.

Q. 7 Mr. Muscente, what is your position and what are your current responsibilities?

A. 7 (MDM): I am the Welding Program Manager for STP and am responsible for coordinating and directing all welding activities including welder training, engineering surveillance of production welding, and development and implementation of welding specifications and procedures. I am also responsible for directing the STP welding reexamination, repair, and restart program and overseeing the evaluation of inaccessible welds being performed by outside consultants. I report directly to the STP General Manager.

Q. 8 Mr. Molleda, what is your position and what are your current responsibilities?

A. 8 I am HL&P's Supervising Engineer and Lead Project Engineer for mechanical-nuclear systems on STP. In this position, I provide direction and guidance to HL&P's STP Mechanical, Nuclear, Health-Physics and Nuclear Fuels Engineering Teams, which perform design reviews of the Westinghouse Nuclear Steam Supply System, B&R designed systems and other vendor supplied designs. Additionally we review numerous specifications for items other than equipment such as weld filler material, stress analysis documents and various NRC issued documents.

Our principal duties relating to the STP welding program are to review and approve the welding specifications and associated welding Technical Reference Documents (TRD) generated by B&R. We review design criteria, design specifications and changes to the criteria or specifications to assure that the design properly addresses appropriate engineering requirements, including regulatory requirements, applicable industry standards and HL&P's design preferences. HL&P Engineering also participates in the resolution of problems that are identified during the design and construction, such as the resolution of field design change requests and nonconformance reports, and participation in the recent Task Force effort to reexamine the adequacy of Project welds made prior to April 11, 1980.

Q. 9 Mr. Purdy, what is your position and what are your current responsibilities?

A. 9 (GRP): I am the Quality Engineering (QE) Manager for the B&R Power Group. I am responsible for the management and direction of QE personnel at the STP site where I report to the Project Quality Assurance (QA) Manager for STP. Since April 1979 when I first joined B&R, I have been directly responsible, among other things, for development of the welding program QA procedures at STP.

Q. 10 Mr. Wilson, what is your position and what are your current responsibilities?

A. 10 (LDW): This information is set forth in A.2 and A.3 of my testimony regarding allegations of harassment and intimidation of QC Inspectors.

Q. 11 Mr. Sullivan, what is your position and what are your current responsibilities?

A. 11 (MS): I am a Principal Consultant for NUTECH and am responsible for advising clients on welding and metallurgical construction problems. Since May 1980, I have been NUTECH's Project Engineer on the STP Welding Task Force, managing the activities of several NUTECH welding engineers at the STP site and at NUTECH's home office. I also directed the work performed at STP by Southwest Research Institute (SwRI), a consulting firm under subcontract to NUTECH that performed and interpreted nondestructive examinations during the Task Force investigation following the NRC's Order to Show Cause.

Q. 12 Dr. Hauser, what is your position and what are your current responsibilities?

A. 12 (DH): I am a Senior Research Scientist at Battelle, and am currently the Program Manager for the Battelle evaluation of the inaccessible AWS structural welds at STP.

Q. 13 Mr. Saltarelli, please summarize your professional qualifications.

A. 13 (EAS): I received a Bachelor of Mechanical Engineering degree from the University of Detroit in 1949 and a Master of Science degree in Mechanical Engineering from Northwestern University in 1950. I am a Registered Professional Engineer in seven States; Pennsylvania, New York, West Virginia, Michigan, Texas, California and Maryland, and am a member of the ASME and the American Nuclear Society. Prior to joining B&R, I worked for twenty-four years in the nuclear power industry, primarily in the areas of nuclear system design and analyses with respect to plant safety and plant operations.

From 1956 to 1967, I was employed at the Bettis Atomic Power Laboratory, Westinghouse Electric Corporation in Pittsburgh, Pennsylvania. I began my career at Bettis as a Senior Engineer in fluid systems design for Navy nuclear power plants and was promoted to various management positions including Bettis Chief Test Engineer at the Mare Island Naval Shipyard, Vallejo, California, in which I was responsible for the technical direction of testing and initial startup of reactor plants for nuclear submarines. My design experience at Bettis encompassed total responsibility for nuclear fluid systems for Navy nuclear plants as well as the design, system construction, and technical direction of the decontamination of the Shippingport Atomic Power Plant. I also directed the program to accomplish decontamination of the Navy nuclear submarines.

From May 1967 to April 1980, I was employed by NUS Corporation where I began as the Manager of power plant engineering and was promoted to positions of increasing management responsibility including Vice-President, Technical Director; Vice-President, Engineering Division; and Group Vice-President, Engineering and Operating Services. While serving in these positions, I provided consulting services to foreign clients in Japan, Taiwan, Sweden, Germany, and Brazil. In addition, I was associated with the STP since its inception, participating in the development of the Preliminary Safety Analysis Report (PSAR) and managing the organization that designed several of the nuclear interface systems. I joined B&R in April 1980 and assumed my present position as Senior Vice-President and Chief Engineer of the B&R Power Group.

Q. 14 Mr. Muscente, please summarize your professional qualifications.

A. 14 (MDM): I received a Bachelor of Science degree in Metallurgical Engineering at the University of Pittsburgh in 1958. I am a Registered Professional Engineer in California and a member of the American Welding Society (AWS) and the ASME.

Prior to joining B&R, I worked for twenty-two years in the nuclear power industry, primarily in the areas of design, fabrication, and construction of nuclear power plant systems and components. I spent eight years working on the design and construction of nuclear powered submarines, and twelve years working for General Electric Company as the Manager of Field Welding Engineering at nuclear power plants in India and Switzerland, and as the Manager of Materials Engineering and QA at nuclear power plants in Switzerland, Spain, and Italy. I joined B&R in July 1980 and assumed my present position.

Q. 15 Mr. Molleda, please summarize your professional qualifications.

A. 15 (JRM): I was graduated from the University of Texas at Austin in 1972 with a Bachelor of Science degree in Mechanical Engineering. That year I joined the City Public Service Board (CPSB) as an engineer in the Generation Design Division. I was involved in various engineering assignments concerning the design and construction of fossil fueled power plants. As a result of CPSB's interest in nuclear power, in 1975 I was assigned to Florida Power & Light's St. Lucie Nuclear Power Station as a startup engineer. There I wrote and performed preoperation tests on the plant's nuclear and balance of plant systems. In 19[illegible] I was assigned to HL&P to work on the STP, where I reviewed equipment specifications and system designs. In 1977 I joined HL&P as a

Senior Engineer in the Nuclear Engineering Division. I headed a team of six engineers who performed reviews of STP nuclear systems and design documents generated by Westinghouse and Brown & Root (B&R). In 1979 I was promoted to my present position.

I am a Registered Professional Engineer in the State of Texas and a member of the American Nuclear Society.

Q. 16 Mr. Purdy, please summarize your professional qualifications.

A. 16 (GRP): Prior to joining B&R, I spent twenty-one years working in the nuclear power industry, eighteen of which were spent in the United States Naval Nuclear Power Program. I worked primarily in the area of construction, operation, and maintenance of nuclear power plants. I also spent approximately one year with Bechtel Power Corporation as a mechanical Quality Control (QC) engineer. I joined B&R in April 1979 as the supervisor of the mechanical QE program for the Power Group. In October of that year, I was promoted to my present position, in which I have been responsible for, among other things, the development of QA procedures regarding welder and inspector training at STP.

Q. 17 Mr. Wilson, please summarize your professional qualifications.

A. 17 That information is set forth in A. 2 of my testimony regarding allegations of harassment and intimidation of QC Inspectors.

Q. 18 Mr. Sullivan, please summarize your professional qualifications.

A. 18 (MS): In 1970, I received a Bachelor of Science degree in Mechanical Engineering from California State Polytechnic University in Pomona, California. I received a Masters degree in Metallurgical Engineering from Lehigh University in 1974. Prior to joining NUTECH, I spent approximately five years at General Electric Company, including three years in GE's Fast Breeder Reactor Department as the project leader for welding process development, and two years with GE's Nuclear Energy Group developing automatic welding equipment and test programs to simulate installation or modification of components in Boiling Water Reactors. I joined NUTECH in 1979 as a Senior Consultant and was promoted to my present position as NUTECH's Principal Consultant in September 1980.

Q. 19 Dr. Hauser, please summarize your professional qualifications.

A. 19 (DH): I received a B.S. in Metallurgical Engineering from Rensselaer Polytechnic Institute in 1962, an M.S. in Metallurgical Engineering from Syracuse University in 1965, and a Ph.D. in Metallurgical Engineering from Ohio State University in 1973. I have been employed by Battelle for approximately 17 years, during which time I have been involved in a variety of materials-joining research projects. These projects have involved arc, electron beam, and solid-state welding of a wide variety of metals and alloys. I have investigated repair-welding practices for cast and wrought alloys and assisted in designing and setting up large-scale welding operations. Other projects have related to gas turbines, pressure-vessel steel, and railroad components.

I have been the Battelle Program Manager of a project to develop a remote mechanized repair system for nuclear reactor piping. This includes developing equipment and procedures and qualifying personnel for pipe severing, joint preparation, counterboring and welding.

I have also been the Battelle Program Manager of an investigation involving laboratory development of experimental arc welding equipment and procedures including the development an all solid-state microprocessor controlled automatic welding system.

I have conducted studies of repair-welding practices for cast and wrought heat-resistant alloys, such as HK-40 and Incoloy 800 used in the petrochemical industry. I have also been involved in the development of improved repair procedures for nickel and cobalt base superalloys in gas turbines. In the course of this work, experimental repairs were made with IN-738 alloy blades.

I have been the Battelle Chief Investigator of a program to design and fabricate small-diameter rocket-motor cases from 18Ni(350) maraging steel. A significant part of this program was directed toward the development of gas tungsten-arc and electron-beam welding procedures. In another program, I assisted in the development of fabrication procedures for H-11 high-strength steel components. I have also helped develop electron-beam welding procedures for M-50 tool steel spheres, and have received a patent for a specialized technique invented during the program.

I have also investigated the effects of welding processes, welding procedures, post-weld heat treatment and base-plate composition on 3.5-inch-thick SA508 Class 2 steel in connection the welding and multiple repairs of a nuclear reactor pressure vessel.

Finally, I have investigated the effects of delta ferrite content of E308-16 stainless steel weld metal, including testing of ultimate and yield strengths, creep rupture, elongation, reduction in area and elastic modulus over the temperature range of 70-1200F.

Q. 20 Panel, what is the purpose of this testimony?

A. 20 (Panel): The purpose of this testimony is to describe the welding program for the South Texas Project. This description will include a discussion of the welding program requirements; the status of the welding program prior to the NRC Order to Show Cause; the results of the Welding Task Force activities performed in response to Item 3(a) of the NRC Order to Show Cause; the recent improvements implemented in the welding program; the status of the welding reexamination, repair and restart programs; and the engineering evaluation of the previously made inaccessible welds.

Q. 21 What NRC requirements and industry Codes govern the safety-related welding program at STP?

A. 21 (Panel): The STP welding program is governed by the requirements of 10 CFR Part 50, Appendix B with respect to welding procedures, QA and nondestructive examination (NDE) of welds. Additionally, at STP, the ASME Boiler and Pressure Vessel Code governs pressure-retaining piping, pipe components and supports, and the AWS Structural Welding Code governs heavy structural steel and supplementary steel such as electrical cable tray and pipe supports. (For purposes of this testimony, the terms "AWS weld" and "ASME weld" will include only those welds on the piping, supports, and steel listed above.) These Codes set forth requirements for such things as welder qualifications, verification of the adequacy of welding procedure specifications, NDE acceptance criteria for completed welds, and appropriate NDE methods for particular types of welds. The ASME Code also requires that an independent third party, the Authorized Nuclear Inspector (ANI), approve all elements of the ASME welding and NDE Programs, and that this ANI oversee the implementation of these programs.

Finally, several NRC Regulatory Guides provide requirements to supplement those contained in the AWS and ASME Codes. These requirements, which apply primarily to materials, welding and NDE methods, set forth minimum standards to be followed in particular situations such as limited access welding.

Q. 22 Mr. Saltarelli, Mr. Muscente, Mr. Wilson and Mr. Purdy, how have the requirements mandated by the NRC and Codes been implemented at STP?

A. 22 (EAS, MDM, LDW, GRP): B&R, with HL&P review and approval, has developed several Construction and QA procedures to implement the requirements mandated in the applicable Codes and standards. In general, four types of procedures are utilized to control the welding activities at STP.

1. Materials Engineering Construction Procedures (MECPs) require a welder to be tested in each specific welding process to be used. Each welder must make a certain

number of test welds which are visually examined by QC Inspectors and subjected to destructive or nondestructive testing. The test welds must be found acceptable before a welder is permitted to perform production welding.

2. MECPs also specify the sequence of operational tasks in making both AWS and ASME welds and the methods by which each task is to be performed. These tasks include cleaning of the weld area, verifying proper weld filler material, checking weld joint dimensions, joining the materials at the weld joint, controlling the heat applied to a weld joint and visually checking the finished weld.

3. Quality Assurance Procedures (QAPs) provide that during the making of the welds, QC inspection must be performed at several procedurally designated "hold points", and that QC personnel periodically must check such items as welding equipment, welding temperature and current. A visual examination is performed when welds are completed, and if the work is deemed satisfactory, NDE is performed and the results evaluated by certified NDE Inspectors.

4. QAPs also require that NDE inspectors must receive a minimum amount of formal training and perform a minimum number of inspections prior to being examined and certified by Level III Inspectors. These procedures also identify, define and illustrate acceptance criteria for each type of

NDE. NDE includes, among other things, liquid penetrant testing (use of red liquid dye which slightly penetrates the weld surface where defects are located), magnetic particle testing (application to the weld of small metal particles which assume irregular patterns wherever defects are located when a magnetic field is applied); and radiographic testing (photographing the interior of the weld by using Gamma rays).

This general procedural framework has been and still is in effect at STP, but the detailed procedures have been revised during the course of implementation of the welding program, as will be explained later in this testimony.

To monitor the overall implementation of the NRC and Code requirements and the STP welding procedures, B&R conducts regular audits of the welding program. These audits are conducted approximately twice per year; once at the site and once in Houston.

(LDW): Establishment of the Materials Engineering, Construction and QA Procedures, training methods, and welding material specifications is the primary responsibility of B&R. HL&P QA reviews and approves these procedures to assure that the QA requirements are properly reflected.

One aspect of the welding program in which we were involved early in the Project was the establishment of the specific welding procedures for the aluminum-bronze pipe in the Essential Cooling Water (ECW) system. Aluminum-bronze is an unusual material and industry has very little experience in welding large diameter pipe made of this material. As a result of investigations we performed, HL&P added a requirement to the inspection procedures that the ECW welds be spot radiographed on a random selection basis to track welder performance, even though the ASME Code does not require any radiographic examinations.

HL&P has performed documented surveilance on a monthly basis covering all aspects of welding, including both weld making and NDE activities. In total, we have performed 374 formal inspections. We also have attended B&R training classes for welding and inspection in order to evaluate the instruction given.

Q. 23 Mr Purdy, what was the status of welding at STP at the time of issuance of the NRC Investigation Report 79-19 and the NRC Order to Show Cause?

A. 23 (GRP): At the time of issuance of the NRC Investigation Report 79-19 and the NRC Order to Show Cause, there was no safety-related welding being performed at the site due to the issuance of a Stop Work Order on April 11, 1980 by the B&R Power Group QA Manager. Prior to the Stop Work, approximately thirty-five percent of the total AWS heavy structural steel welding, approximately two percent of the total AWS supplementary steel welding and less than one percent of the total ASME welding had been performed at Unit 1. Less than one percent of the total AWS and ASME welding had been performed at Unit 2.

Q. 24 Please explain why safety-related welding at STP was stopped.

A. 24 (GRP): Problems revealed as a result of two audits and a special investigation conducted in late 1979 and early 1980 indicated that the STP welding procedures were not being fully and properly implemented. While the welding program, as set forth in those procedures, was generally in compliance with applicable Codes and standards, QC Inspectors were not always identifying procedural deficiencies during the welding process, and NDE Inspectors were not always identifying deficiencies in the completed welds. This failure to implement adequately all Project procedures resulted in a level of welding quality at STP which was less than that mandated by the program. In order to concentrate all efforts on resolving the problems, to assess the implications of the problems that had been occurring and to prevent recurrence of those problems, the B&R Power Group QA Manager issued a Stop Work Order on safety-related welding on April 11, 1980.

Q. 25 Please describe the specific problems which formed the basis for the decision to stop work.

A. 25 (GRP): In late 1979 and early January 1980, during the course of an NRC audit of the STP QA Program, NRC investigators verbally indicated to HL&P that they had discovered some problems with radiography, particularly in the areas of radiographic quality and interpretation. In response to these NRC concerns, a review was performed of existing production weld radiographs. The results of this review indicated that some of the film quality did not satisfy procedural requirements, that defect indications sometimes went undetected, and that indications observed by radiographic interpreters were often not recorded on the appropriate forms. As a result of these findings, all NDE conducted at the Site was suspended in January 1980 except for that which was conducted under the direct supervision of the NDE Level III Inspectors. This temporary suspension of almost all site NDE provided an opportunity to ensure that no site NDE would be performed until NDE personnel were properly retrained and certified.

In March 1980, a scheduled Materials Engineering audit of the welding program was completed, and several problems were identified. Specifically, the Procedure Qualification Records did not always contain enough information to indicate proper qualification of Weld Procedure Specifications, the QA Program of a subcontractor that performed certain types of NDE for the Houston Materials Engineering Laboratory had not been properly qualified, and the QA Program of the calibration facility used by the Materials Engineering Laboratory had not been properly qualified.

As a result of the findings in the Materials Engineering audit, a special follow-up audit of the welding program at STP was conducted in early April 1980. This audit indicated that although welders were trained and qualified in accordance with the requirements of the ASME Code, some did not possess enough "on-the-job" practical knowledge to assure performance of high quality field welding, that the QC Inspector assigned to monitor welder qualification testing was not properly certified to inspect welding operations, and that several welding construction procedures did not comply with applicable specification requirements.

Q. 26 Mr. Muscente and Mr. Purdy, what conditions did B&R and HL&P set for the lifting of the Stop Work Order?

A. 26 (MDM, GRP): B&R and HL&P jointly agreed to take the following corrective actions prior to lifting the Stop Work Order: 1) confirm the qualification of STP safety-related welding procedures; 2) review construction procedures against ASME Code requirements and revise if necessary; 3) review procedures to ensure that weld acceptance criteria have been approved by Level III QA personnel; 4) ensure that all welder qualifications have been inspected by certified QC Inspectors; 5) improve adherence to procedures for weld filler material control; and 6) develop a Materials Engineering Procedure for the control of weld procedure qualifications. HL&P informed the NRC's Region IV of these planned corrective actions on April 15, 1980, and the Region IV Director confirmed his understanding of the actions on April 17, 1980.

Work on these six items subsequently was integrated into a comprehensive restart program for safety-related welding which will be discussed later in this testimony. Items 1, 2, 3, 4, and 6 were satisfactorily closed out by NRC Inspection Report 80-38 dated January 30, 1981. Item 5 was satisfactorily closed out by NRC Inspection Report 81-03 dated February 11, 1981.

Q. 27 What findings concerning the STP welding program were contained in the NRC Inspection Report 79-19?

A. 27 (MDM, GRP): Less than three weeks after STP welding was stopped, the NRC issued Inspection Report 79-19 which identified the following items of noncompliance with respect to the STP welding and NDE programs: 1) B&R Weld Filler Material Specification did not contain the latest Document Change Notices (DCN's); 2) STP construction procedures failed to incorporate requirements for welding protection against adverse environmental conditions; 3) the quality of several radiographs was such that proper interpretation was not possible; 4) linear indications contained in several radiographs were not recorded on interpretation sheets; 5) the evaluation of certain liquid penetrant indications was not in compliance with the ASME Code; and 6) radiographic evaluation of some welder qualification tests did not comply with the ASME Code in that the penetrameter (radiographic image quality indicator) was placed on the side of the test pipe close to the radiographic film ("film side") rather than close to the radiation source ("source side").

Q. 28 What actions were taken to resolve these items of noncompliance?

A. 28 (MDM, GRP): All of the items of noncompliance listed in Inspection Report 79-19 were satisfactorily closed out by the NRC within a few months after the Report was issued. First, the Weld Filler Material Specification and all other outdated documents were brought up to date by incorporating the latest revisions.

Second, STP welding procedures were revised to include requirements for protection against rain, snow, wind and airborne particles. Compliance with the revised procedures was stressed both in welder training sessions and in the field.

Third, a QAP setting forth methods for radiographic film processing was developed. In addition, the QAP with respect to radiographic film examination was revised to require the recording of all observed film conditions on interpretaton sheets. These procedures were implemented just after the NRC completed its audit, and compliance was closely monitored by QA/QC personnel.

Fourth, all NDE personnel who conducted liquid penetrant testing were given additional training in inspection techniques and procedures. While this retraining was taking place, all such testing was suspended at the STP site unless under the direct supervision of the NDE Level III Inspector.

Finally, source side penetrameters were required to be used when feasible in both welder qualification tests and field welding. Radiography personnel were retrained and recertified according to the correct procedures and were lectured as to the need to follow applicable project requirements. In addition, a test was set up to compare the qualification results actually obtained with the results which would have been obtained using source side penetrameters. The test indicated no significant difference in results and supported the acceptability of the welder qualification tests.

Q. 29 Mr. Saltarelli, what action was taken in response to the NRC's Order to Show Cause?

A. 29 (EAS): Upon issuance of the Show Cause Order on April 30, 1980, B&R and HL&P formed a special Task Force to determine whether the safety-related welding completed at STP as of April 11, 1980 was performed in compliance with Code and Project requirements. The Task Force was also given the responsibility of identifying any repair work that might be required and establishing a schedule for completion of such work.

Q. 30 Mr. Saltarelli and Mr. Sullivan, how was the Task Force organized and who were its members?

A. 30 (EAS, MS): The Task Force was separated into a Review Team and an Independent Review Committee. The Review Team, which formulated the investigation plan and conducted the investigations, was chaired by the B&R Engineering Project Manager for STP. Its members included B&R engineers and technicians from the Materials Engineering, Construction and QA Departments and engineers from HL&P and NUTECH. NUTECH retained additional specialists in nondestructive examination from Southwest Research Institute to assist in reviewing the radiography, visual and liquid penetrant examinations.

The Independent Review Committee consisted of two NUTECH engineers knowledgeable about the ASME Code and nuclear plant construction, and one SwRI engineer knowledgeable about NDE at nuclear power plants. This Committee reviewed and approved the Review Team investigation plan, monitored the investigation to ensure that the plan was properly implemented, provided technical assistance and assisted the Task Force in formulating recommendations for further investigation and corrective action.

Q. 31 Mr. Molleda, how did HL&P participate in the Task Force?

A. 31 (JRM): At the time that the Show Cause Order was issued, the Project was in the process of reevaluating the welding program. A Stop Work Order had been issued on safety related welding on the Project, and I was involved in the evaluation of the alternatives for correcting the welding problems that had been identified. I was also designated by HL&P to keep abreast of the work of the welding Task Force. I reviewed the progress of the Task Force efforts to assure that the NRC welding concerns were adequately addressed, that a comprehensive investigation was performed and that the results were properly reported to the NRC.

I assigned Mr. Daniel Martinez, HL&P's cognizant Engineer for ASME Code welding, to work on the Task Force. Mr. Martinez worked full time for about two months to complete the work of the Task Force subgroup that investigated applicable Codes and standards that affected the welding program.

During the field activities of the Task Force, I visited the site weekly to review the progress of the Task Force and to discuss the status of the various subtasks that it was performing. Additionally, I met with the Task Force leader in Houston to discuss the overall efforts of the Task Force, received weekly updates on the status of the Task Force efforts and reviewed the documents that defined and established the proposed course of action. Ultimately my group in HL&P Engineering reviewed and commented on the Task Force reports discussing their examination of the welding program.

Q. 32 Mr. Saltarelli and Mr. Sullivan, what was the scope of the Task Force investigation?

A. 32 (EAS, MS): The Task Force defined the scope of its review to encompass examination of randomly selected safety-related ASME piping welds and AWS structural welds made by B&R from the start of construction until the time safety-related welding was stopped on April 11, 1980. All STP welding procedures and documentation were also examined. The Task Force members developed a plan to evaluate four specific areas of the welding program: (1) the safety-related AWS welding program; (2) the ASME welding program including welder qualifications; (3) the Nondestructive Examination program; and (4) Code commitments as identified in the engineering specifications and implementing procedures.

Q. 33 Mr. Saltarelli, Mr. Sullivan and Mr. Molleda, please summarize the conclusions contained in the Task Force Interim Report issued July 28, 1980.

A. 33 (EAS, MS, JRM): The Task Force Interim Report, which formed the basis for HL&P's response to the NRC's Order to Show Cause, was issued after completion of approximately 75 percent of the investigation previously described. The Report indicated that much of the documentation and most of the procedures were in compliance with Code and Project requirements. However, deficiencies were identified in the AWS and ASME welds as well as in the performance of NDE. To correct these deficiencies, the Task Force recommended repair of specific deficient welds and further investigation to identify possible additional deficiencies. The subsequent reexamination, repair, and restart programs, described later in this testimony, were developed by B&R and HL&P after careful consideration of the findings in this Report.

Q. 34 Mr. Sullivan, please describe the Task Force investigations performed after issuance of the Interim Report.

A. 34 (MS): The Task Force completed its investigations with some restructuring of its originally planned activities. The Task Force continued its review of ASME documentation and procedures but revised and increased the scope of its inspection program for ASME welds by examining additional welds made prior to the Stop Work Order of April 11, 1980. The Task Force completed its investigations and issued its Final Report in April 1981. This Final Report superseded the Interim Report.

Q. 35 Mr. Saltarelli and Mr. Muscente, what actions were taken in response to the recommendations contained in the Task Force Final Report?

A. 35 (EAS, MDM): All significant Task Force recommendations with respect to procedural changes were implemented as part of the corrective actions required prior to initiating the welding restart program. Moreover, all of the Task Force recommendations with respect to reexamination and repair of accessible ASME and AWS welds and evaluation of inaccessible welds are being implemented.

Q. 36 Mr. Sullivan, please summarize the conclusions contained in the Task Force Final Report with respect to AWS welds.

A. 36 (MS): The Task Force visually examined a random sample of seventy-nine safety-related AWS welds selected from all areas of the plant in accordance with accepted sampling procedures. This examination revealed sixty-one welds with nonconformances such as undersized welds, improper contour, overlap, undercut, and arc strikes.

The Task Force therefore recommended that all accessible safety-related structural welds be reexamined, that all such welds not in compliance with the AWS Code be repaired and that the adequacy of all inaccessible AWS welds be determined based on the types of nonconformances found in the reexamination of the accessible welds. In addition, it was recommended that all AWS welders and inspectors be retrained to the requirements of the AWS Code and applicable STP procedures.

Q. 37 Please summarize the conclusions contained in the Task Force Final Report with respect to the AWS construction procedures and weld documentation.

A. 37 (MS): The AWS welding procedure specifications were reviewed and found to be substantially in compliance with Code requirements. AWS construction procedures were also found to be substantially in compliance with Code requirements except for two discrepancies with respect to the frequency of Code-required examinations and tests. Corrective action was recommended.

The AWS shop and field erection weld documentation system was found to be generally in compliance with the Code, although inspected welds could not always be traced to a specific inspector or inspection report. In addition, it was not always possible to verify that only qualified welders were making welds, or that qualified welders were always welding within their qualifications. Although this detailed information is not required by the Code or Project procedures, the Task Force recommended that the AWS documentation system be modified to ensure that all inspected welds are traceable to an inspector and to an inspection report. It was also recommended that each welder and welding procedure specification be identified for each weld to facilitate tracking of welder performance.

Q. 38 Please summarize the conclusions contained in the Task Force Final Report with respect to the ASME welds.

A. 38 (MS): All radiographs of completed and accepted ASME welds were reviewed by certified NDE Level III Examiners in radiography. Twenty-five percent of the radiographed welds which previously had been accepted were considered unacceptable because of radiographic discrepancies with technique, film quality or interpretation of indications. Approximately fifteen percent of the welds had radiographs with rejectable indications requiring repair.

In addition to the review of all radiographed ASME welds, the Task Force repeated Code-required visual examination and liquid penetrant testing on a random sample of ASME welds that originally were accepted on the basis of these types of NDE. The review of twelve welds from the Essential Cooling Water (ECW) system revealed arc strikes, weld spatter and other minor surface imperfections. This review was deemed to be inconclusive, however, due to the small sample population (only twenty-six welds accessible) and the nonrandom sample distribution. The review of a random sample of ninety-three of approximately four hundred ASME welds in the non-ECW system revealed that thirteen of forty-three socket welds and one of fifty groove welds had penetrant test noncompliances. Two additional groove welds had visual noncompliances.

Based on this information, the Task Force recommended that the following actions be taken: (1) all accessible ASME welds with known deficiencies should be repaired; (2) all other accessible ASME welds should be visually reexamined, liquid penetrant tested and repaired if necessary; and (3) data from the reexamination should be used in the evaluation of the adequacy of the inaccessible ASME welds.

Q. 39 Please summarize the conclusions contained in the Task Force Final Report with respect to ASME documentation.

A. 39 (MS): Several types of documentation such as weld data cards and weld material requisitions were examined for approximately thirteen hundred ASME welds. The results indicated that the documentation for ASME pipe welds generally meets the ASME Code requirements, although a few minor discrepancies such as inaccurate data entries were found.

The Task Force recommended that these be corrected and that the documentation review be improved.

The Task Force review of weld filler material documentation including purchase orders, filler material specifications and certified material test reports indicated that all weld filler material was supplied by properly approved vendors and that the specific material used complied with Code requirements. The Task Force also found the ASME construction procedures and welding procedure specifications to be substantially in compliance with the Code. Minor discrepancies were noted and corrections recommended.

Q. 40 Please summarize the conclusions contained in the Task Force Final Report with respect to welder qualifications.

A. 40 (MS): The Task Force evaluated welder performance test records and weld data cards to verify welder qualification tests and to determine whether welders were qualified to perform the production welding already completed. The information on the weld data cards supported the adequacy of the qualifications and except for one minor discrepany, was found to meet Code and Project requirements. The welder qualification test records revealed two problems: (1) film side penetrameter placement for some of the tests; and (2) the use of ASME acceptance criteria for both ASME and AWS welder qualifications. The Task Force recommended that the possible effects of the first problem be investigated, but found the second not serious enough to require further investigation.

Q. 41 Please summarize the conclusions contained in the Task Force Final Report with respect to the NDE Program.

A. 41 (MS): The Task Force compared the NDE procedures for radiography, magnetic particle, liquid penetrant and visual testing with applicable Code requirements. All procedures were found to be substantially in compliance with the Code, although the Task Force recommended several revisions to correct minor discrepancies.

The Task Force review of the qualification files for NDE Inspectors identified various types of irregularities in the qualification of twenty-one of the seventy personnel, including uncertified personnel performing NDE, an inspector who signed as a higher level and expiration of an eye exam certification. In addition, the review determined that documentation regarding nine of the twenty-one inspectors showed insufficient training and/or experience in performing examinations. The Task Force concluded, however, that program improvements implemented since the Stop Work Order of April 11, 1980 were sufficient to ensure proper control of the NDE Inspector certification processes.

The Task Force reviewed the NDE certification examinations and training courses and found them to be appropriate for each certification level. Recommendations to improve the overall certification program included updating NDE qualification examinations by replacing old questions, providing a Level III review of all inspector qualifications and reexamining all inspections performed by unqualified inspectors.

Q. 42 Please summarize the conclusions contained in the last section of the Task Force Final Report with respect to the identification of Code commitments in specifications and procedures.

A. 42 (MS): The Task Force reviewed Engineering specifications and implementing Construction/QA procedures in order to determine whether applicable Codes and standards were adequately identified and whether the same commitments had been made in all documents. The Task Force found minor inconsistencies in the identification of the applicable edition and addendum of the relevant Codes, and found an occasional failure to indicate revision numbers in certain procedures and specifications. These inconsistencies were not found to have had any detrimental effect on weld quality, but the Task Force recommended that the inconsistencies be corrected and that Engineering specifications and construction QA procedures be revised to reflect the most recent project commitments.

Q. 43 Mr. Purdy, Mr. Wilson and Mr. Muscente, who was responsible for revising and approving the STP Construction and QA procedures so that the Stop Work Order could be lifted and the welding restart program initiated?

A. 43 (GRP, LDW, MDM): The revision of the STP welding procedures was a joint undertaking by B&R, HL&P, and third-party consultants. B&R's Chief Welding Engineer and B&R personnel from Materials Engineering and QA, including QE, proposed a number of changes to the welding procedures. These changes were then reviewed and commented upon by B&R Construction and Level III Inspectors from B&R and HL&P. Further review was provided by the Task Force and by an independent Level III Inspector retained by B&R in July 1980 to oversee the welding restart activities. Final revisions were agreed upon and the new procedures were approved by all affected B&R and HL&P disciplines.

Q. 44 Please describe the revisions made to the STP Construction and QA procedures.

A. 44 (MDM, LDW, GRP): QAPs and MECPs, including Welder Performance Qualifications, Category I Structural Steel (AWS) Safety-Related Welding, ASME Safety-Related

Piping and Support Welding, and Weld Filler Material Control, were revised in several respects. Words and definitions were simplified to increase clarity and facilitate ease of understanding. The structure of the procedures was reorganized so that all related items for each affected craft were grouped together and superfluous procedures eliminated. This reorganization eliminated inconsistent references among procedures for different crafts. Finally, all Code and specification requirements were incorporated directly into the text of the procedures so that the procedures were "self-contained" without reference to outside materials.

Q. 45 Mr. Wilson, has the HL&P program for welding changed as a result of the B&R audits in late 1979-early 1980, the NRC's investigation during the same period and the NRC's Show Cause Order?

A. 45 (LDW): Yes. Numerous improvements in our program resulted from the intensive reexamination of the welding and QA programs which began in early 1980. HL&P QA has increased its involvement in the consideration of nonconformances concerning welding and NDE. The NCR's are trended by our QA Systems group members who notify me of any significant trends. In addition, my group reviews and approves the disposition of all welding or NDE NCR's and Corrective Action Requests. We can and have asked for HL&P engineering assistance in reviewing specific proposed dispositions. This approval process assures that proposed resolutions meet Project quality requirements. This involvement with NCR's and the trending also increases our ability to recognize and address any significant programmatic deficiencies.

We also work with the B&R QE and QA organizations in evaluating programmatic deficiencies and proposing solutions. This process has been greatly enhanced by our moving into the offices occupied by our counterparts at B&R.

Another significant change has been the creation of an HL&P QC group to perform most of the HL&P field inspections. By relieving my QA personnel of the time-consuming hardware inspection process, we are better able to analyze the overall operation of the QA/QC program. The HL&P QC Inspectors also are available to do special inspections or verifications at the request of my QA group.

While the QC personnel do most HL&P inspections, my group witnesses special inspections of particularly critical or difficult work. These inspections are not planned, but rather, are performed whenever we believe the need exists. A recent example was the reinspection of three aluminum-bronze pipe welds which confirmed that the original inspections were performed properly.

Under the previous QA program, HL&P QA reviewed radiographs on a monthly surveillance basis. This random review proved insufficient in scope and frequency to detect the problems with film quality and interpretation which were noted by the NRC. We are committed to ensuring that all future radiography meets Project requirements. We currently have an HL&P certified Level III NDE Inspector review 100 percent of the radiographs and test reports in addition to B&R's Level III Inspector. This effort represents an additional level of review that completely duplicates B&R's efforts. This 100 percent review will continue until a long term trend of high reliability is attained. We also witness the performance of other NDE tests in the field on a random basis in order to check their compliance with procedural requirements.

Another major change has been the use of implementation reviews, in lieu of checklists, as the primary tool for evaluating B&R's QA/QC performance. The checklists covered a great many items, but in restricted detail. Because it was time consuming to review each of the large number of checklist items, HL&P did not conduct an in-depth examination of any single area. In contrast, the implementation review can be tailored to fit particular circumstances and expanded to any depth. It is, in essence, an indepth review of adherence to program requirements. The checklist system normally detected occasional procedural deficiencies, but it was very difficult to detect systematic or programmatic problems and underlying causes. The implementation review allows us to examine a particular activity from start to finish, in detail and in-depth. This type of examination is much more likely to provide us with a good evaluation of the QA program being investigated.

Another area of change has been in our personnel. We have enlarged the staff, but more importantly, we are continually upgrading the quality of our staff. One of our new employees is a former Authorized Nuclear Inspector and another is an expert in NDE who is certified as a Level III Inspector of radiography. Each person working in the section is given a series of tests to determine technically strong and weak areas. We then schedule training on both a quarterly and yearly basis to enhance skills and improve weak areas on an individual-by-individual basis. In addition, all HL&P QA personnel must pass required tests and participate in an internship program to familiarize them with the STP QA program before conducting any implementation reviews. Salaries and relocation benefits also have been increased in order to attract more experienced personnel and we are using a personnel search firm to find prospective employees.

Q. 46 Mr. Saltarelli, Mr. Muscente and Mr. Purdy, have additional organizational or programmatic improvements been made to the STP welding program? If so, please describe them.

A. 46 (EAS, MDM, GRP): Several additional improvements have been made to the STP welding program. First, Mr. Muscente was hired to provide management oversight of the entire welding program in the newly-created position of STP Welding Program Manager. His responsibilities include maintaining proper coordination among the Engineering, Construction, and QA elements of the welding program and assuring that welding program requirements are satisfactorily implemented.

Mr. Muscente prepared an STP Welding Program Description which defines the responsibilities and interrelated functions of the various welding-related organizations including Construction, Engineering, and QA. This document has been issued to all affected B&R and HL&P personnel on the project, and should help ensure that each employee understands his responsibilities and is capable of performing his tasks properly.

To assure that welders are properly trained and qualified, the welder training program has been divided into five separate programs based on experience and quality of performance. Separate training programs are given to experienced and inexperienced new hires, and to employed welders who are performing well, having occasional difficulties or having difficulties with particular processes. As a result of these distinct types of training, the overall program has been tailored to each individual welder's needs.

To attract more experienced new welders and keep qualified welders at STP, a welder incentive program has been adopted. This program offers increased hourly salaries for certain classes of welders with specific qualifications and performance records. A bonus is also offered to those who meet all requirements for a period of six months.

To assure that welder proficiency is maintained at a high level and that welding problems are quickly discovered, systems for tracking welder proficiency and repair rates have been developed. The Project Welding Engineering Department now keeps records of the number of welds made by each welder and the number of weld repairs. Welding Engineering also decides, based on these records, whether additional training is necessary.

Six experienced welding supervisors and four qualified welding engineers were newly hired or transferred to the STP site. These additional personnel should help improve the overall quality of the welding and welding supervision at STP.

Responsibility for controlling certain welding activities has been redefined. For example, to prevent the use of incorrect weld material, specific responsibility for controlling and issuing weld material has been assigned to one person who keeps records as to the material being utilized, the users of the material, and where the welding was occurring.

The NDE certification examination questions have been rewritten to apply more directly to specific NDE activities at STP. These revisions should allow more effective evaluation of potential NDE Inspectors, and should improve the quality of those Inspectors finally certified.

Finally, to improve the attitude of the welders, welding supervisors and other welding personnel, the "zero defects" concept has been initiated. In addition, the importance of quality workmanship and adherence to project requirements repeatedly has been emphasized in informal meetings and training sessions. These meetings will continue until STP construction is completed.

Q. 47 Mr. Saltarelli, Mr. Purdy, Mr. Wilson and Mr. Muscente, have revised procedures and programmatic changes been effective?

A. 47 (EAS, GRP, LDW, MDM): Yes. The new procedures and programmatic changes have clarified the division of responsibility among the different disciplines, resulting in fewer impediments to getting the work done in an orderly manner. The welding records are more accurate, resulting in a smoother, more efficient flow of documentation. Finally, the welder training program is more thorough and supervision and inspection are more rigorous, resulting in higher quality welds, as will be explained in more detail below.

Q. 48 Mr. Saltarelli and Mr. Muscente, in addition to the procedural and programmatic revisions, what actions were taken with respect to weld deficiencies?

A. 48 (EAS, MDM): As a result of the Task Force conclusions with respect to weld deficiencies, B&R and HL&P senior management decided in September 1980 that reexamination of all accessible safety-related AWS and ASME welds and repair, where required, was the most conservative course to follow. This reexamination and repair program is more extensive than that recommended by the Task Force, however, because it will encompass radiography of 100 percent of the accessible ASME welds in the ECW system, requiring that those ECW welds buried under backfill be unearthed. This program is being conducted pursuant to a detailed reexamination and repair plan submitted by HL&P to the NRC's Region IV on September 10, 1980.

Q. 49 When were the reexamination, repair and restart programs for AWS and ASME welding implemented?

A. 49 (EAS, MDM): In October 1980, the NRC's Region IV authorized that reexamination and repair of AWS welds, as well as a limited restart of new AWS welding, could commence on October 6, 1980. Similar authorization was given for ASME reexamination, repair and limited restart on November 24, 1980. These authorizations were based on the following findings: (1) management systems and special control procedures were established; (2) personnel training was completed; (3) adequate staffing existed to perform and manage the work; (4) all commitments regarding safety-related welding made in the Response to the NRC Order to Show Cause were fulfilled; and (5) all corrective actions for previously identified noncompliances related to AWS and ASME welding were completed.

In late October 1980, the NRC authorized an expansion of AWS production welding activities through December 1980 in accordance with a previously submitted twelve-week work plan. A similar expansion of ASME production welding in accordance with a ten-week work plan was authorized in January 1981. Reexamination and repair activities for AWS and ASME welds were to continue as originally planned.

The AWS twelve-week work plan was successfully completed as scheduled,, and the NRC Region IV authorized resumption of AWS welding on a normal production basis in January 1981.

ASME welding is proceeding according to a new twelve-week work plan, after which B&R and HL&P will propose a resumption of normal production basis ASME welding.

Q. 50 Mr. Wilson, what has been HL&P involvement in the development of the welding reexamination, repair and restart programs?

A. 50 (LDW): As noted earlier, we were extensively involved in the procedure revisions which necessarily preceded initiation of these programs. We also reviewed and commented upon the specific plans developed by B&R. After the AWS and ASME programs began, we conducted an extensive implementation review to assure adherence to program requirements. During this review, we checked to be sure that the relevant Project procedures and welding restart program commitments were being implemented. We found that the B&R personnel generally understood the new procedures and were properly implementing them. We did uncover a few minor problems which are currently being resolved.

Q. 51 Mr. Saltarelli and Mr. Muscente, please summarize the results of the ASME and AWS reexamination and repair programs.

A. 51 (EAS, MDM): To date, approximately half of accessible AWS welds made prior to the Stop Work Order have been reexamined. Only six percent of these welds contained deficiencies directly related to weld strength such as undercut and undersized welds, while fifty-four percent contained deficiencies related to workmanship standards such as arc strikes or weld spatter, which are easily corrected by grinding or brushing the weld surface. All deficiencies have been repaired, inspected and accepted.

Approximately half of the accessible non-ECW ASME welds made prior to the Stop Work Order have been reexamined, and eight percent contained deficiencies. In addition, fifteen percent of the accessible ECW pipe welds have been reexamined by both visual and liquid penetrant methods, as required by the ASME Code, and by radiography, which is not Code required. Surface testing showed deficiencies in one percent of the welds, while radiographs of the same welds showed indications of deficiencies in eighty-three percent of the welds. All deficiencies have been repaired, and the repairs inspected and accepted.

Because virtually all of the ECW welds were found to be acceptable pursuant to the Code-required testing, it is our judgment that the welds would be suitable for their intended service even without repair of the deficiencies identified by radiography. Nevertheless, B&R and HL&P have committed to radiographing 100 percent of the ECW welds and repairing all deficiencies. Thus, when the reexamination and repair program is completed, the welds will have been examined and found acceptable under the strictest of standards.

Q. 52 Mr. Saltarelli, Mr. Muscente and Mr. Wilson, please summarize the results of the ASME and AWS restart programs.

A. 52 (EAS, MDM, LDW): Since the restart of AWS welding, the reject rate has been maintained at less than one percent. This means that one percent of the completed welds inspected by QC personnel have been rejected as not complying with Project procedures and have had to be repaired. The reject rate for ASME non-ECW class 3 pipe welds made since January 5, 1981 has been maintained at about two percent; six percent for radiographed ASME class 2 pipe welds; and twenty-two percent for radiographed butt welds in aluminum-bronze ECW piping which is due to the difficulty of welding on this type of material. All of these reject rates represent significant reductions in the rates achieved prior to implementation of the welding program improvements, particularly the rate for aluminum-bronze ECW piping which formerly was approximately sixty percent.

In addition to these relatively low reject rates, reports issued by the independent third-party Level III Inspector surveying the AWS and ASME welding restart programs indicate that the procedures, personnel training, and management systems associated with the welding are being properly implemented to assure that welds will satisfy applicable

Code requirements and procedures. Results of QC inspections indicate that all quality requirements are being met and HL&P's Level III Inspector has noted considerable improvement in the performance of radiographic testing. Finally, NRC inspections conducted subsequent to the restart activities have found no items of noncompliance relative to AWS or ASME welding activities.

Q. 53 How would you evaluate the results of the reexamination, repair, and restart programs?

A. 53 (EAS, MDM, LDW): The high percentage of acceptable AWS and ASME welds made under the restart programs and the favorable inspections by both QC personnel, the independent Level III Inspector and the NRC indicate that the corrective actions taken by B&R and HL&P to improve the welding program are sound and are being implemented satisfactorily. Therefore, we are completely confident that these "new" welds meet all applicable Code and Project requirements. We are also confident that in the future, the STP welding program will continue to be fully implemented so that weld deficiencies will be identified by QC personnel and repaired as necessary.

The accessible AWS and ASME welds made prior to the Stop Work Order are being reexamined, repaired when necessary and inspected by personnel who have been retrained, requalified, and/or recertified pursuant to STP's revised procedures. Because the restart program is proceeding so successfully pursuant to the new procedures, we are confident that the reexamination and repair program will proceed equally well, and that when the program is completed in late 1981, the "old" welds will meet applicable Code and Project requirements.

Q. 54 Mr. Muscente and Mr. Molleda, in addition to the reexamination and repair work performed on accessible welds made prior to April 1980, what action was taken regarding inaccessible welds?

A. 54 (MDM, JRM): Consistent with the Task Force recommendations, B&R and HL&P determined that an engineering analysis should be made of all inaccessible ASMF and Category I structural steel (AWS) welds made prior to April 11, 1980 to determine what kinds of deficiencies are likely to exist in these welds and what effect such deficiencies may have on the structural integrity of the welds. For purposes of this analysis, inaccessible welds are defined as those embedded in concrete or buried under concrete structures. Approximately 500 AWS welds, or 1.5 percent of the approximately 35,000 AWS welds made as of April 11, 1980 are inaccessible. Approximately fifty ASME welds, or 2.9 percent of the approximately 1700 ASME welds made prior to April 11, 1980, are inaccessible.

Q. 55 Mr. Muscente and Mr. Molleda, who was chosen to perform the evaluation of inaccesible AWS welds, and when were they chosen?

A. 55 (MDM, JRM): In February 1981, B&R, with HL&P approval, retained Battelle to perform the engineering evaluation of the inaccessible welds. Battelle is a research and development firm with expertise in welding analyses, metallurgy and NDE. B&R, with HL&P approval, also retained Professor Roy B. McCauley, a noted expert in the field of metallurgy, welding engineering, testing, and evaluation to assist Battelle and make independent conclusions about the conditions of the welds. Professor McCauley's resume is attached hereto as Attachment No. 1.

Q. 56 Mr. Molleda, how has HL&P been involved in the evaluation of inaccessible welds?

A. 56 (JRM): HL&P reviewed and approved the plan for the study and concurred in the selection of consultants for the work. We have met with Dr. Hauser and with Professor McCauley to discuss the program and have accompanied them in visits to the STP site to examine and select representative welds for laboratory testing. As the program progresses, we intend to continue our involvement in the work activities being performed by B&R and the consultants by participating in meetings, reviewing and commenting on reports and records, and participating in discussions with B&R engineers.

Q. 57 Dr. Hauser, please explain the staffing and organization of the evaluation team.

A. 57 (DH): Battelle has designed an evaluation program and since March has been analyzing the accessible welds in order to develop information for use in evaluating the inaccessible welds. Battelle is providing approximately thirteen scientists, welding experts, and mathematicians, plus support staff to conduct this program. Professor McCauley has advised Battelle in designing and implementing the evaluation program. He will continue to review Battelle's work until completion, at which time he will review the final results of Battelle's engineering analyses, advise B&R and HL&P as to the condition of the inaccessible AWS welds, and recommend any corrective action that may be required. B&R and HL&P have and will continue to coordinate and direct all evaluation activities, provide data to Battelle from the reexamination and repair program, and review and approve all program decisions.

Q. 58 Please describe the scope of the evaluation of inaccessible AWS welds and how the work is organized.

A. 58 (DH): Battelle and Professor McCauley were charged with assessing the structural integrity of the inaccessible AWS welds at STP. With Professor McCauley's assistance, Battelle determined that this goal could be achieved by reviewing and thoroughly analyzing the data generated from the ongoing STP reexamination and repair program for accessible AWS welds. Evaluation of this data will continue until Battelle decides, based on statistical and engineering judgement, that an acceptable data base exists from which to establish final conclusions. Battelle is also reviewing the original STP design drawings of accessible and inaccessible welded connections, reviewing pertinent literature about the significance of various types of weld deficiencies on strucutural integrity, and examining and testing representative samples of existing AWS welds containing deficiencies.

Using this information, Battelle is conducting a program comprising three tasks: (1) a statistical analysis to determine the type, characteristics, size and frequency of deficiencies that may exist in the inaccessible welds; (2) a stress analysis, incorporating the statistical results, to determine the actual load-carrying capacity of the inaccessible welds and the allowable loads which can be applied to welds with certain combinations of weld deficiencies, for comparison with the STP design loads; and (3) a metallurgical analysis of sample welds and weld deficiencies to provide additional information for the statistical and stress analyses. All of these tasks are being performed concurrently.

Q. 59 What stress analysis methods did Battelle select, and why are they considered reasonable?

A. 59 (DH): The stress analyses of AWS welded connections will be performed using accepted design stress and elementary fracture mechanics techniques. Some stress analyses may be performed using a sophisticated computer method of finite element analysis. All of these methods have been utilized frequently in analyses of nuclear systems and have yielded conservative results. Battelle therefore considers their use reasonable in the STP evaluation.

Q. 60 Is it your judgement that the various types AWS Code deficiencies have different effects on the strength or performance of welds?

A. 60 (DH): Yes. The presence of a deficiency in a weld does not necessarily mean that the weld will be unable to perform its intended service. Indeed, the presence of certain types of deficiencies will have little or no effect on the performance of the weld. For example, when a weld is moderately concave or convex, or contains weld spatter or small amounts of porosity, there is little or no likelihood that the weld strength will be reduced.

The material being welded can also influence the effect of deficiencies on the structural integrity of the welds. The material used at STP is a low hardenability carbon steel which is not as susceptible to brittleness or to cracking as many other types of steel. Thus, deficiencies like arc strikes and spatter are likely to have an insignificant effect on the structural integrity of the STP welds. Moreover, a material like A-36 steel generally is very ductile; i.e., it is able to absorb strain without breaking or cracking. Welds made of this material can therefore withstand deficiencies that concentrate strain, such as undercut, surface roughness and overlap, with little or no strength reduction.

Q. 61 Has Battelle previously performed evaluations similar to the STP inaccessible AWS weld evaluation? If so, please describe them.

A. 61 (DH): Battelle has performed numerous analyses which are similar to the statistical, stress, and metallurgical analyses being performed at STP. For example, Battelle has conducted a metallurgical failure analyis of a stainless steel joint from a nuclear power plant, has statistically analyzed the effects of weld deficiencies in Navy nuclear piping to determine the actual cyclic load-carrying capacity of the welds, and has compared the results of the analysis with Navy design specifications.

Q. 62 Is it your judgement that the methods being used to perform the inaccessible AWS weld evaluation at STP are reasonable and sound?

A. 62 (DH): Yes. As I previously described, Battelle is using sophisticated computer techniques in conjunction with analytical methods which are frequently used in the design and evaluation of nuclear systems. In addition, the information being generated by the STP reexamination and repair program is detailed and thorough. Finally, Professor McCauley and Battelle analysts are highly qualified and experienced in their respective fields. This combination of factors undoubtedly will produce a reliable assessement of the condition of the inaccessible AWS welds at STP.

Q. 63 What is the status of the inaccessible AWS weld evaluation program?

A. 63 (DH): The evaluation program should be completed and a Final Report issued in late 1981 or early 1982.

Q. 64 Mr. Muscente, who will perform the evaluation of inaccessible ASME welds and how will the evaluation team be organized?

A. 64 (MDM): In early May 1981, B&R, with HL&P approval, plans to identify an outside firm with special expertise to perform an evaluation of the inaccessible ASME welds made prior to April 11, 1980 to determine whether they are suitable for their intended service. The subcontractor will develop an evaluation plan and will perform all analyses.

B&R and HL&P will coordinate and direct all evaluation activities, provide data to the subcontractor, and review and approve all program decisions.

Q. 65 Please describe generally how the evaluation will be performed.

A. 65 (MDM): I anticipate that the evaluation will encompass three principal tasks, although these may change depending upon the recommendations of the subcontractor. These tasks are:

1. A determination of the condition of the welds based on a review of the available radiographs and the data obtained from the reexamination and repair program;

2. A review of original STP design specifications and operational criteria relative to the temperature, pressure, and thermal cycles which the ECW and non-ECW systems must withstand; and

3. An evaluation, based on data from the first and second tasks, as to whether the welds are suitable for their intended service under actual operating conditions at STP.

Q. 66 What is the expected schedule for the inaccessible ASME weld evaluation?

A. 66 (MDM): The evaluation should commence in May 1981 and should be completed in late 1981, at which time the subcontractor will issue a Final Report.

TH:06:G

CAREER SUMMARY

Attachment No. 1

ROY BARNARD McCAULEY

Occupation: Director, Center for Welding Research
Professor Departments of Welding Engineering and Metallurgical Engineering

Welding Engineering Laboratories
The Ohio State University
190 West 19th Avenue
Columbus, Ohio 43210

Phone: 614/422-3241

Specilization: Fabrication Metallurgist

(1) Welding Engineering Education
(2) Quality Performance Audits
(3) Welding Metallurgy
(4) Discontinuity Studies
(5) Testing and Evaluation

Degrees, Institutions, Date:

B.A. - Cornell College - 1940
M.S. - Illinois Institute of Technology - 1943

Teaching Experience:

Assistant in Metallurgy, 1940-43 - Illinois Institute of Technology
Instructor in Metallurgy, 1943-47 - " " " "
Acting Chairman, Met. Engr. 1944-46 - " " " "
Assistant Professor, Met. Engr. 1947-50 - " " " "
Instructor, Welding Engr., 1950-54 - The Ohio State University
Assoc. Prof. & Chm., Welding Engr., 1954-56 - " "
Research Supervisor - Engineering Experiment Station, 1954-60
Assistant to the Dean of Engineering, 1957-59
Prof. Welding Engr., 1956-Date - The Ohio State University
Chairman Welding Engr., 1956-79 - " " " "
Director, Welding Research - 1960-79 - " " "
Building Representative - Welding Engr. Labs, 1969-79
Professor, Metallurgical Engineering, 1972-date, The Ohio State University

Full Time Industrial Experience:

Columbia Tool Steel Company - 1938-39

Part Time Industrial Experience:

Vice President, McCauley Alloy Co. (Chicago, IL) 1941-42
Consultant Manufacturing Metallurgy and Quality Assurance, 1943-date
Registered Professional Engineer, State of Illinois, 1946-date
State of Ohio, 1966-date
Licensed Radioisotope Radiographer, Health Office, A.E.C. 1952-66

POOR ORIGINAL

Honorary Affiliations:

- Cornell Men's Senate Key
- The Society of the Sigma Xi
- Tau Beta Pi
- Phi Lambda Upsilon
- Pi Tau Sigma
- Sigma Gamma Epsilon

Principal Publications: (see separate sheets)

Contributor to:

- American Society for Metals Handbook
- Society for Nondestructive Testing Handbook
- Society of Tool Engineers Handbook
- Lincoln Electric Company Procedure Handbook

Other Career Summaries:

- Who's Who in America
- Who's Who in the Midwest
- Who Knows -- and What
- Who's Who in American Education
- The Blue Book
- Leaders in American Science
- Honorarium Americana
- Engineers of Distinction
- Who's Who in Europe
- American Men & Women of Science

Scientific and Professional Society Affiliations:

- Member - American Society for Nondestructive Testing, 1942-date
  - Handbook Committee - 1957-65; 1977-date
  - Mehl Honor Lecture - 1965
- Member - American Society for Metals
  - Education Committee - 1947
  - Seminar Committee - 1948
  - Handbook Committee No. 8 - 1957-58
  - National Handbook Committee - 1961-63
  - Handbook Chapter Chairman - 1964-71
- Member - American Society for Engineering Education, 1940-77
  - Chairman, Curriculum Committee, Illinois-Wisconsin-Indiana Section - 1944-48
  - Research Relations with Industry - 1962-date
- Member - American Society of Mechanical Engineers
  - Nuclear Survey - 1970-date
- Member - American Foundryman's Association, 1944-50
  - Handbook Committee, 1946-48

Member - American Welding Society, 1956-date
  Technical Representative, Columbus Section, 1952-54
  Director, Columbus Section, 1954
  Secretary, Columbus Section, 1954-55
  Vice Chairman, Columbus Section, 1955-56
  Chairman, Columbus Section, 1956-57
  Executive Committee, Columbus Section, 1957-58
  Vice Chairman, National Educational Activities Comm. 1956-58
  Chairman, National Educational Advisory Council, 1956-58
  National Nominating Committee, 1958-59
  Meritorious Certificate Award, 1959
  National Membership Committee, 1957-60
  Director-at-Large, 1960-63
  Adams Memorial Membership, 1960
  Vice President, 1963-66
  Chairman, Publication & Promotion Council, 1963
  Chairman, Technical Council, 1964
  Chairman, Districts Council, 1965
  President, 1966
  Chairman, Administrative Council, 1966
  Chairman, National Nomination Committee, 1967
  Board of Directors, 1967-70
  Chairman, Executive & Finance Committee, 1968
  Member Educational Activities Committee, 1969-76
  Pipeline Materials Task Force-Welding Research Council, 1973-date
  Chairman, Committee on Higher Education, 1977-date
  Samuel W. Miller Gold Medal 1978

Member - International Institute of Welding, 1960-date
  Expert, American Council, New York City, 1961
  Expert, American Council, Oslo, Norway, 1962
  Expert, American Council, Helsenki, Finland, 1963
  Chairman, Commission on Education, Prague, Czechoslovakia, 1964
  Chairman, Commission on Education, Paris, France, 1965
  Chairman, Commission on Education, Delft, Holland, 1966
  Chairman, Commission on Education, London, England, 1967
  Chairman, Colloquim on Education, London, England, 1967
  Chairman, Commission on Education, Warsaw, Poland, 1968
  Chairman, Commission on Education, Kyoto, Japan, 1969
  Chairman, Commission on Education, Lausanne, Switzerland, 1970
  Member Subcommission 5F Defects in Welds, 1970-date
  Chairman, Commission on Education, Stockholm, Sweden, 1971
  Chairman, Commission on Education, Toronto, Canada, 1972
  Chairman, Commission on Education, Dresseldorf, Germany, 1973
  Chairman, Commission on Education, Budapest, Hungary, 1974
  Chairman, Commission on Education, Sidney, Australia, 1976
  Subcommission Chairman, Destructive Testing, 5-D, 1977-date
  Chairman, Commission on Education, Copenhagen, Denmark, 1977
  Chairman, Commission on Education, Dublin, Ireland, 1978
  Chairman, Commission on Education, Bratislava, Czechoslovakia, 1979
  Chairman, Commission on Education, Lisbon, Portugal, 1980

Member - International Platform Association, 1974-76
  1976-date Smithsonian Associates, National Member
  1974-date Organizational Member American Council, IIW
  1977-date USA Technical Advisory Group, ISO/TC44-SC5, Committee on Mechanical Testing of Welds

POOR ORIGINAL

Married: Audrey Paulsen McCauley, October 10, 1941

Children: Roy Barnard McCauley, III, September 20, 1943
Paul Thomas McCauley, August 23, 1946
Robert William McCauley, May 21, 1952
Andrew John McCauley, October, 1955

Special Activities:

Church School Teacher, Maple Grove Methodist Church, Columbus, Ohio
Member, Worthington Garden Club
Board of Trustees, Wesley Foundation, The Ohio State University
Board of Advisers, Franklin County Agricultural Extension Service
Faculty Associate - Blackburn House, The Ohio State University

Other Honors:

1959 National Meritorious Certificate Award, American Welding Society
1960 Adams Memorial Membership Award, American Welding Society
1964-date Chairman, Commission on Education, International Institute of Welding
1965 Robert F. Mehl Lecture, American Society of Nondestructive Testing
1966 Silver Certificate, American Society for Metals
1966 President, American Welding Society
1967 Life Membership, American Welding Society
1972 R. D. Thomas International Achievement Award, American Welding Society
1974-date Chairman, Subcommission on Destructive Testing, International Institute of Welding
1975 Distinguished Service Award, American Welding Society
1978 Samuel Wylie Miller Gold Metal, American Welding Society
1979 Silver Plaque - International Institute of Welding
1979 Member, Ohio State University Welding Engineering Alumni Club
1980 Silver Certificate American Welding Society

Professional Recognition:

1946-date, Registered Professional Engineer, State of Illinois, #5560
1966-date, Registered Professional Engineer, State of Ohio, #31314
1975-for life, Certified Manufacturing Engineer, Society of Mfg. Engrs.

LIST OF CONSULTANTS

1960 - date

Roy B. McCauley

1959-1962	Republic Steel Company
1960-1961	Dravo Corporation
1960-1962	Columbus & Southern Ohio Electric
1961-1962	Robert W. Hunt Company
1961-1962	U. S. Army Engineers - Washington, D.C.
1962-1963	Dayton Light & Power
1963-1964	Capitol Manufacturing Company
1962-1964	Svendrup Parcel & Associates
1963-1964	United Air Products
1963-1964	Picklands Mather Corp.
1961-1964	Allis Chalmers Manufacturing Company
1963-1964	Colonial Pipeline Corp.
1964-1965	North American Aviation, Division Space and Information
1960-date	U. S. Air Force - Arnold Air Force Base
1964-1971	U. S. Corps of Engineers, Tulsa District
1964-1980	Union Carbide, Nuclear Division
1964-1971	Whirlpool Corp. - Research Laboroatires
1965-1972	U. S. Navy - Ordnance
1967-1971	Bethlehem Steel Corp.
1967-date	National Board of Boiler & Pressure Vessel Inspectors
1969-date	American Society of Mechanical Engineers
1969-1970	Harischfeger Corp.
1971-1972	C. E. Morris Company
1971-1972	Detroit Edison, Inc.
1971-1976	Travelers Insurance
1972-1974	Consolidated Edison Company of New York, Inc.
1972-1974	Bishopric Products
1972-1974	Sun Shipbuilding
1972-date	Battelle Memorial Institute
1972-1973	Zurich Insurance
1974-1976	Aerojet Nuclear Company
1974-date	U. S. Corps of Engineers, Huntington District
1974-date	Allegheny Power Service Corp.
1974-date	Zimpro Corp.
1974-date	Aladdin Industries
1975-1977	Electric Mutual Liability Insurance Company
1975-1977	Triodyne, Inc.
1976-date	Technical Audits Associates
1976-1977	National Bureau of Standards
1977-1978	Consolidated Paper Company
1977-date	Boeing Airplane Company
1977-1980	General Motors Company

POOR ORIGINAL

Short Courses for Industrial Engineering Personnel.

The Ohio State University
University of Minnesota
Dravo Corporation
Allis Chalmers Manufacturing Co.
Erie Mining Company
Jeffrey Manufacturing Corp.
Union Carbide Corporation, Nuclear Division
Oak Ridge Nuclear Research Institute
Bettis Atomic Division, Westinghouse Electric Co.
Morgan Engineering Corp.
U. S. Army Engineers
U. S. Air Force
Humble Oil Company
Associated Welding Societies of Yugoslavia
American Welding Society, School of Welding Technology
North American Aviation Corp., Division of Space and Information
National Board of Boiler & Pressure Vessel Inspectors
Aladdin Industries
Aluminum Company of America
Union Carbide Corp., Plastics and Chemicals Division
Nuclear Regulatory Authority

ARTICLES

Roy B. McCauley

Causes and Cures of Defects in Magnesium Castings, Metal Progress, May 1944.

Causes and Cures of Defects in Heat Treating Magnesium Castings, Metal Progress, June 1944.

A Rapid Metallographic Polishing Method, Materials and Methods, June 1946.

Hardness Prediction in Welding, Engineering Experiment Station News, The Ohio State University, February 1954.

The Ohio State University, (R. S. Green & Roy B. McCauley) "The Relationship Between Hardenability of Steels and Their Weldability", Cleveland Ordnance District U. S. Army Research Command, Project No. TB4-10 (RF 509), January 1, 1955.

Welding Engineering at The Ohio State University, Engineering Experiment Station News, The Ohio State University, February 1955.

Behavior of Spot Welds Under Stress, The Welding Journal, February 1956.

Spot Welds Under Stress, The Welding Engineer, May 1956.

One Solution to Manpower--Welding Technology, The Welding Journal, April 1957.

What Industry Can Do to Assist Engineering Education, Proceedings International Acetylene Association, 1957.

Welding Engineering in Engineering Education, Educational Symposium, American Welding Society, 1957.

Effects of Porosity on Mild Steel Welds, The Welding Journal, May 1958.

A Quantitative Evaluation of Residual Stress Relief in Pipe Weldments, The Welding Journal, April 1958.

The Technical Institute in Welding Education, The Welding Journal, April 1958.

How to Educate for Welding, Welding Engineer, August 1960, p. 33-35.

The Ohio State University, Lawrence Friedman & R. B. McCauley, "Influence of Metallurgical and Related Characteristics on Resistance Spot Welding of Galvanized Steel", International Lead Zinc Research Organization, Project No. ZM-97, EES 244, July 15, 1965.

The Welding Industry Needs More Graduate Welding Engineers, Welding Design & Fabrication, March 1961, p. 8-11.

Semi-Automatic Arc Welding: A Basic Cost Cutting Tool, Part I, Factory, June 1963, p. 80-85

Semi-Automatic Arc Welding: A Basic Cost Cutting Tool, Part 2, Factory, July 1963, p. 92-100.

Ohio State University, Quentin Van Winkle & R. B. McCauley, "Methods for Measuring the Properties of Penetrant Flaw Inspection Materials", Aeronautical Systems Division Air Force Systems Command, Project No. WADD-TR-60-520 (7381) (EES 912), February 1964.

The Effects of Porosity in Quenched and Tempered Steel, The Welding Journal, September 1964, p. 408-414.

Measurement and Improvement Methods and Materials Concerned with Dye Penetrant Flaw Detection, 1965 Conference American Society of Quality Control.

Research to Develop Methods for Measuring the Properties of Penetrant Flow Inspection Materials, WAD Technical Report, Final (WADD-TR-60-520) (Project 7381 Task No. 738102) Part I, June 1960, Part II, Nov. 1960; Part III, Feb. 1963, Part IV, Feb. 1964.

Examination and Detection of Weld Defects, National Board Proceedings, 35th General Meeting, National Board of Boiler and Pressure Vessel Inspectors (1966), p.29-79.

Discontinuity Evaluation, Proceedings of the 1966 Symposium on Nondestructive Testing of Welds, p. 12-21.

Standards for the Acceptance of Weld Defects, Proceedings Fifth International Conference on Nondestructive Testing, Montreal, 1967, p. 472-477.

Quality Assurance in Welding, American Iron & Steel Symposium National Metal Congress, Detroit, October 1968, Metals Engineering Quarterly, Feb. 1969, Vol. 9, No. 1, pp. 96-101; also Welding High Strength Steels, Materials and Processes Engineering Book Shelf, American Society for Metals (1969).

Influence of Metallurgical Characteristics on Resistance Welding of Galvanized Steel, The Welding Journal, October 1969, pp. 454s-462s.

The Effects of Porosity on High Strength Aluminum 7039 Welds, The Welding Journal, July 1970, pp. 311s-321s.

The Meetings of Commission XIV - Welding Instruction at the Lausanne Assembly, Welding in the World, Vol. 9, No. 7/8, 1971, pp. 266-269.

Report of the Stockholm (Sweden) Assembly Meetings of the Commission XIV - Welding Instruction, Welding in the World, Vol. 10, No. 5/6 (1972), pp. 160-172.

Report of the Toronto (Canada) Meetings of the Commission XIV Welding Instruction Welding in the World, Vol. II, No. 5/6, 1973, pp. 173-178.

Ultrasonic Longitudinal Mode Welding of Aluminum Wire, The Welding Journal, June 1974, pp. 252s-260s.

Arc Strikes on High Strength, The Welding Journal, December 1975, pp. 879-884.

Report of the Dusseldorf (Germany) Meetings of the Commission XIV Welding Instruction, Welding in the World, Vol. 12, No. 5/6 (1975), pp.152-156

Weldability Considerations for ASTM A633 High Strength Low Alloy Line Pipe Steel, The Welding Journal.

Report of the Budapest (Hungary) Meetings of the Commission XIV Welding Instruction, Welding in the World, Vol. 14, No. 9/10 (1976) pp. 210-214.

Report of the Tel Aviv (Israel) Meetings of the Comission XIV Welding Instruction, Welding in the World, Vol. 14, No. 9/10 (1976) pp. 210-212.

Hyperbaric Welding, Welding Design and Fabrication, April 1977, pp. 98-100

The Welding Engineering Program at The Ohio State University, Metals Technology Conference, Australia Institute of Metals.

Report of the Sydney (Australia) Meetings of the Commission XIV Welding Instruction, Welding in the World. Vol. 15, No. 7/8 (1977) pp. 151-154.

Report of the Copenhagen (Denmark) Meetings of the Commission XIV Welding Instruction, Welding in the World.

Report of the Dublin (Ireland) Meetings of the Commission XIV Welding Instruction, Welding in the World, Vol. 16, No. 7/8 (1978) pp. 152-155.

THESES DIRECTED BY
PROF. ROY B. McCAULEY

1. Walter Rex Edwards 1953
   Correlation between observed and predicted effects of heat input on the physical and metallurgical properties of the heat-affected zone for bead-on-plate welds.

2. Richard E. Kutchara. 1953
   Mechanisms of embrittlement in titanium alloys.

3. John F. Rudy 1953
   The effects of the macro-metallurgical structure of a spot weld on its physical properties.

4. Gordon E. Cossaboom. 1954
   An investigation of the correlation of weldability and hardenability of steels by use of charpy v-notch impact specimens.

5. David R. Mitchell. 1954
   A study of the weldability of certain Alpha-Beta titanium alloys.

6. Kenneth J. Irwin 1955
   An analysis of the correlation between variable microstructure and energy impact values.

7. Paul W. Turner 1955
   Data on the weldability of certain Alpha-Beta titanium alloys.

8. Jack E. Cook 1957
   A quantitative evaluation of residual stress relief in pipe weldments.

9. George K. Hickox 1959
   A study of strength factors on induction brazed butt joints.

10. Robert K. Fink 1960
    Studies in the mechanics of brittle fracture in steel.

11. William H. Hill. 1961
    A study of residual stress and cracking in preheated welds of a thin ultra high strength steel.

12. John Deen Bramblett. 1963
    Arc physics - CO_2 fineweld consumable electrode welding.

13. Joe D. Nunnikhoven 1963
A method of measuring the reflection of a rudy laser light beam from a metal surface.

14. James Willard Bradley. 1963
The effects of porosity on high-strength steel welds.

15. Ronald P. Hudec. 1965
Measurement of residual stress in a variable restraint weld specimen by x-ray diffraction.

16. Joseph E. Stari. 1965
Incomplete penetration in low-carbon martinsitic stainless steel weldments.

17. Lawrence M. Friedman 1965
Influence of metallurgical and related characteristics on resistance spot welding of galvanized steel.

18. Robert D. Amspoker 1965
The effect of selected heat inputs and arc atmospheres hydrogen percentages on gas tungsten arc welding on 18% nickel maraging steel.

19. Donald Harvey Orts 1967
The effects of zinc coating in resistance spot welding galvanized steel.

20. Ronald J. Shore. 1968
Effects of porosity on high strength aluminum 7039 welds.

21. Ching Hua Chien. 1971
Arc strikes and their influence on pipe material properties.

22. James C. Yeh. 1971
Ultrasonic longitudinal mode welding of aluminum wire.

23. Kenneth Coryell. 1973
Weldability considerations for ASTM A633 high-strength low-alloy pipeline steel.

24. Michael L. Killian 1974
Hyperbaric gas tungsten-arc welding.

25. Carlos Nolasco 1974
Welded HAZ tougness characterization of the line pipe ASTM-A-633 steel.

26. Thomas A. Nevitt 1975
    Application of hypertaric gas tungsten arc welding to high strength low alloy steels.

27. Boris Anzulovic. 1976
    Analysis of vibrational stress relieving.

28. Scott A. Anderson. 1979
    The influences of hyperbaric plasma arc welding on the thermal and mechanical properties of a HSLA microalloyed steel.