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Flaw Evaluation and Weld Overlay Designs for Plant E. I. Hatch Unit 1 Spring 1990 Refueling Outage

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1.0 INTRODUCTION

During the Spring 1990 refueling outage, Georgia Power Company (GPC) performed ultrasonic examinations on recirculation, residual heat removal (RHR) and reactor water clean-up (RWCU) system welds at Plant E. I. Hatch Unit 1 (Hatch Unit 1) in accordance with GPC's commitment related to NRC Generic Letter 88-01 and NUREG-0313, Rev. 2 [1]. These inspections included flawed, unflawed and previously overlayed repaired welds in these systems. During these inspections, flaws believed to be due to intergranular stress corrosion cracking (IGSCC) were detected in twelve 28-inch diameter recirculation pipe welds which required weld overlay repairs. IGSCC flaws in five of these welds were previously detected during the Winter 1985/86 refueling outage but were left unrepaired based on flawed pipe evaluations [2]; hence a total of seven new flawed welds were identified in the 28-inch diameter recirculation pipe welds during the 1990 refueling outage. Four unrepaired flawed welds which were mitigated by induction heating stress improvement (IHSI) during the 1985/86 outage were also inspected. No changes were found in the flaws in these welds compared to previous inspection results. These welds have thus remained stable since the 1985/86 outage. Flaw descriptions of these four welds were previously provided after the 1985/86 refueling outage [2]. No other new flaws were detected in the smaller diameter pipes of the recirculation system nor in the other piping system welds which were included in the inspection program. A summary of the flaw descriptions for the twelve 28-inch diameter recirculation flawed welds is presented in Appendix A.

Weld overlay repairs have been applied at Hatch Unit 1 since 1982. Thirty-five (35) overlays were either newly applied or built-up and surface finished during the 1985/86 outage [2]. Of these thirty-five overlays, four were in the reactor water cleanup (RWCU) system, three were in the residual heat removal (RHR) system and the remaining twenty-eight (28) were in the

recirculation system. In addition, an overlay was applied to an unflawed weld (Weld No. 24B-R-12) to enhance inspectability. Three more weld overlays were applied to IGSCC-flawed welds on the RWCU system during the Spring 1987 outage [3]. During the Fall 1988 outage, overlays were applied to two safe end-to-nozzle welds [4] in the recirculation system. In addition, during the 1988 outage, the RWCU system inside containment (from the drywell penetration X-14 to the RHR suction line) was replaced eliminating all the seven previously applied weld overlays on this system. During the replacement of this portion of the RWCU system, two welds which had undergone repairs during installation, (Weld Nos. 6-D-1 and 6-D-9) were also repaired by weld overlays. These weld repairs were not associated with IGSCC and as such the weld overlays of these two welds are not classified as IGSCC repairs.

In summary, a total of thirty-four weld overlays associated with IGSCC were present at Hatch Unit 1 prior to the 1990 outage. These include the overlay on RHR weld 24B-R-12, which although not IGSCC-related, is classified and inspected as a NUREG-0313, Rev. 2 Category E weldment. Two overlays applied on the newly replaced RWCU system during the 1988 outage are also not IGSCC-related. Twelve additional overlays associated with IGSCC were applied during the 1990 outage bringing the total number of IGSCC-related overlays to forty-six (46) at Hatch Unit 1. There also remain four flawed, unoverlayed but IHSI-mitigated welds in the plant, which remained unchanged from prior inspections.

A selected number of the pre-1990 outage overlays were inspected during the 1990 outage per GPC's in-service inspection commitment. There was no evidence of cracks propagating into the overlays in these welds. Minor flaws associated with lack of fusion between weld beads, which occurred during the overlay repairs, were observed in some of these overlays. They were evaluated per the requirements of the ASME, Section XI [5].

The purpose of this report is to document the design/analysis and evaluation activities conducted on the twelve 28-inch diameter flawed welds identified during the 1990 outage. The evaluations of the pre-1990 weld overlay repairs and flawed welds have been documented previously [2,3,4]. Flaws identified in weld overlays repaired before the 1990 outage, but inspected during the 1990 outage, will also be documented. Section 2 of this report presents the weld overlay design and flaw evaluation criteria. Section 3 presents stress components and stress combination data. Information on pipe component dimensions is also included in this section. Section 4 presents evaluation methods and results. A comparison of design and as-built weld overlay dimensions is also presented in Section 4. Section 5 addresses the system-wide effects of weld overlay shrinkage on unoverlayed welds in the system. The analysis which was performed on the Hatch Unit 1 recirculation system is presented together with predicted shrinkage-induced stress data. Sections 6 and 7 present summary/conclusions and references used in this evaluation. Appendix A provides the UT inspection results for the twelve 28-inch diameter flawed welds and Appendix B presents the weld overlay design drawings for these welds. Appendix C provides updated flawed pipe analysis of the IHSI-mitigated circumferentially flawed welds.

2.0 REPAIR AND EVALUATION CRITERIA

2.1 Repair Description

The twelve weld overlays applied at Hatch Unit 1 during the 1990 refueling outage were designed and repaired as "standard" weld overlays. The repairs were made by increasing the pipe wall thickness through the deposition of weld metal circumferentially around the water-backed pipe in the weld region using the machine GTAW welding process. The weld metal used for the weld overlay application was Type 308L stainless steel containing 0.02 wt. % maximum carbon with controlled delta ferrite content in order to provide resistance to IGSCC propagation. In addition to providing the required wall thickness to restore the ASME Code safety margin, the welding process in the water-backed condition also produces a strong compressive residual stress pattern on the inside of the pipe which provides further resistance to IGSCC.

The overlay repair for each flawed weld was carefully controlled using the following steps in order to assure the integrity of the overlay:

1. Surface preparation by grinding of existing weld crowns and any local protrusions to blend smoothly into the base metal plus the removal of oxides and other foreign materials from the area to be overlayed.

2. Layout of weld overlay per the design drawing by punchmarking appropriately on the pipe.

3. Liquid penetrant examination of the surface to be overlayed to assure surface is free of indications in accordance with ASME, Section XI [5].

4. Measurement of wall thickness on each side of the weld to be overlayed using UT techniques.

5. Delta ferrite content measurement of the completed first layer to meet the ferrite content requirement of 7.5 FN. Where the ferrite level was below 7.5 FN, the extremely low carbon level was demonstrated to provide equivalent IGSCC resistance at the reduced ferrite level. (See Section 4.4 for detail)

6. Surface preparation of the completed weld overlay to assure adequate surface contour and smoothness for UT examination.

7. Measurement of the final overlay thickness by UT techniques.

8. Liquid penetrant examination of the final overlay surface in accordance with ASME, Section XI.

9. Volumetric examination of the completed weld overlay repair and part of the original pipe wall in accordance with UT techniques developed by EPRI.

2.2 Design of Standard Weld Overlay Repairs

The requirements for design of weld overlay repairs are defined in NUREG-0313, Rev. 2 [1]. The analytical bases for the design of the repairs are in accordance with the requirements of ASME Section XI, IWB-3641 [5] as specified in NUREG-0313. Weld overlay repairs are considered to be acceptable long term repairs to IGSCC-flawed weldments if they meet a conservative set of design assumptions which qualify them as "standard" weld overlays, in accordance with NUREG-0313. The three principal design requirements to qualify a weld overlay as a "standard" weld overlay and, therefore, as an IGSCC Category E weld in accordance with Reference 1 are:

1. The design basis flaw for the repair is a circumferentially oriented flaw which extends 360° around the component, and is through the original

component wall. This conservative assumption eliminates concerns about the reliability of the ultrasonic inspection which initially identified the flaw. In addition, potential concerns about the toughness of the original butt weld material are not applicable, since no credit is taken in the design process for the load carrying capability of the remaining component wall ligament.

2. As required by ASME Section XI, IWB-3641 [5], a combination of internal pressure, deadweight and seismic stresses is used in the design of weld overlay repairs. Thermal and other secondary stresses are not required to be addressed, since the toughness of the original butt weld material is not a concern for a standard weld overlay, and since no credit is taken for the remaining uncracked ligament in the original pipe wall.

3. Following the repair, the surface finish of the repair must be sufficiently smooth to allow ultrasonic examination through the overlay material and into a portion of the original wall. The purpose of this examination is, in part, to demonstrate that the repair thickness does not degrade with time due to continued flaw propagation.

2.3 Evaluation of Flaws in Weld Overlays

During UT examination of pre-1990 outage overlays and also the overlay repairs performed during the 1990 outage, indications were identified in some of these overlays. Most of these indications were classified as lack of fusion between weld beads during the overlay application with no measurable width. These indications are evaluated against the requirements of ASME Section XI, IWB-3514.3 [5] to show that they are acceptable. A

boat sample was taken from the weld overlay on Weld 28A-2 for metallurgical examination. This examination revealed that the reported UT indications in the overlay were actually porosity in the weld metal. The ASME Section III, Appendix VI standards for rounded indications were used to evaluate the acceptability of the observed porosity.

3.0 STRESS COMPONENTS AND COMBINATIONS

3.1 Summary of Stress Components

The stress information required for weld overlay design and analysis was taken from Reference 6. The components considered in these designs and analyses included pressure, dead weight, seismic (OBE), and thermal expansion stresses. These components are presented in Table 3-1 for each weld requiring repair or evaluation.

3.2 Stress Combinations for Weld Overlay Design

Table IWB-3641-1 of ASME Section XI [5] defines allowable flaw depth in austenitic steel base metal and associated gas tungsten arc welds (GTAW) as a function of the stress ratio (Pm+Pb)/Sm. Thus the pertinent stress combination for weld overlay design is:

$$P_m + P_b = \sigma_{pressure} + \sigma_{DW} + \sigma_{seismic}$$

Table IWB-3641-5 requires including expansion stresses in the above stress ratio when evaluating flaws in shielded metal arc or submerged arc weldments (SMAW or SAW), to account for the concern of potentially low toughness in these flux weld materials. However, since the design basis for the Hatch Unit 1 weld overlays assumes a through wall flaw extending 360°, no credit for the original flux weld material is taken, and the overlays are entirely GTAW weldments. Therefore, the flux weld toughness concern does not apply and thermal stresses are not needed for the overlay design. Thermal stresses are included in Table 3-1 for completeness, however.

The geometry of each pipe size (outside diameter and nominal wall thickness) is summarized in Table 3-2. In calculating the stress, the measured wall thickness was used if it was available. Otherwise nominal wall thickness was used in calculating the stresses.

Table 3-1

Stress Components for Flawed Weld Locations

WELD NUMBER	STRESS COMPONENTS PRESSURE	DEADWEIGHT	THERMAL	SEISMIC (OBE)
12AR-G-4	6667	214	6284	1814
12BR-A-4	6667	1443	7407	1680
12BR-E-4	6667	1448	7424	1821
20B-D-4	5391	643	3176	1790
28A-2	6731	571	727	857
28A-4	6836	433	396	762
28A-6	7292	664	935	1038
28A-7	6250	285	870	1018
28A-8	7292	586	937	573
28A-14	7302	856	555	1097
28B-8	7214	396	710	956
28B-9	7214	639	720	647
28B-10	7292	577	732	933
28B-13	7302	497	573	1489
28B-14	7302	469	630	1557
28B-15	7302	904	767	1156

Table 3-2

Piping System Geometry Data

System	Nominal Pipe Size (in.)	Pipe O.D. (in.)	Nominal Wall Thickness (in.)
RWCU	6	6.628	0.5494
Recirculation	12	12.746	0.693
RHR	20	20.00	0.937
Recirculation	22	22.00	1.100
RHR	24	24.00	1.150
Recirculation (Suction)	28	28.00	1.213
Recirculation (Discharge)	28	28.00	1.390

4.0 WELD OVERLAY DESIGN EVALUATION AND RESULTS

Twelve (12) new weld overlay repairs were applied to IGSCC-like flaw indications during the 1990 outage at Hatch Unit 1. These twelve new weld overlays are in 28-inch diameter recirculation system pipe welds. Six of these weld overlays are in Loop A and six weld overlays are in Loop B. In addition, minor flaws were detected in five pre-1990 weld overlays. The following sections describe the design analyses and as-built evaluations performed for the new overlays and flaw evaluations performed for the pre-1990 overlays.

4.1 Design of Standard Weld Overlay Repairs

Where flaws requiring repair were detected during the present outage, weld overlay repairs were designed based upon the criteria described in Section 2. The applied stress ratio used in the weld overlay design was calculated from data presented in Reference 6 with stress components combined as defined in Section 3 of this report. The flaw was assumed to extend 360° circumferentially and to be through the original pipe wall. The program pc-CRACK [7] was used to size the weld overlay using ASME Section XI, IWB-3640 criteria. Low carbon level, elevated ferrite weld wire was utilized in the overlay welding so that the design thickness could include credit for the first welded layer.

Design and as-built dimensions for the new (1990 outage) weld overlays are presented for comparison in Table 4-1. All weld overlay design drawings are included in Appendix B. The as-built (post-surface finish) thickness for each overlay was compared with the design thickness to determine acceptability of each overlay. The dimension listed in the as-built columns represent the minimum of all data points measured at each weld overlay. The thicknesses of the as-built overlays meet or exceed the design values in all cases.

Table 4-1

Weld Overlay Design and As-Built Dimensions

Weld Number	Design Length (in.)	As-Built Length (in.)	Design Thickness (in.)	As-Built Thickness (in.)
28A-2	6.40	7.60	0.46	0.50
28A-4	6.40	7.88	0.45	0.48
28A-6	6.20	7.61	0.44	0.54
28A-7	3.50	4.20	0.49	0.75
28A-8	3.50	5.31	0.43	0.465
28A-14	5.70	7.20	0.52	0.595
28B-8	3.50	4.60	0.44	0.57
28B-9	3.50	4.75	0.44	0.545
28B-10	6.20	7.60	0.44	0.48
28B-13	3.50	4.35	0.52	0.59
28B-14	3.50	4.79	0.52	0.60
28B-15	6.70	8.31	0.52	0.62

4.2 Evaluation of Flaws In Weld Overlay Repairs

During the ultrasonic examinations of weld overlay repairs during the 1990 outage at Hatch Unit 1, embedded flaws were identified in a total of seven weld overlay repairs. These flaws and the weld overlays are summarized in Table 4-2. Five of the flawed repairs were applied during previous outages. These are discussed in section 4.2.1. The remaining two flawed repairs were applied during the 1990 outage. One of the 1990 weld overlay repairs was evaluated as acceptable by IWB-3500. This weld (28B-9) is discussed in section 4.2.2. A metallurgical "boat sample" was removed from the other weld overlay, weld (28A-2), and the repair was shown to be acceptable based upon the results of metallurgical examination of that sample. The evaluation of 28A-2 is summarized in section 4.2.3. All seven of the weld overlays with identified embedded flaws were shown to be acceptable for continued operation without further repair.

4.2.1 Evaluation of Defects in Pre-1990 Outage Weld Overlays at Hatch Unit 1

During ultrasonic examinations of the weld overlay repairs applied prior to the current outage at Hatch Unit 1, flaw indications were found in five of the overlays. These overlays and the associated indication notifications (INFs) are as follows:

Weld No.	Indication Notification Number
1B31-1RC-28B-4	I90H1024
1E11-1RHR-24A-R-13	I90H1016
1E11-1RHR-24B-R-12	I90H1035
1B31-1RC-22BM-4	I90H1013
1B31-1RC-12AR-F-2	I90H1011

Table 4-2

Summary of Flaws in Overlays

Weld Number	t[1] (in.)	L[2] (in.)	Evaluated a[3] (in.)
12AR-F-2	1.45	11.95	0.1
22BM-4	1.68	3.4	0.1
24A-R-13	1.48	1.2	0.1
24B-R-12	1.72	4.15	0.1
28A-2	1.85	3 x 360°[4]	(4)
28B-4	2.15	11.65	0.1
28B-9	1.74	4.25	0.1

Notes:

1) t = As-built original pipe wall thickness plus overlay thickness.

2) L = Combined length of all flaws in the overlay.

3) Evaluated "a" is half the flaw width, conservatively assumed to be 0.1 in. for all flaws (actual width too small to measure).

4) Post repair UT examination revealed three axial locations in the repair where indications extending 360° around the pipe for a width of approximately 1/2 inch existed in the first welded layer. Metallurgical examination determined that these flaws were due to porosity in the first welded layer (see Section 4.2.3).

The flaw indications in these overlays were generally characterized as lack of fusion between weld beads during the overlay application. They are not connected to the original IGSCC flaws in the pipe wall.

These flaws have been evaluated under the requirements of ASME Section XI, IWB-3500 [5] utilizing two approaches. In the first approach, the flaws were assumed to be planar flaws while in the second approach they were assumed to be laminar flaws. In either case, the requirements of the Code were satisfied, indicating that the overlays are acceptable for continued operation and that the flaws do not undermine the original design basis of the overlays.

4.2.2 Evaluation of Defects in Weld Overlay Applied to Weld 1B31-1RC-28B-9

As identified in INF No. I90H1045, flaw indications were found in the new weld overlay applied to weld 1B31-1RC-28B-9 during the post-application ultrasonic examination. The flaw indications were characterized as interbead lack of fusion and they are not connected to the original flaws for which the weld overlay was designed.

The flaws have been evaluated to the requirements of ASME Code, Section XI, IWB-3500 [5] by considering them either as planar or laminar flaws. In either case, the requirements of the Code are satisfied indicating that the subject weld overlay is acceptable for service without modification.

4.2.3 Evaluation of Flaws Identified in the Weld Overlay on Weld 1B31-1RC-28A-2

The original UT examination of the overlay applied to weld 1B31-1RC-28A-2 identified laminar indications which were too large to be acceptable by Section XI, IWB-3500 [5]. For this reason, a boat sample was removed from the overlay to identify the exact nature of the flaws. A review was performed of a metallurgical report [8] prepared by Babcock & Wilcox (B&W), which documented the laboratory examination of the boat sample. The sample was directly over an apparent laminar or lack of bond type indication in the weld overlay material, which was detected ultrasonically during the post-repair examination. Reference 8 reported that the observed UT indications were in fact not laminations or lack of bond defects, but were due instead to porosity in the first welded layer of the repair. The report further concluded that the observed porosity would have no significant effect on the mechanical properties of the weldment, and is acceptable by ASME Section III, Appendix VI standards for rounded indications.

Structural Integrity's review of the Reference 8 report and related data from the site, resulted in the conclusion that the observed flaws in weld 28A-2 are acceptable without repair or further action beyond repairing the cavity left by the boat sample. This conclusion is based upon the following facts in addition to the B&W observations described above:

1. The acceptability of the indications with respect to ASME Section III, Appendix VI which was reported above and independently verified by SI.

2. The weld overlay design thickness of 0.46" is maintained outboard of the identified porosity flaws. The integrity of the weld overlay repair would not be degraded by the observed flaws, even if they produced a

significant reduction in the mechanical strength of the weld layer.

3. The weld overlay material and the underlying pipe material are still inspectable ultrasonically. Consequently, it is still possible to monitor the IGSCC flaw in the base metal, as recommended by NUREG-0313, Rev. 2 [1]. It is also possible to monitor the observed porosity indications for changes, although none are expected.

4. The observed indications appear to be an isolated occurrence, in that similar indications were not reported in the weld overlays on other welds.

5. There is no indication of connection of the observed porosity with the original IGSCC indications in the base metal.

6. Reference 8 estimates that the observed porosity results in a reduction in cross sectional area of less than 5%. On this basis, there is no reason why the first welded layer (which contains the observed porosity) cannot be considered as part of the design thickness of the weld overlay repair, since the normal requirements for considering the first layer were met. (i.e., the original pipe surface was shown to be clean by dye penetrant examination, and the first welded layer was shown by actual measurement to contain delta ferrite of at least 7.5 FN).

The following actions were taken by GPC as a result of the UT indications and subsequent boat sample results from the weld overlay repair of 28A-2:

1. The UT characteristics of the observed porosity indications, as noted during the current examination of this weld overlay, were recorded and carefully documented for comparison with any future similar "laminar" indications in future weld overlays. Such documentation will aid in the resolution of weld overlay indications in the future.

2. It is believed that indications such as those revealed by the metallurgical examination of the boat sample could be due to contamination of weld material or pipe surface. The procedures associated with dye penetrant examination of pipe surfaces prior to overlay repair and with weld material control were reviewed to determine whether it was desirable to add controls or hold points to these procedures to increase assurance of clean surfaces and materials.

3. During future ultrasonic examinations of the repair to weld 28A-2, the "laminar" indications will also be examined in detail, in order to provide added assurance that the weld overlay is not degraded.

In summary, it was concluded that the observed porosity does not degrade the integrity of the weld overlay repair on weld 28A-2, and consequently, no further repair activity was required. This conclusion is based upon the observations in Reference 8, and on the observation that a standard overlay containing the design thickness of 0.46 inches is maintained outboard of the identified porosity indications.

4.3 Evaluation of One-Sided Weld Overlays

Six of the weld overlay repairs applied during this outage, as well as several from prior outages, were applied to pipe-to-valve or pipe-to-pump weldments, in which the component side of the weld is a material generally considered to be highly resistant to IGSCC [10, 11]. For this reason, and to avoid welding on the

cast material, which could lead to opening up potential casting defects, a short weld overlay repair has been used. The overlay only covers the susceptible, pipe side of the weld, and ends on the crown of the weld between the weld centerline and the fusion line on the component side of the weld (see Figure 4-1). This section of the report summarizes a generic analysis which has been performed to validate this design concept with respect to ASME Code rules.

Figure 4-2 illustrates a finite element model which was constructed to bound the one-sided weld overlays applied at Hatch Unit 1. The wall thicknesses on either side of the overlay were chosen as minimums, and a flaw was assumed, through the original pipe wall and 360° in the heat affected zone (HAZ) on the pipe side of the weld. Worst case loads for the subject overlays at Hatch Unit 1 were applied to the model, and the resulting stresses were evaluated at two critical sections on the short side of the overlay, as indicated in Figure 4-2. Primary and primary plus secondary stresses were determined by linearizing actual stresses from the finite element model along the critical sections. A comparison was made to applicable ASME Code allowable stress values [12].

The resulting stress comparisons at the two critical sections are listed in Table 4-3. It is seen from this table that the stresses meet the applicable ASME Code allowables.

4.4 Evaluation of Reduced Ferrite Level In Initial Weld Layer

An evaluation was performed by SI to document the technical basis for acceptance of low carbon, reduced ferrite Type 308L stainless steel weld metal as Reference 1 approved material for the initial weld overlay layer at Hatch Unit 1. This evaluation was necessitated by the fact that one heat of weld metal, containing greater than 10FN ferrite when deposited as a weld pad, occasionally produced ferrite levels between 6.0 and 7.5 FN in

Table 4-3

ASME Code Stress Evaluation Results
for One-Sided Weld Overlay

	Section 1	Section 2	Code Allowable
Primary Stresses:			
P_m	15.24 ksi	16.75 ksi	16.95 ksi
$P_m + P_b$	18.38 ksi	20.21 ksi	25.43 ksi
Secondary Stresses:			
$P_l + P_b + Q$	43.74 ksi	40.77 ksi	50.85 ksi

the first weld overlay layer of some of the 28-inch diameter recirculation system weld overlay repairs. Due to the radiation exposure concerns related to requiring one or more additional weld overlay layers if the first layer was disregarded as an IGSCC barrier, an alternative evaluation approach was employed, utilizing Reference 1 guidance, to allow for a limited reduction in ferrite level in the weld provided that sufficient reduction in carbon level is also present. This approach is described in the following paragraphs.

The evaluation of the acceptability of reduced ferrite, low carbon Type 308L stainless steel consisted of a review of the open literature. This literature review, documented in References 9-11, illustrates that one is technically justified in reducing the ferrite level in this weld metal without reducing the IGSCC resistance if there is a sufficient reduction in the carbon level. This carbon-ferrite trade-off results from the fact that the materials-related cause of IGSCC in these austenitic stainless steels in the BWR environment is the fact that excess carbon is in solution during the welding or otherwise heat treating of these materials. This excess carbon combines with the chromium which is in solution, thereby forming chromium carbides preferentially along the grain boundaries. The reduced chromium zone at the grain boundaries, or "chromium depleted zone", is often sufficiently reduced in chromium so that this region is no longer "stainless". A material is identified as "sensitized" in this condition and IGSCC becomes a real possibility.

Ferrite in the alloy helps prevent the chromium depletion in two ways. Firstly, the equilibrium chromium level in ferrite is much greater than in austenite. Consequently, "chromium depletion" due to carbide formation has a much less damaging effect at ferrite grain boundaries in an austenitic stainless steel which contains ferrite. Secondly, the carbon diffusion in the ferrite

is much greater than in the austenite in these steels. Consequently, most chromium carbide forms at ferrite-austenite or ferrite-ferrite grain boundaries rather than on austenite-austenite boundaries, where "chromium depletion" is a significant concern.

Low carbon austenitic stainless steel alloys, such as Type 316 nuclear grade stainless steel, attain their excellent resistance to IGSCC because they contain no more than 0.02 wt. % carbon in the alloy. This family of alloys is identified by Reference 1 as resistant to IGSCC due to a reduced carbon level. Reference 1 also identifies Type 308L stainless steel weld metal, containing 0.035 wt. % carbon and 7.5 FN ferrite, as resistant to IGSCC. This reference states further, in the case of cast alloys, the further reduction in ferrite to 5 FN is allowable, depending on carbon content and other factors.

Studies have been performed by the Electric Power Research Institute and by General Electric Company to examine the carbon-ferrite trade-off in imparting IGSCC resistance to duplex austenitic base stainless steel weld metal. References 9 through 11 identify some of that research and Figures 4-3 and 4-4 from References 10 and 11 represent graphical presentations of the IGSCC resistance which can be obtained as one changes the carbon and the ferrite levels in these alloys. One can observe from these figures that there is a strong carbon-ferrite trade-off in providing equivalent resistance to IGSCC in this class of duplex stainless steels. Figure 4-4 illustrates that for austenitic stainless steel castings containing 0.02 wt. % carbon or less, approximately 5.5% ferrite produces an alloy which is highly resistant to IGSCC even in the severely sensitized condition. One observes from this curve that at a carbon level of 0.035 wt. %, (as is allowed by Reference 1), more than 12% ferrite would be required to achieve the same resistance to IGSCC. Figure 4-3 illustrates that a decrease in carbon level from 0.035 wt. % to 0.02 wt. % results in a decrease of approximately 2% in the

ferrite level necessary to provide an equivalent resistance to IGSCC.

These results illustrate that there is a carbon-ferrite adjustment one can employ for producing an equivalent resistance to IGSCC in the BWR environment. The Nuclear Regulatory Commission has recognized that trade-off in NUREG-0313, Rev. 2 [1]. The industry has utilized this carbon-ferrite trade-off in specifying acceptance levels for use of cast components as conforming materials by following the guidance presented in Figures 4-3 and 4-4 [10, 11].

At Hatch Unit 1, a heat of Type 308L stainless steel has been used which contains 0.019 wt. % carbon (Heat # XT5941), and which has produced an as-deposited ferrite content which has been measured at between 6.0 and 7.5 FN ferrite in some beads. Based upon the results presented above, in order to obtain an IGSCC resistance equivalent to that for a heat containing 7.5 FN ferrite and 0.035 wt. % carbon, one is technically justified in reducing the ferrite to 5.5 FN without reducing the IGSCC resistance in this heat of material below the minimum specified in NUREG-0313, Rev. 2. The results indicate, therefore, that one may use this heat of weld metal for the first overlay weld layer provided no reading in that layer is below 5.5 FN ferrite. If a single reading is below 5.5 FN, but above 5.0 FN, one may still accept the layer provided that two additional measurements in the immediate vicinity of the low measurement are equal to or greater than 5.5 FN.

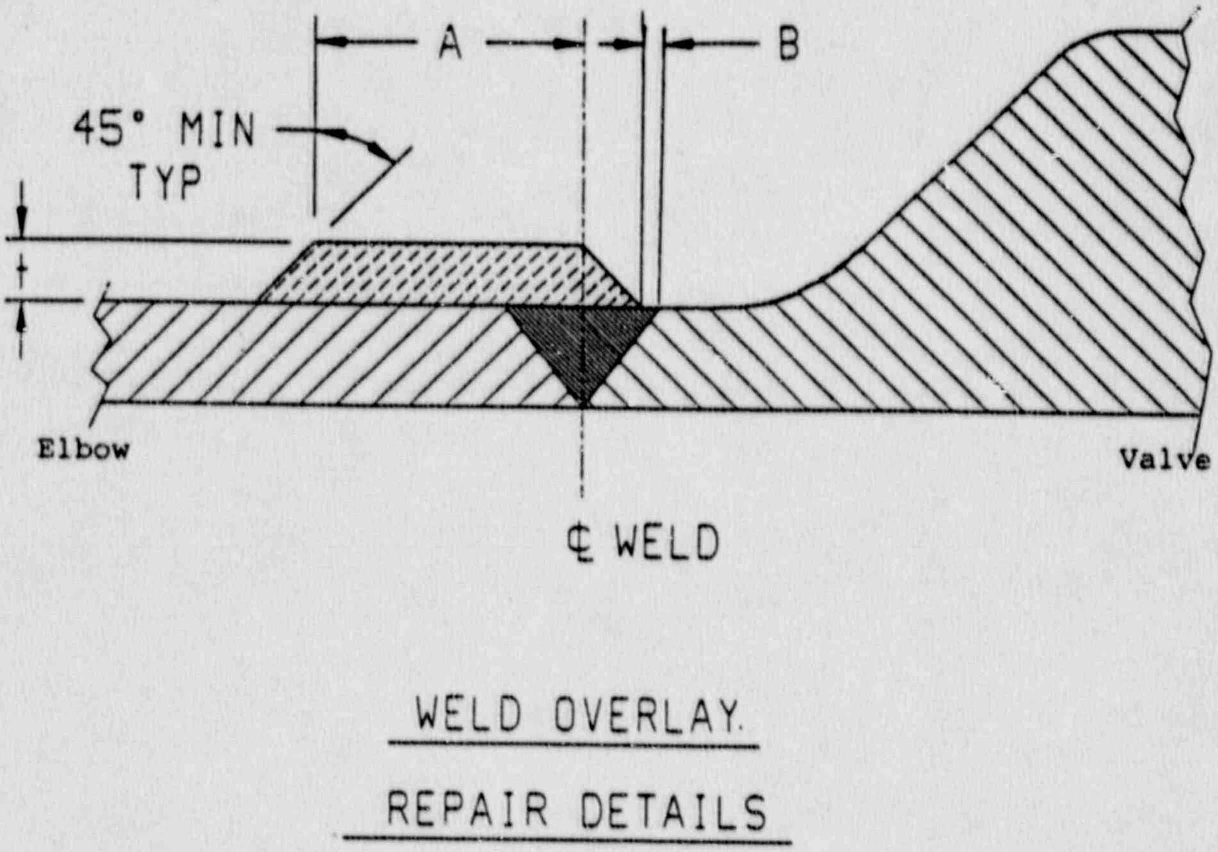


Figure 4-1. Illustration of Short Weld Overlay Design at Cast Pumps and Valves

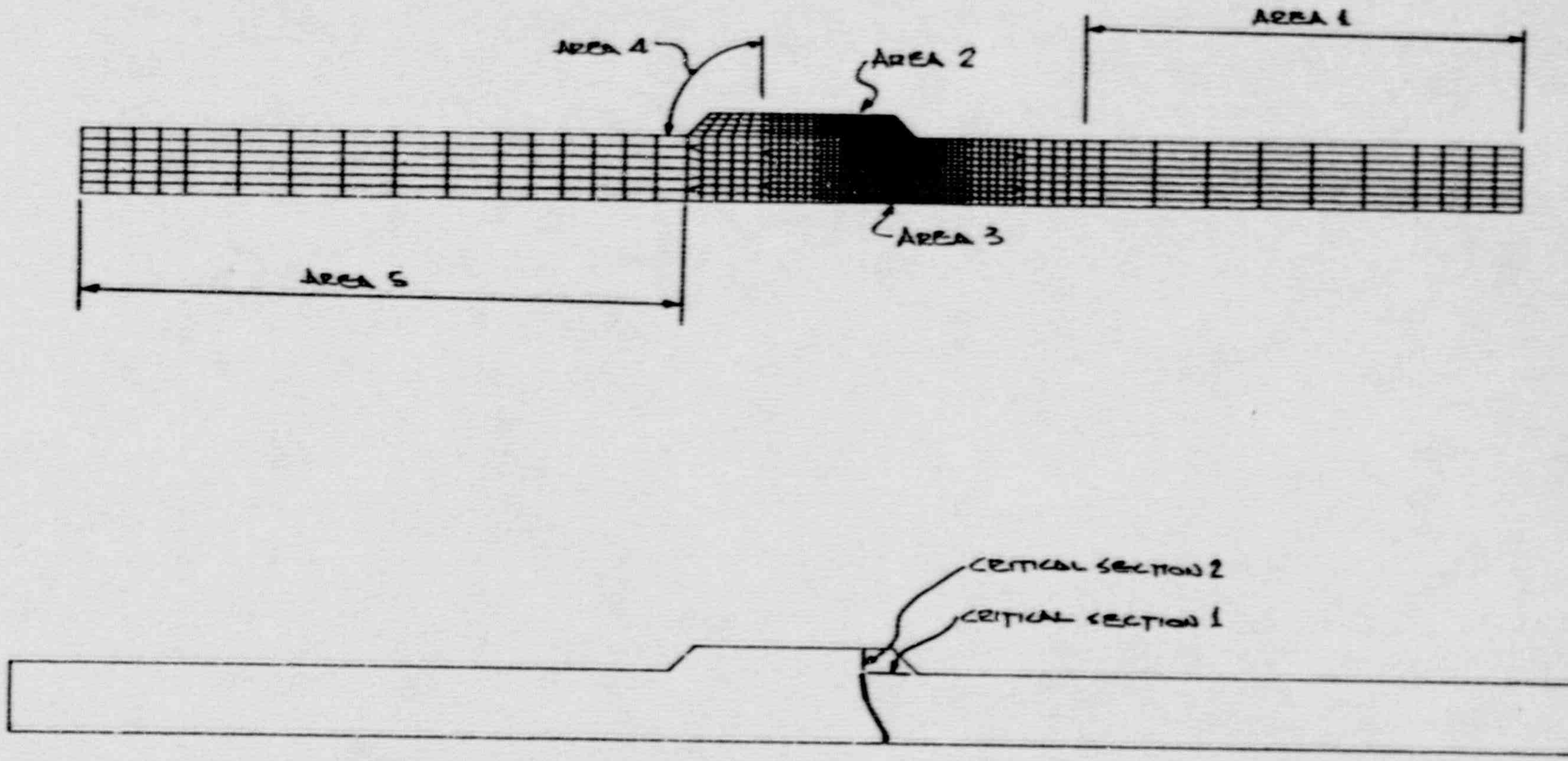


Figure 4-2. Hatch Unit 1 Short Overlay Finite Element Model

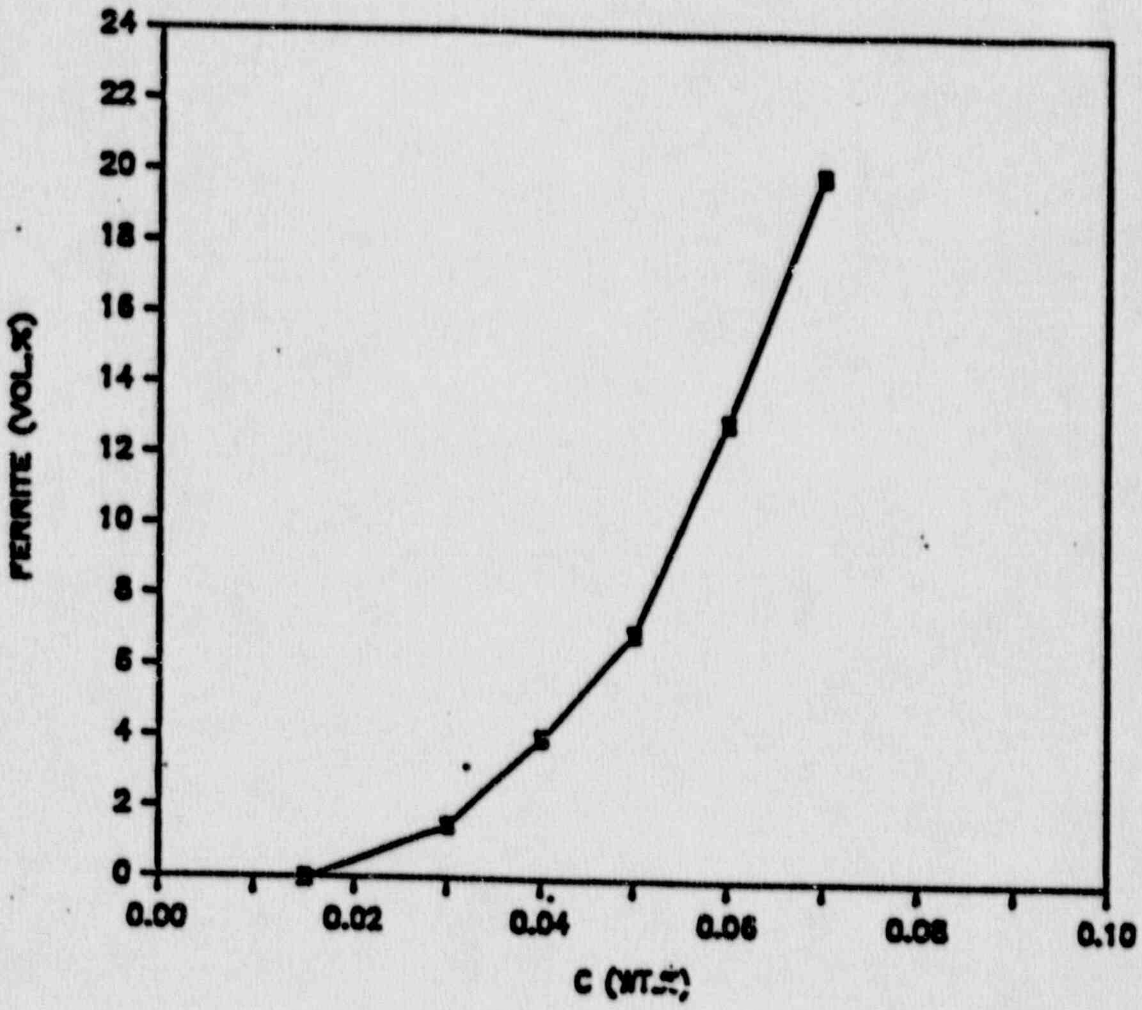


Figure 4-3. Predicted Ferrite Requirements Versus Carbon Content to Provide Significant Resistance Against SCC for Grade CF-8 Castings (Reference 10)

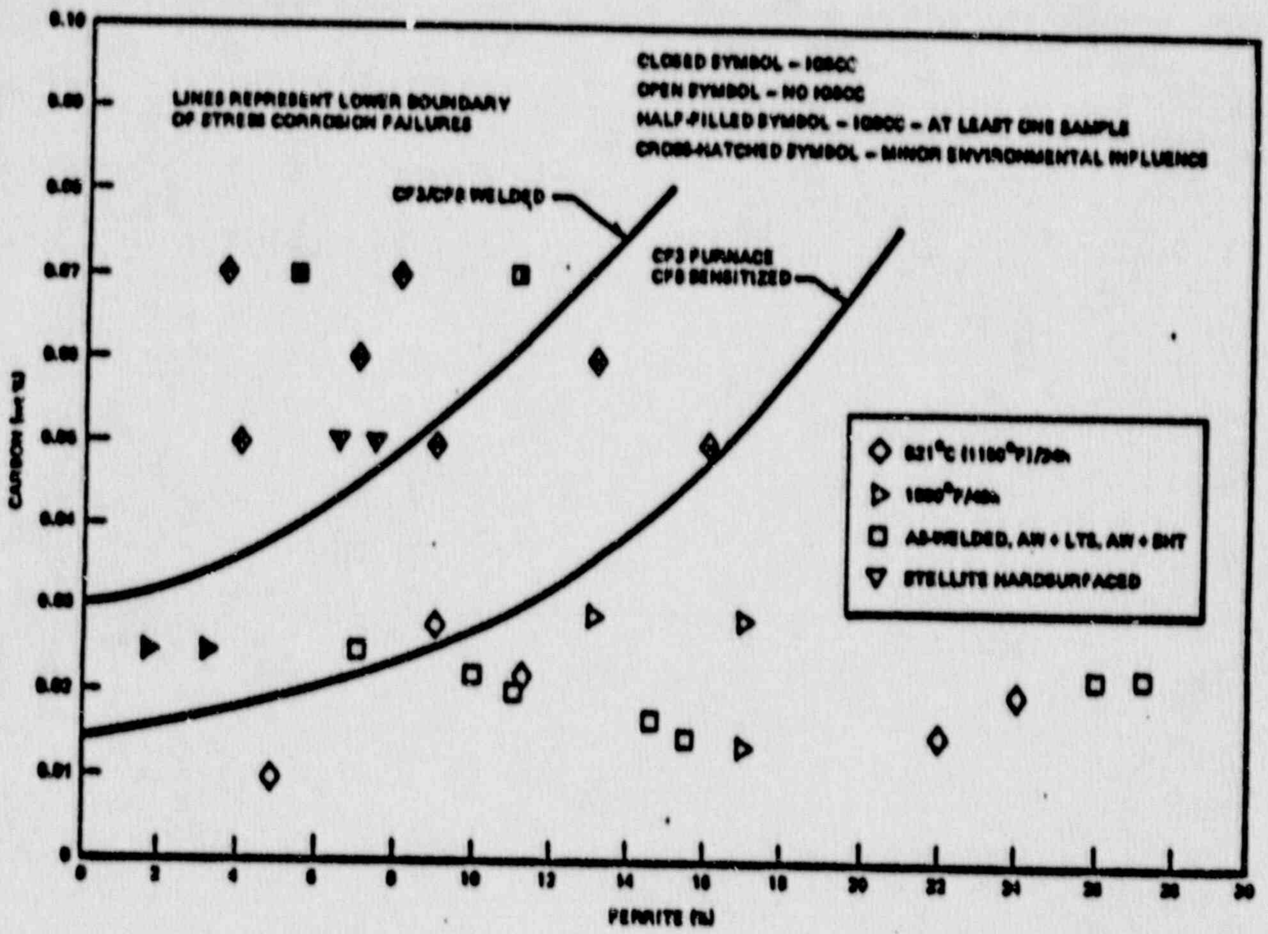


Figure 4-4. Combined Influence of Carbon Content and Percent Ferrite on IGSCC Resistance (Reference 11)

5.0 EVALUATION OF WELD OVERLAY SHRINKAGE STRESSES

5.1 Background

5.1.1 Causes of Weld Overlay Shrinkage Stresses

Stresses develop in a piping system after application of one or more weld overlays due to the weld shrinkage at the overlays. These stresses are system-wide, and are similar in nature to restrained free-end thermal expansion or contraction stresses. The level of stresses resulting from weld overlay shrinkage are a direct result of the number and location of the weld overlays, the shrinkage per overlay, and the piping system geometry. Axial shrinkage produces tensile secondary stresses at locations co-linear with the overlay, and predominantly bending secondary stresses at locations which are separated and not co-linear with the welding location (e.g., locations separated by an elbow, see Figure 5-1). In addition, weld overlays can produce stresses at fixed points in parallel runs of piping if the two runs are tied together by a stiff run (see Figure 5-2). This latter situation is typical of 12" recirculation system risers. The highest stressed point in a recirculation system with several weld overlays is typically at recirculation riser to inlet nozzle connections. Weld overlay shrinkage in a vertical run of such a riser produces bending on the horizontal run leading to the inlet nozzle. This bending stress is typically highest at the nozzle-to-pipe or pipe-to-safe end weld.

Three aspects of the weld overlay application determine the magnitude of weld overlay shrinkage which will be produced. The first of these is the pipe size. Larger pipes (with correspondingly thicker walls) are stiffer and shrink less than do smaller lines. Typically the amount of shrinkage measured in 28" lines is roughly 1/4 to 1/5 of that produced on 12" pipe for the same weld overlay design. Consequently, shrinkage stresses

predicted in 28" pipe are also only a small fraction of the worst stresses predicted in 12" pipe.

The second factor which contributes to the magnitude of the observed weld overlay shrinkage is the length of the overlay. For the same pipe size, a longer overlay will produce greater axial shrinkage and (depending on system geometry) larger stresses than would a shorter overlay.

The final factor which has an effect on the shrinkage is the number of weld layers applied to produce a particular overlay thickness. Field measurements suggest that the bulk of the shrinkage occurs as a result of application of the first two welding layers. Subsequent layers have progressively less effect. This suggest that the magnitude of the shrinkage is related to the volume of metal cooling at any one time, compared to the amount (including original pipe wall) which has already solidified.

5.1.2 Effects of Weld Overlay Shrinkage

In ASME Code terminology, the stresses produced by the shrinkage of weld overlays are secondary stresses. However, they are essentially constant with operating time, so there are no official ASME Code limits on this stress component. Nonetheless, they could potentially increase the susceptability of unoverlayed welds to future IGSCC and decrease the effectiveness of stress remedies such as IHSI. Therefore, it has become common practice to evaluate these stresses in systems with relatively large numbers of overlays, to assure that they remain within reasonable bounds. This is done for flawed and unflawed weld locations as discussed below.

Unflawed Locations

At unflawed locations, the stress imposed by shrinkage will combine with existing applied and residual stresses to determine susceptibility to crack initiation, e.g., by the IGSCC mechanism. In the case of weld locations which have not received residual stress mitigation (e.g., with IHSI) the pre-existing inside surface tensile residual stresses may combine with the tensile component of stress due to shrinkage to make the location very susceptible to crack initiation. Even if the location has been treated with IHSI, the superposition of the tensile stress due to shrinkage on the IHSI residual stress pattern will tend to reduce the effectiveness of IHSI in inhibiting crack initiation. The shrinkage stresses at such locations are tabulated and compared to the expected ID surface compressive stresses due to IHSI, to assess the potential effect of the overlays on unflawed welds.

Flawed Locations

At unoverlayed flawed weld locations, similar effects to those on unflawed locations will be experienced. The tensile stress superimposed on the location's stress field may make the location more prone to further crack initiation. In addition, the shrinkage stress may act in concert with applied and residual stresses to promote further crack propagation and to increase the rate of that growth. To evaluate this effect, stresses due to weld overlay shrinkage are added to applied and residual stresses in performing crack growth calculations to demonstrate acceptability of an existing flaw without repair.

Such evaluations are not required for flawed location which have been weld overlay repaired, since it is generally believed that the residual stress benefits of the weld overlay will overwhelm the global shrinkage effects, and since the design basis for the overlay is a 360° through-wall crack in the original weldment and

the overlay itself is highly resistant to IGSCC, even in the presence of tensile stresses.

5.2 Weld Overlay Shrinkage

In order to predict the magnitude of the stresses resulting from weld overlay shrinkage, it is necessary to measure or estimate the amount of shrinkage which occurred during the weld overlay application process. This was done manually at Hatch Unit 1. First, the design length of each weld overlay was "laid out" on the weld to be repaired. The centerline of the existing butt weld was determined, and the design length of the design overlay in each direction (upstream and downstream of the weld centerline) was marked on the pipe using punch marks at several azimuthal locations. An additional set of marks was placed approximately 1/2" to 1" beyond each end of the design overlay length, typically at 4 azimuthal locations separated by 90°. This latter set of 8 punch markings (4 on each end of the overlay region) was used to determine shrinkage.

The distance between each azimuthal pair (upstream-downstream) of punch marks was measured using a vernier caliper (see Figure 5-3). The weld overlay was then applied between the inner set of markings, which define design length. Following the completion of overlay welding, the distance between the outside set of punch marks was again measured with vernier calipers. The difference between the before and after welding measurements for each azimuthal location was tabulated, and the four differences were averaged. The average values from these measurements for each overlay are tabulated as the weld overlay axial shrinkage in Table 5-1, and were used as input into the analysis discussed below to determine shrinkage-induced stress at all unoverlayed locations in the recirculation system.

5.3 Analysis of Weld Overlay Shrinkage Stresses

5.3.1 Background

As pointed out earlier, the stresses produced by weld overlay shrinkage are not confined to the vicinity of the repair, but rather can affect remote locations. Consequently, it is necessary to consider the system as a whole, and to consider all overlay repairs, in determining the stresses which will result from overlay shrinkage.

The analytical approach used in this evaluation includes preparation of a finite element model of the entire piping system. A typical model is shown in Figure 5-4. The actual weld overlay shrinkages measured at the repair sites are input at the nodes corresponding to repaired welds in the form of "cold elements", which simulate the mechanical shrinkage observed in the field through use of negative pseudo-thermal expansion. Mechanical anchors and rigid restraints are built into the model, as appropriate for the piping support system, but no other loads are included.

After preparation of the above model, the stresses at all points in the system are calculated elastically. Because the stress at welds is of concern to IGSCC (rather than within components), all stress indices are set equal to 1.0. Also, in combining axial and bending stresses, absolute summation is used.

Typically, stresses calculated in the above manner for piping larger than 12" are rarely larger than 1 ksi. However, it is not unusual to see stresses in the 12" risers which are predicted to be in the vicinity of 15-20 ksi or larger. The highest stressed locations are almost always at the junction of riser to inlet nozzle and occasionally at the junction of riser to ring header.

There are several conservatisms in the above type of analysis. First of all, since the stress is elastically calculated, stresses may be overpredicted. Refining the approach to include consideration of the true material stress-strain behavior would give more reasonable results. Secondly, nozzles are typically modeled as rigid and the flexibility of elbows and other components may be underpredicted.

5.3.2 Modeling Details

The ALGOR SUPERSAP finite element computer program [13] was used to calculate the piping stresses due to weld overlay shrinkage in the recirculation system. Figures 5-5 and 5-6 present the model with element numbers and node numbers. Since loop A and loop B of the recirculation system are mirror images of each other, the same model was applied to analyze the shrinkage effect for both loops.

The actual weld overlay shrinkages measured at the repair sites as summarized in Table 5-1, were input at the nodes corresponding to repair welds in the form of "cold elements". This approach is used to simulate the mechanical shrinkage observed in the field through the use of negative pseudo-thermal expansion. Temperature differences at the cold element were calculated as:

$$\Delta T = \frac{\delta}{\alpha L} \tag{1}$$

where ΔT is the temperature difference from the reference temperature at the cold element, δ is the as-built weld overlay shrinkage, α is the coefficient of thermal expansion, and L is the length of the weld overlay element.

For boundary conditions, all nozzles are assumed to be rigidly anchored. Also, support is not included in the model at the location of the recirculation pump.

5.3.3 Results

Resulting shrinkage stresses in the Hatch Unit 1 recirculation system welds are summarized in Tables 5-2 and 5-3. From these tables, it is seen that shrinkage stresses in the unrepaired welds are small in the 28-inch welds, (less than 2 ksi). Shrinkage stresses in the 22-inch ring header are also less than 2 ksi. The highest shrinkage stress is in the riser welds. The highest stress is 13.26 ksi in the 'C' riser and 12.12 ksi in the 'H' riser at the cross on the ring header.

5.4 Evaluation of Shrinkage Stress Effects

Because of the design basis assumption of a 360° through-wall flaw used for all overlay designs, as discussed in Section 4 of this report, the above shrinkage stresses will have no effect on the weld overlay designs. They are secor ˘ ry stresses and thus the application of high toughness weld metal eliminates any low toughness concern which would require their inclusion in weld overlay design. Also because of the relatively small magnitude of shrinkage stresses in all unoverlayed welds, and the application of IHSI at Hatch Unit 1, the effects of weld overlay shrinkage on uncracked welds are not considered significant.

There are three Category F welds in the recirculation system (12AR-G-4, 12BR-A-4 and 12BR-E-4) which were found to have circumferential cracks in the 1985/86 outage. All three of these welds had stress improvement by IHSI in that outage. They were reinspected in the current outage and found to contain no change in the indications observed in 1985/86.

The total service stresses, including the revised shrinkage stresses in these three welds are listed in Table 5-4. Flaw evaluation for these three welds was redone to reflect the new shrinkage stress values, and is reported in Appendix C. This analysis uses the same methodology and criteria as was used in 1986 to evaluate the flaw indications, including taking credit for IHSI in the crack growth evaluation. The revised evaluation shows that the new shrinkage stresses do not alter the results of the evaluation. One other flawed weld (20B-D-4) located on the RHR suction was unaffected by the revised shrinkage stress analysis. The flaw evaluation for this weld is therefore the same as that performed during the 1985/86 outage [2].

Table 5-1

Summary of the As-Built Weld Overlay Shrinkage

Weld Number	WOL Length (in.)	Pre-1990 Outage Shrinkage (in.)	1990 Outage Shrinkage (in.)
12AR-F-2	3.82	0.146	
12AR-F-3	4.19	0.276	
12AR-F-4	4.53	0.335	
12AR-G-3	4.52	0.259	
12AR-H-2	3.81	0.141	
12AR-H-3	4.47	0.348	
12AR-H-4	4.41	0.391	
12AR-J-3	4.19	0.256	
12AR-K-2	4.76	0.228	
12AR-K-3	4.28	0.365	
12BR-B-3	4.00	0.329	
12BR-C-2	4.07	0.156	
12BR-C-3	3.72	0.344	
12BR-C-4	4.13	0.317	
12BR-D-2	4.32	0.332	
12BR-D-3	4.25	0.330	
12BR-E-2	3.98	0.158	
12BR-E-3	4.08	0.287	
22AM-1	6.33	0.014	
22AM-4	6.75	0.000	
22BM-1	7.78	0.013	
22BM-4	6.64	0.039	
28A-2	7.60		0.0425
28A-4	7.88		0.1775
28A-6	7.61		0.0900
28A-7	4.20		0.0698
28A-8	5.31		0.0875
28A-10	4.64	0.036	
28A-12	5.00	0.066	
28A-14	7.20		0.3625
28B-3	6.15	0.091	
28B-4	5.97	0.058	
28B-8	4.60		0.0163
28B-9	4.75		0.2325
28B-10	7.60		0.2893
28B-11	4.72	0.089	
28B-13	4.35		0.1158
28B-14	4.79		-0.0150 (1)
28B-15	8.31		-0.2300 (1)
28B-16	5.00	0.046	

(1) Average measured value indicated growth after weld overlay repair. A value of zero was conservatively used in shrinkage stress analysis.

Table 5-2

Recirculation Loop A Weld Shrinkage Stress

Weld Number	Stress (ksi)	Weld Number	Stress (ksi)
28A-1	0.13	12AR-F-1	6.98
28A-2	--	12AR-F-2	--
28A-3	0.09	12AR-F-3	--
28A-4	--	12AR-F-4	--
28A-5	0.13	12AR-F-5	2.54
28A-5A	0.25	12AR-G-1	5.40
28A-6	--	12AR-G-2	4.18
28A-7	--	12AR-G-3	--
28A-8	--	12AR-G-4	5.97
28A-9	0.21	12AR-G-5	7.22
28A-10	--	12AR-H-1	12.12
28A-11	0.078	12AR-H-2	--
28A-12	--	12AR-H-3	--
28A-13	0.23	12AR-H-4	--
28A-14	--	12AR-H-5	7.52
28A-15	0.47	12AR-J-1	4.22
28A-16	0.5	12AR-J-2	4.19
28A-17	1.56	12AR-J-3	--
22AM-1	--	12AR-J-4	7.18
22AM-2	1.66	12AR-J-5	8.54
22AM-3	1.07	12AR-K-1	4.87
22AM-4	--	12AR-K-2	--
		12AR-K-3	--
		12AR-K-4	2.91
		12AR-K-5	3.64

Table 5-3

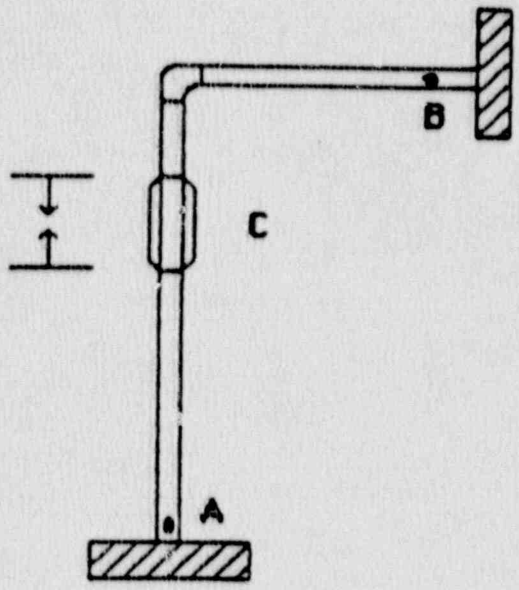
Recirculation Loop B Weld Shrinkage Stress

Weld Number	Stress (ksi)	Weld Number	Stress (ksi)
28B-1	0.17	12BR-A-1	5.84
28B-2	0.17	12BR-A-2	1.19
28B-3	--	12BR-A-3	0.69
28B-4	--	12BR-A-4	1.97
28B-5	0.94	12BR-A-5	2.29
28B-6	0.86	12BR-B-1	5.68
28B-7	0.36	12BR-B-2	2.08
28B-8	--	12BR-B-3	--
28B-9	--	12BR-B-4	5.53
28B-10	--	12BR-B-5	6.44
28B-11	--	12BR-C-1	13.26
28B-12	0.36	12BR-C-2	--
28B-13	--	12BR-C-3	--
28B-14	--	12BR-C-4	--
28B-15	--	12BR-C-5	--
28B-16	--	12BR-D-1	5.51
28B-17	0.58	12BR-D-2	--
28B-18	1.6[illegible]	12BR-D-3	--
22BM-1	--	12BR-D-4	5.60
22BM-2	1.48	12BR-D-5	6.51
22BM-3	1.11	12BR-E-1	8.48
22BM-4	--	12BR-E-2	--
		12BR-E-3	--
		12BR-E-4	6.4
		12BR-E-5	--

Table 5-4

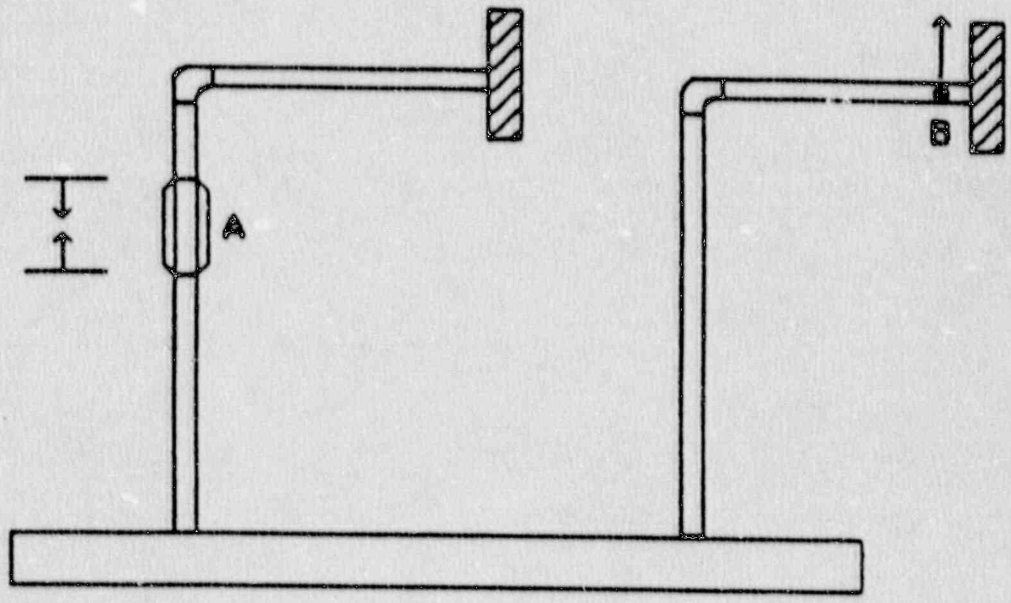
Service Stresses in Unoverlayed, Flawed Welds

Weld Number	Nominal Thickness (in.)	Press. (ksi)	DW (ksi)	Thermal (ksi)	Shrk. (ksi)	Total (ksi)
12AR-G-4	0.693	6.67	0.21	6.28	5.97	19.13
12BR-A-4	0.693	6.67	1.44	7.41	1.97	17.49
12BR-E-4	0.693	6.67	1.45	7.42	6.40	21.94



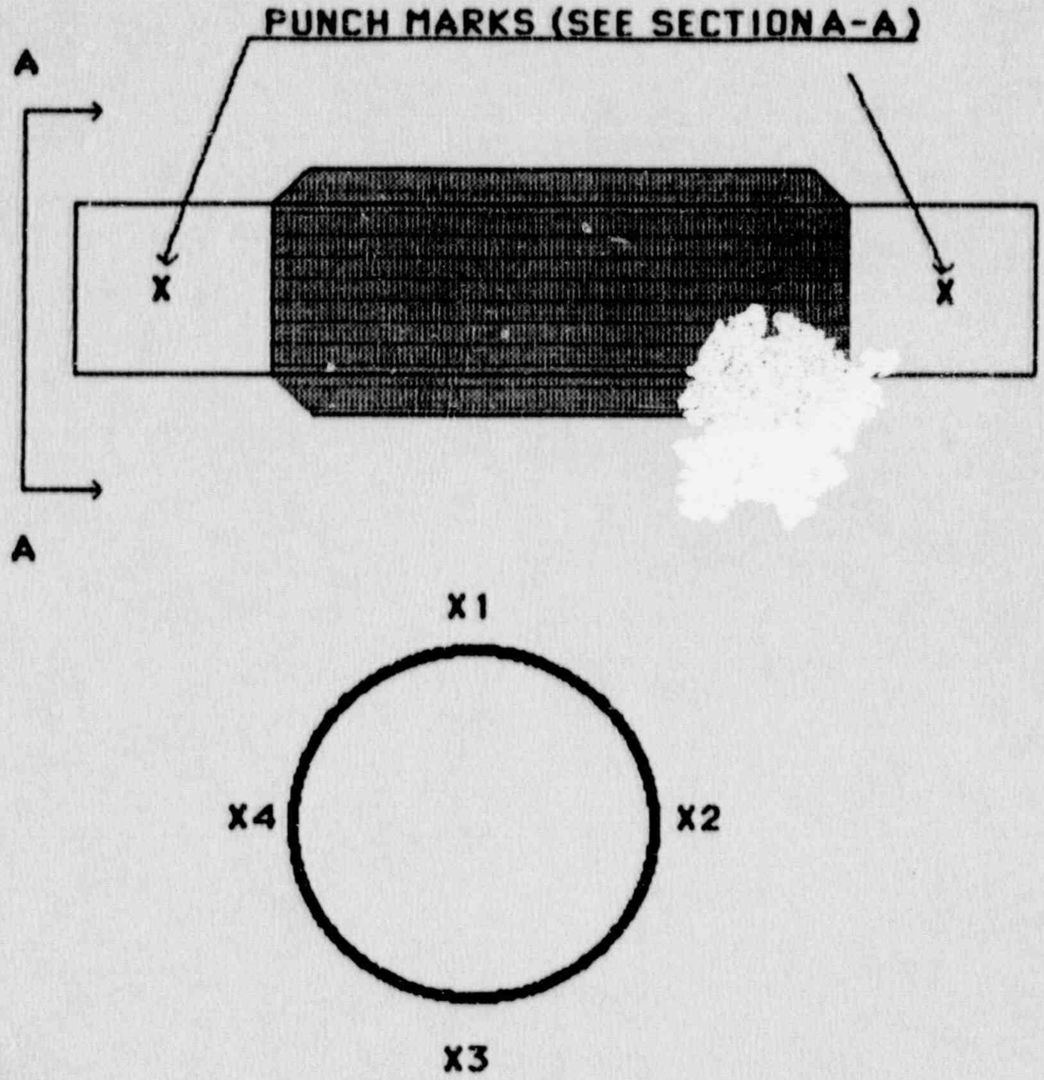
WELD OVERLAY SHRINKAGE AT C PRODUCES
TENSILE STRESS AT A
BENDING STRESS AT B

Figure 5-1. Remote Effects of Weld Overlay Shrinkage



WELD SHRINKAGE AT A PRODUCES
UPWARD BENDING AT B

Figure 5-2. Effects of Weld Overlay Shrinkage On Parallel Piping



SECTION A-A
PUNCH MARKS AT 4 AZIMUTHAL LOCATIONS
(90° APART)

1. PLACE PUNCH MARKS BEFORE BEGINNING WELDING.
2. MEASURE DISTANCE BETWEEN EACH PAIR (UPSTREAM/DOWNSTREAM) OF MARKS BEFORE AND AFTER WELDING

Figure 5-3. Measurement of Weld Overlay Shrinkage

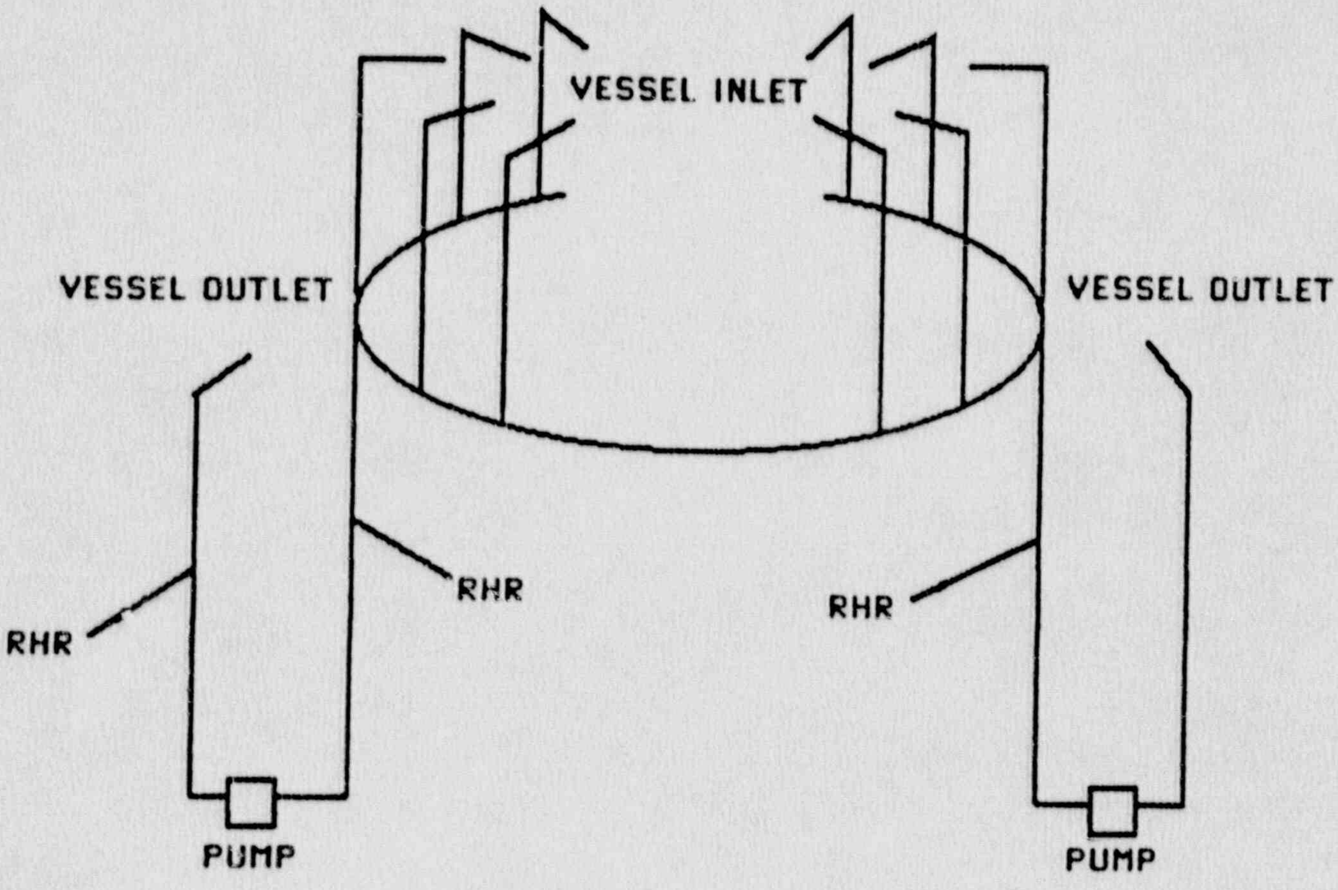


Figure 5-4. Typical Schematic Model of BWR Recirculation System

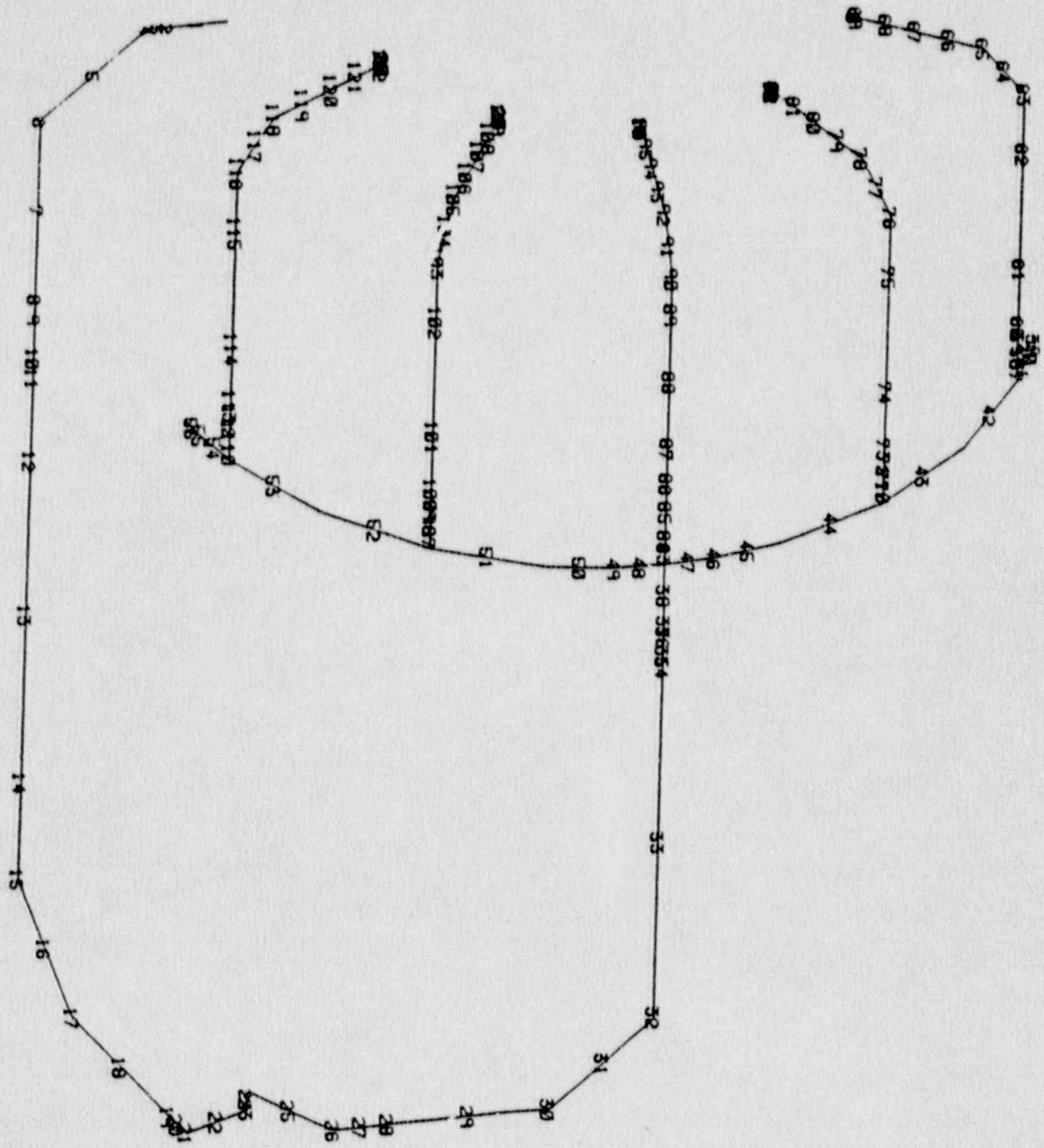


Figure 5-5. Finite Element Model of the Recirculation System Piping - Hatch Unit 1 (Element Numbers)

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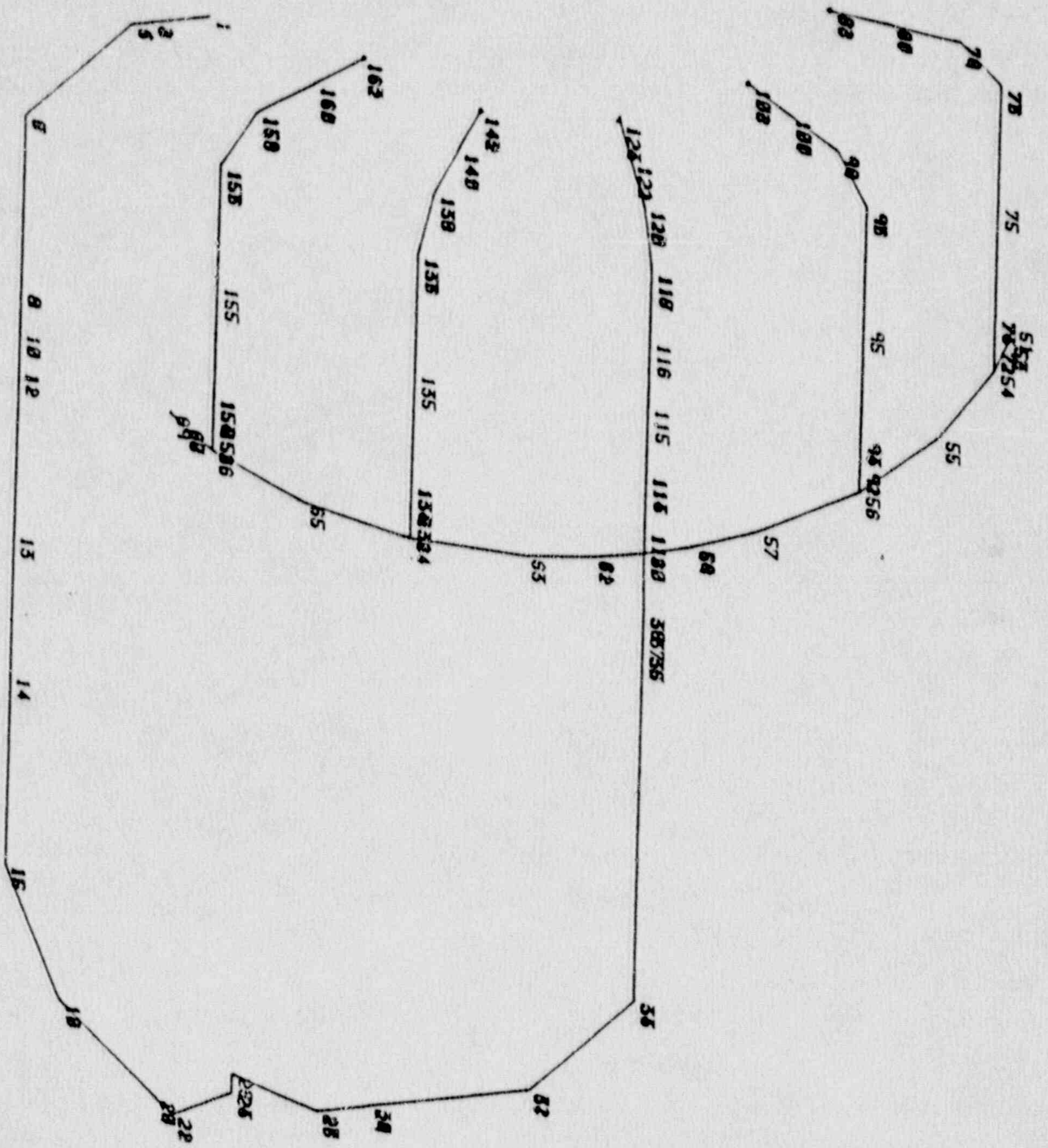

Figure 5-6. Finite Element Model of the Recirculation System Piping - Hatch Unit 1 (Node Numbers)

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6.0 SUMMARY AND CONCLUSIONS

Ultrasonic (UT) examinations performed at Hatch Unit 1 during the 1990 outage identified flaws judged to be IGSCC in the vicinity of sixteen piping welds. Of these sixteen flawed welds, twelve were on the 28-inch recirculation piping system, three were on the 12-inch risers and one was on the RHR system. IGSCC in nine of these flawed welds have been detected in previous outages and hence, seven new flawed welds were identified during the 1990 outage. All seven of the new flawed welds were located in the 28-inch recirculation piping.

The twelve 28-inch flawed welds were repaired using weld overlays leaving four unrepaired flawed welds at Hatch Unit 1. All the overlays were designed as standard overlays per the requirements of NUREG-0313, Rev. 2. A comparison of the as-built and designed overlay dimensions indicates that all the as-built dimensions exceed the design dimensions. The addition of these twelve overlay repairs brings the total number of IGSCC-related overlays at Hatch Unit 1 to 46 at the end of the 1990 outage. Two other overlays at Hatch Unit 1 are not IGSCC-related.

UT examinations were also performed on pre-1990 overlays as well as the overlays applied during the 1990 outage. There was no evidence of cracks propagating into the overlays. Small indications identified in some of these overlays were mainly due to lack of fusion between weld beads during the repair process and were not connected to the original design basis flaws. One weld overlay, containing weld related defects, had a metallurgical sample removed to confirm the size and distribution of these non-relevant defects. The remainder of these flaws were evaluated per the requirements of ASME Section XI and were found to be acceptable, indicating that all overlays at Hatch Unit 1 to be adequate.

The axial shrinkage resulting from the application of the weld overlays during the 1990 outage was added to previously measured shrinkage from prior outages and the results were used to perform a shrinkage analysis of the recirculation system. The shrinkage stresses obtained from this evaluation were found to have increased only slightly from those calculated from previous analysis. The shrinkage stresses were added to other service stresses to perform a "flawed pipe" evaluation of the four unrepaired flawed welds at Hatch Unit 1. The evaluation showed that the service stresses at these flawed weld locations are changed only slightly from the results reported earlier and hence no crack growth is predicted at these locations. These welds received induction heating stress improvement (IHSI) during the 1985/86 outage and since then, the flaws have not shown any growth. These welds were therefore returned to service without any additional mitigation.

In summary, all flawed welds identified at Hatch Unit 1 have been evaluated by ASME Section XI and NUREG-0313, Rev. 2, and determined to be acceptable for long term, continued operation.

7.0 REFERENCES

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2. SIR-86-002, "Evaluation of IGSCC Flaw Indications and Weld Overlay Designs for Plant E. I. Hatch Unit 1 - Fall 1985/86 Maintenance/Refueling Outage," Revision 2, Structural Integrity Associates, April 1986.

3. SIR-87-014, "Flaw Evaluation and Repair Design for Plant E. I. Hatch Unit 1 - Spring 1987 Outage," Revision 1, Structural Integrity Associates, June 1987.

4. SIR-88-036, "Plant Hatch Unit 1 - Transmittal of Recirculation Inlet Safe End Weld Overlay Design Packages," Revision 0, Structural Integrity Associates, November 1988.

5. American Society of Mechanical Engineers Boiler & Pressure Vessel Code, Section XI, 1986 Edition Including All Addenda.

6. General Electric Company, "Results of Seismic Evaluation, As-Built Recirculation Piping Including Replacement Actuator for F031 Discharge Valve", Design Memo 170-113, dated September 26, 1984.

7. Structural Integrity Associates Computer Program, pc-CRACK, Version 2.0 dated April, 1989.

8. Babcock & Wilcox, "Laboratory Examination of a Weld Overlay from the Edwin I. Hatch Nuclear Station", RDD:91:5194-01:01, May 1990.

9. EPRI Topical Report, Research Project T303-1, "Technical Justification For Extended Weld Overlay Design Life", May, 1987.

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11. ASTM Special Technical Publication 756, "Stainless Steel Castings", Prepared By General Electric Company For ASTM, American Society For Testing and Materials, 1982, pp. 26-47.

12. American Society Mechanical Engineers, Boiler and Pressure Vessel Code, Section III, 1986 Edition Including All Addenda.

13. Algor Interactive Systems, Inc., SUPERSAP Computer Software, Version 9.000, July 1989.

APPENDIX A

UT Inspection Results

WELD NO.: 1B31-1RC-28A-2

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.213"

	UPSTREAM	DOWNSTREAM
CONFIGURATION:	SAFE END	PIPE

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (%)	ORIENT.	LOCATION	DISPOSITION
1988	0.90	22	CIRC.	SAFE END	LEAVE AS-IS
	5.20	14	CIRC.	SAFE END	
	1.25	19	CIRC.	PIPE SIDE	
1990	0.80	25	CIRC.	SAFE END	STANDARD OVERLAY APPLIED
	5.50	37	CIRC.	SAFE END	
	1.25	15	CIRC.	PIPE SIDE	
	4.00	19	CIRC.	PIPE SIDE	

WELD NO.: 1B31-1RC-28A-4

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.213"

	UPSTREAM	DOWNSTREAM
CONFIGURATION:	ELBOW	PIPE

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (IN.)	ORIENT.	LOCATION	DISPOSITION
1988	SPOT	0.10	AXIAL	PIPE SIDE	LEAVE AS-IS
	0.36	0.12	AXIAL	PIPE SIDE	
	SPOT	0.07	AXIAL	ELBOW SIDE	
	SPOT	0.09	AXIAL	PIPE SIDE	
	SPOT	0.12	AXIAL	PIPE SIDE	
	SPOT	0.12	AXIAL	PIPE SIDE	
	0.20	0.11	AXIAL	PIPE SIDE	
1990	0.10	0.25	AXIAL	PIPE SIDE	STANDARD OVERLAY APPLIED
	0.15	0.22	AXIAL	PIPE SIDE	
	0.15	0.25	AXIAL	ELBOW SIDE	
	0.15	0.32	AXIAL	PIPE SIDE	
	0.15	0.33	AXIAL	PIPE SIDE	
	0.20	0.24	AXIAL	PIPE SIDE	
	0.15	0.20	AXIAL	PIPE SIDE	
	6.85	0.25	CIRC.	PIPE SIDE	
	5.00	0.22	CIRC.	PIPE SIDE	
	0.15	0.15	AXIAL	PIPE SIDE	
	6.50	0.30	CIRC.	PIPE SIDE	
	3.25	0.70	CIRC.	PIPE SIDE	

WELD NO.: 1B31-1RC-28A-6

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.213"

	UPSTREAM	DOWNSTREAM
CONFIGURATION:	PIPE	ELBOW

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (%)	ORIENT.	LOCATION	DISPOSITION
1988	0.60	11	AXIAL	ELBOW SIDE	LEAVE AS-IS
	0.65	9	AXIAL	ELBOW SIDE	
	1.00	22	AXIAL	ELBOW SIDE	
1990	0.60	9	AXIAL	ELBOW SIDE	STANDARD OVERLAY APPLIED
	0.70	12	AXIAL	ELBOW SIDE	
	0.95	24	AXIAL	ELBOW SIDE	
	1.75	10	CIRC.	PIPE SIDE	
	2.20	17	CIRC.	PIPE SIDE	
	1.20	9	CIRC.	PIPE SIDE	
	4.70	12	CIRC.	ELBOW SIDE	

WELD NO.: 1B31-1RC-28A-7

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.213"

	UPSTREAM	DOWNSTREAM
CONFIGURATION:	ELBOW	VALVE

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (IN.)	ORIENT.	LOCATION	DISPOSITION
PRIOR TO 1990	NO REPORTABLE INDICATIONS				NONE REQUIRED
1990	4.90	0.72	CIRC.	ELBOW SIDE	STANDARD OVERLAY APPLIED
	0.25	0.41	AXIAL	ELBOW SIDE	

WELD NO.: 1B31-1RC-28A-8

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.213"

	UPSTREAM	DOWNSTREAM
CONFIGURATION:	VALVE	PIPE

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (IN.)	ORIENT.	LOCATION	DISPOSITION
PRIOR TO 1990	NO REPORTABLE INDICATIONS				NONE REQUIRED
1990	0.70	0.18	AXIAL	PIPE SIDE	STA: 'DARD OVERLAY APPLIED
	1.00	0.10	AXIAL	PIPE SIDE	
	1.00	0.12	AXIAL	PIPE SIDE	
	13.00	0.45	CIRC.	PIPE SIDE	

WELD NO.: 1B31-1RC-28A-14

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.390

	UPSTREAM	DOWNSTREAM
CONFIGURATION:	ELBOW	PIPE

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (%)	ORIENT.	LOCATION	DISPOSITION
PRIOR TO 1990	NO REPORTABLE INDICATIONS				NONE REQUIRED
1990	0.98	29	AXIAL	ELBOW SIDE	STANDARD OVERLAY APPLIED
	0.84	29	AXIAL	ELBOW SIDE	
	0.77	37	AXIAL	ELBOW SIDE	
	0.77	26	AXIAL	ELBOW SIDE	
	0.42	30	AXIAL	ELBOW SIDE	
	0.84	27	AXIAL	ELBOW SIDE	
	0.56	15	AXIAL	ELBOW SIDE	
	0.28	26	AXIAL	ELBOW SIDE	
	0.56	34	AXIAL	ELBOW SIDE	

WELD NO.: 1B31-1RC-28B-8

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.213"

	UPSTREAM	DOWNSTREAM
CONFIGURATION:	ELBOW	VALVE

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (IN.)	ORIENT.	LOCATION	DISPOSITION
1988	0.25	0.20	AXIAL	ELBOW	LEAVE AS-IS
	0.25	0.22	AXIAL	ELBOW	
1990	0.20	0.45	AXIAL	ELBOW SIDE	STANDARD OVERLAY APPLIED
	0.25	0.30	AXIAL	ELBOW SIDE	
	0.20	0.30	AXIAL	ELBOW SIDE	
	0.15	0.85	AXIAL	ELBOW SIDE	
	0.80	0.36	AXIAL	ELBOW SIDE	
	0.15	0.65	AXIAL	ELBOW SIDE	
	0.15	0.46	AXIAL	ELBOW SIDE	
	0.60	0.30	CIRC.	ELBOW SIDE	

WELD NO.: 1B31-1RC-28B-9

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.213"

	UPSTREAM	DOWNSTREAM
CONFIGURATION:	VALVE	PIPE

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (%)	ORIENT.	LOCATION	DISPOSITION
PRIOR TO 1990	NO REPORTABLE INDICATIONS				NONE REQUIRED
1990	4.00	37	CIRC.	PIPE SIDE	STANDARD OVERLAY APPLIED
	2.00	13	CIRC.	PIPE SIDE	
	6.00	25	CIRC.	PIPE SIDE	

WELD NO.: 1B31-1RC-28B-10

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.213"

	UPSTREAM	DOWNSTREAM
CONFIGURATION:	PIPE	ELBOW

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (IN.)	ORIENT.	LOCATION	DISPOSITION
1988	2.50	0.24	CIRC.	ELBOW SIDE	LEAVE AS-IS
	0.10	0.24	CIRC.	ELBOW SIDE	
	13.00	0.21	CIRC.	ELBOW SIDE	
	0.50	0.32	AXIAL	ELBOW SIDE	
	0.50	0.28	AXIAL	ELBOW SIDE	
1990	2.50	0.40	CIRC.	ELBOW SIDE	STANDARD OVERLAY APPLIED
	1.00	0.40	CIRC.	ELBOW SIDE	
	17.00	0.25	CIRC.	ELBOW SIDE	
	0.45	0.72	AXIAL	ELBOW SIDE	
	0.45	0.80	AXIAL	ELBOW SIDE	

WELD NO.:	1B31-1RC-28B-13	
NOM. PIPE SIZE:	28"	
NOM. PIPE THK.:	1.390"	
	UPSTREAM	DOWNSTREAM
CONFIGURATION:	PIPE	VALVE

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (%)	ORIENT.	LOCATION	DISPOSITION
PRIOR TO 1990	NO REPORTABLE INDICATIONS				NONE REQUIRED
1990	6.20	47	CIRC.	PIPE SIDE	STANDARD OVERLAY APPLIED

WELD NO.: 1B31-1RC-28B-14

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.390"

	UPSTREAM	DOWNSTREAM
CONFIGURATION:	VALVE	ELBOW

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (%)	ORIENT.	LOCATION	DISPOSITION
PRIOR TO 1990	NO REPORTABLE INDICATIONS				NONE REQUIRED
1990	15.00	24	CIRC.	ELBOW SIDE	STANDARD OVERLAY APPLIED
	5.00	28	CIRC.	ELBOW SIDE	
	0.60	24	AXIAL	ELBOW SIDE	
		38	AXIAL	ELBOW SIDE	
		26	AXIAL	ELBOW SIDE	

WELD NO.: 1B31-1RC-28B-15

NOM. PIPE SIZE: 28"
NOM. PIPE THK.: 1.390"

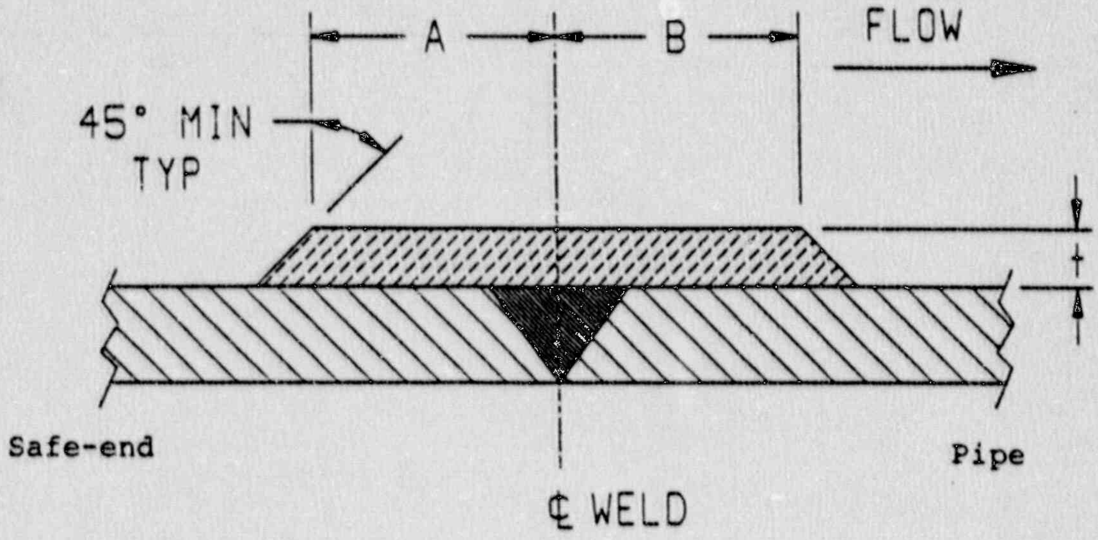
	UPSTREAM	DOWNSTREAM
CONFIGURATION:	ELBOW	PIPE

DESCRIPTION OF FLAWS

OUTAGE	LENGTH (IN.)	DEPTH (%)	ORIENT.	LOCATION	DISPOSITION
PRIOR TO 1990	NO REPORTABLE INDICATIONS				NONE REQUIRED
1990	0.70	61	CIRC.	ELBOW SIDE	STANDARD OVERLAY APPLIED
	1.70	55	CIRC.	ELBOW SIDE	
	18.50	55	CIRC.	ELBOW SIDE	
	12.40	66	CIRC.	ELBOW SIDE	
	11.60	61	CIRC.	ELBOW SIDE	
	1.10	62	CIRC.	ELBOW SIDE	
	28.00	64	CIRC.	ELBOW SIDE	
	1.70	55	CIRC.	PIPE SIDE	
	4.00	61	CIRC.	PIPE SIDE	
	65.20	68	CIRC.	PIPE SIDE	
	8.90	66	CIRC.	PIPE SIDE	

APPENDIX B

Weld Overlay Design Drawings



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28A-2	1)Circ 0.8" Long x 25% a/t 2)Circ 5.5" Long x 37% a/t 3)Circ 4" Long x 15% a/t 4)Circ 1 1/4" Long x 19% a/t	0.46"	3.20"	3.20"	

PREPARED BY: [signature]	DATE 6/25/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28A-2 (per NUREG-0313, Revision 2)
CHECKED BY: [signature]	DATE 6/25/90	

JOB NO: GPCO-18Q	PLANT / UNIT: Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.	REV 2
FILE NO: GPCO-18Q-301	DWG NO: GPCO-18Q-001		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.

2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

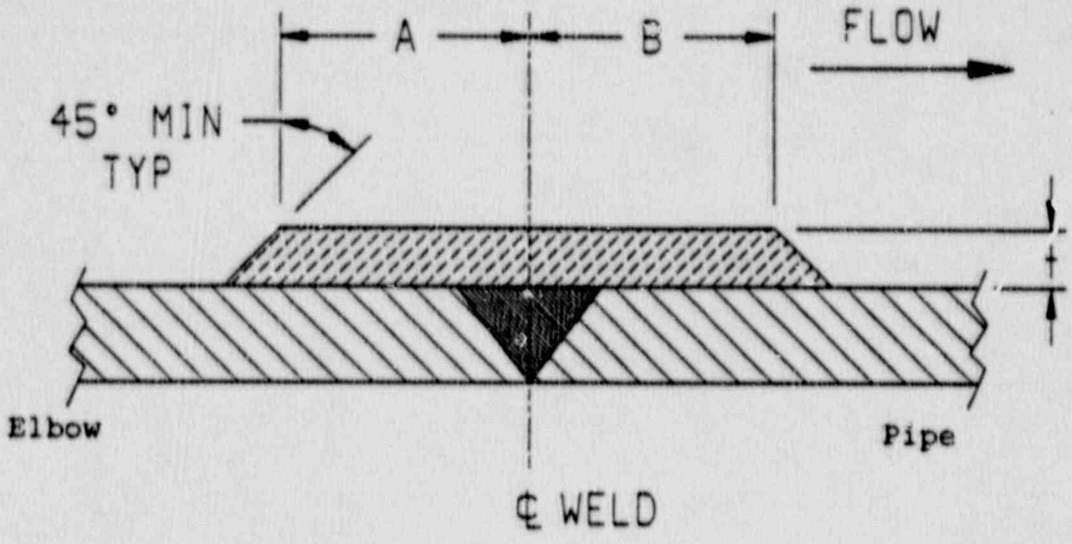
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.

5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28A-4	8 Axial Flaws Plus 1)Circ 6.85" Long x 19% a/t 2)Circ 5" Long x 17% a/t 3)Circ 6" Long x 23% a/t 4)Circ 3 1/4" Long x 54% a/t	0.45"	3.20"	3.20"	

PREPARED BY:	DATE 6/25/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28A-4 (per NUREG-0313, Revision 2)	
CHECKED BY:	DATE 6/25/90		
JOB NO: GPCO-18Q	PLANT / UNIT: Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES INC.	REV 2
FILE NO: GPCO-18Q-301	DWG NO: GPCO-18Q-002		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.

2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

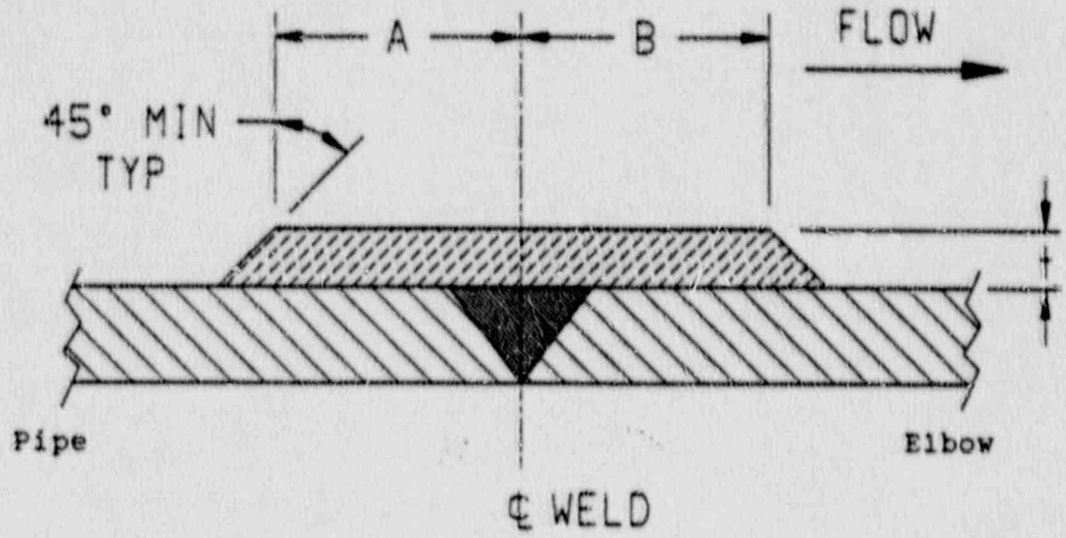
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.

5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28A-6	3 Axial Flaws plus 1)Circ. 1.75" long x 10% a/t 2)Circ. 2.2" long x 17% a/t 3)Circ. 1.2" long x 9% a/t 4)Circ. 4.7" long x 12% a/t	0.44"	3.10"	3.10"	

PREPARED BY: [signature]	DATE: /25/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28A-6 (per NUREG-0313, Revision 2)
CHECKED BY: H L Gustin	DATE: 6/25/90	

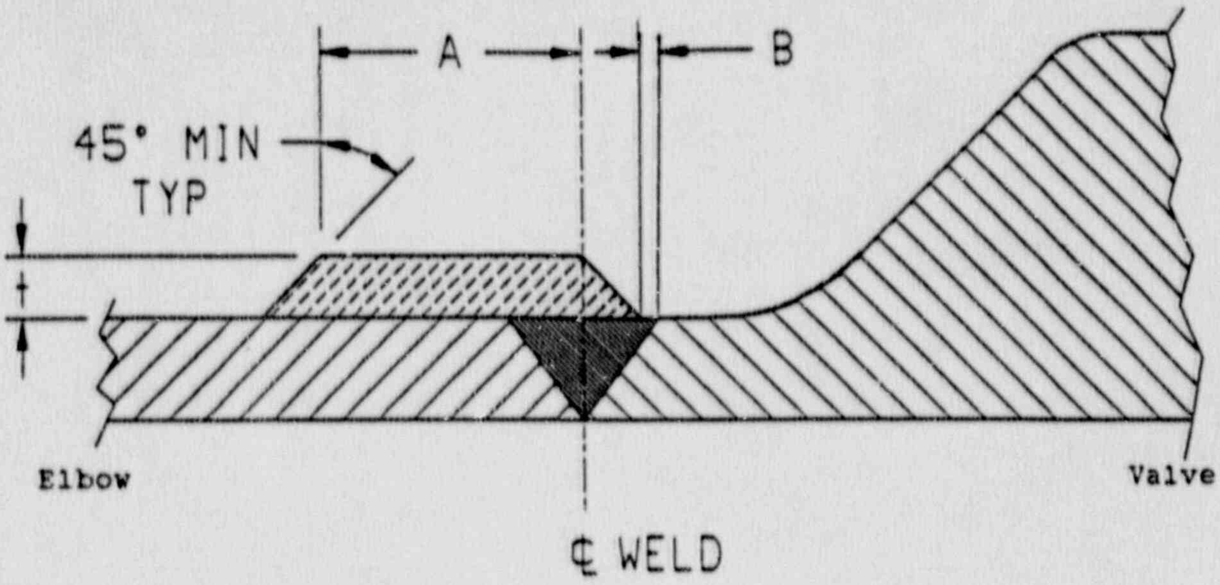
JOB NO: GPCO-18Q	PLANT / UNIT: Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.	REV 2
FILE NO: GPCO-18Q-302	DWG NO: GPCO-18Q-003		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.
2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.
4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.
5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.
6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

GPCO-18Q-003, Rev. 2, Page 2 of 2

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28B-8	7 Axial Flaws plus 1) Circ. 0.6" long x 25% a/t	0.44"	3.50"	≥0.125"	

PREPARED BY:	DATE	DESCRIPTION:
[signature]	6/25/90	Standard Weld Overlay Repair Design for Weld 1B31-1RC-28B-8 (per NUREG-0313, Revision 2)
CHECKED BY: [signature]	DATE 6/25/90	

JOB NO:	PLANT / UNIT:		REV
GPCO-18Q	Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.	2
FILE NO: GPCO-18Q-303	DWG NO: GPCO-18Q-004		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.

2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

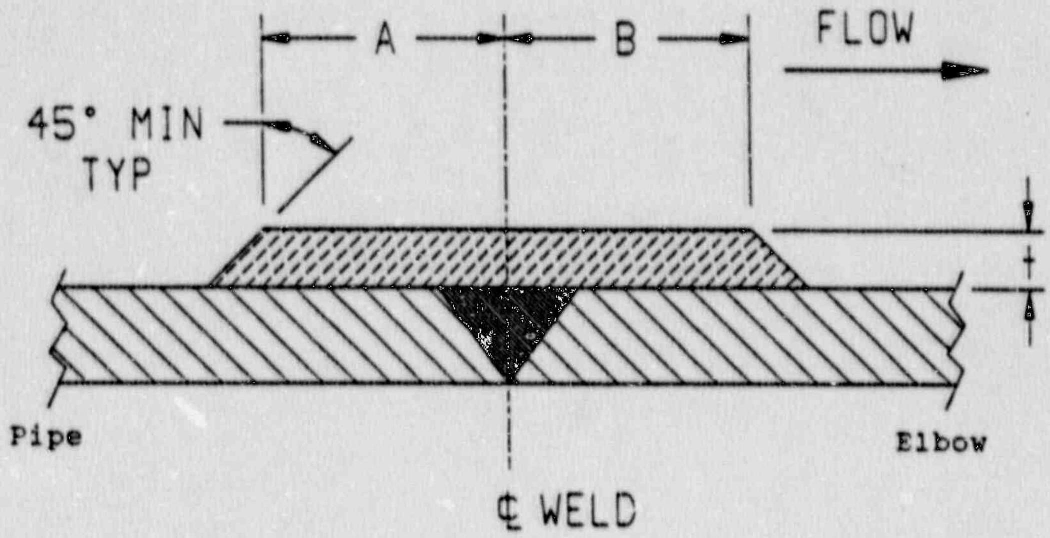
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.

5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28B-10	2 Axial Flaws plus 1) Circ 2.5" long x 33% a/t 2) Circ 1" long x 33% a/t 3) Circ 17" long x 21% a/t	0.44"	3.10"	3.10"	

PREPARED BY: [signature]	DATE 6/25/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28B-10 (per NUREG-0313, Revision 2)
CHECKED BY: [signature]	DATE 6/25/90	

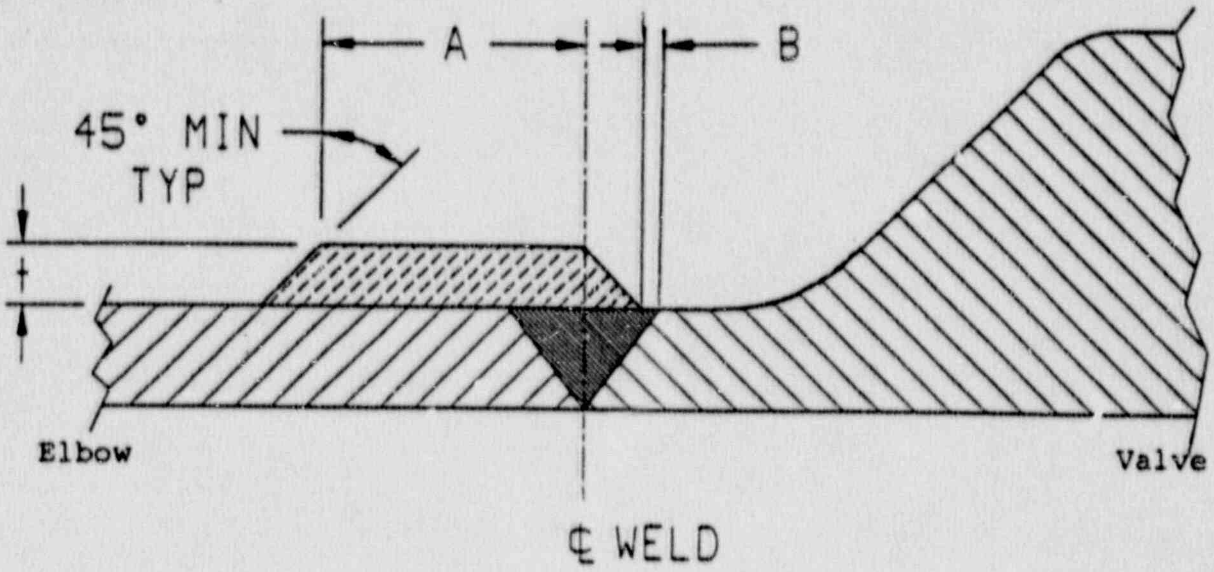
JOB NO: GPCO-18Q	PLANT / UNIT: Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.	REV 2
FILE NO: GPCO-18Q-303	DWG NO: GPCO-18Q-005		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.
2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.
4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.
5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.
6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

GPCO-18Q-005, Rev. 2, Page 2 of 2

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28A-7		0.49"	3.50"	≥0.125"	

PREPARED BY: [signature] DATE 6/25/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28A-7 (per NUREG-0313, Revision 2)
CHECKED BY: [signature] DATE 6/25/90	

JOB NO:	PLANT / UNIT:		REV
GPCO-18Q	Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.	2
FILE NO: GPCO-18Q-308	DWG NO: GPCO-18Q-010		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.

2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

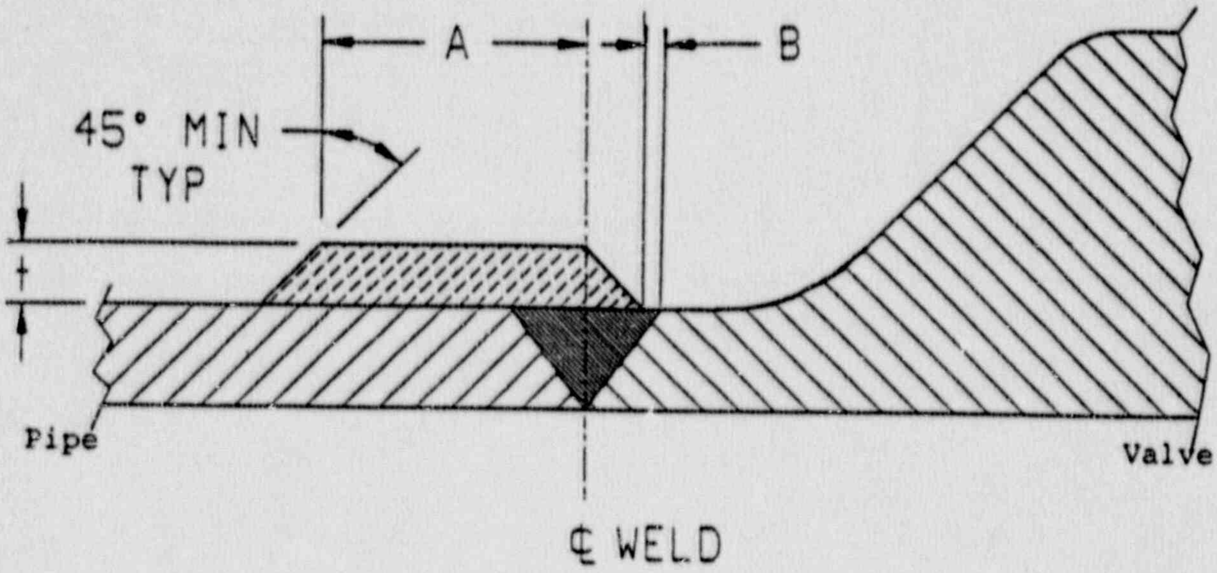
4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.

5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

GPCO-18Q-010, Rev. 2, Page 2 of 2

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28A-8		0.43"	3.50"	≥0.1[illegible]	

PREPARED BY: [signature]	DATE 6/2?/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28A-8 (per NUREG-0313, Revision 2)
CHECKED BY: [signature]	DATE 6/25/90	

JOB NO: GPCO-18Q	PLANT / UNIT: Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.	REV 2
FILE NO: GPCO-18Q-309	DWG NO: GPCO-18Q-011		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.

2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

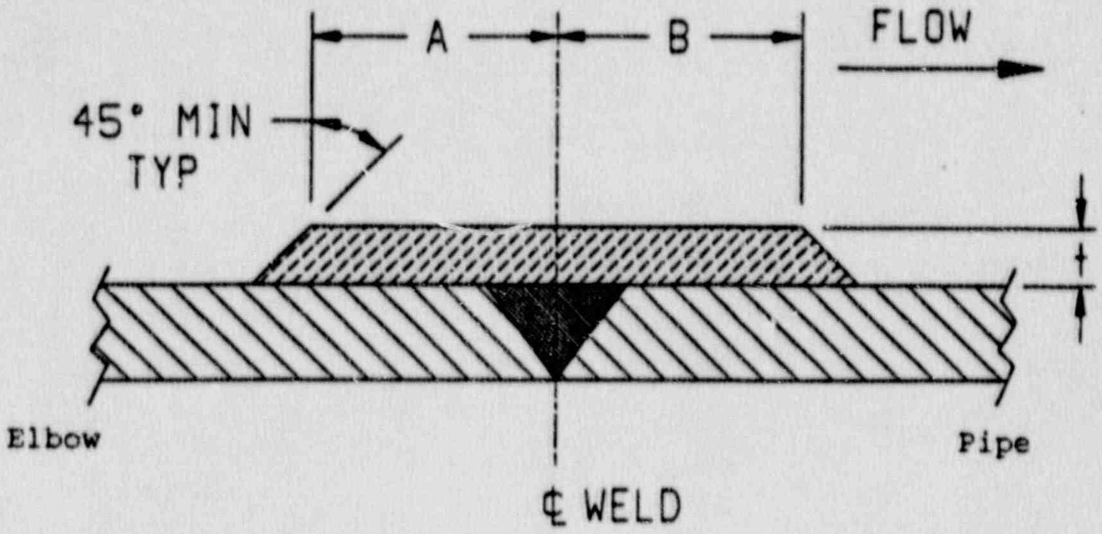
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.

5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28A-14		0.52"	3.35"	3.35"	

PREPARED BY: [signature]	DATE 4/16/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28A-14 (per NUREG-0313, Revision 2)
CHECKED BY: J.F. Copeland	DATE 4-16-90	

JOB NO: GPCO-18Q	PLANT / UNIT: Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES INC.	REV 1
FILE NO: GPCO-18Q-310	DWG NO: GPCO-18Q-012		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.

2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

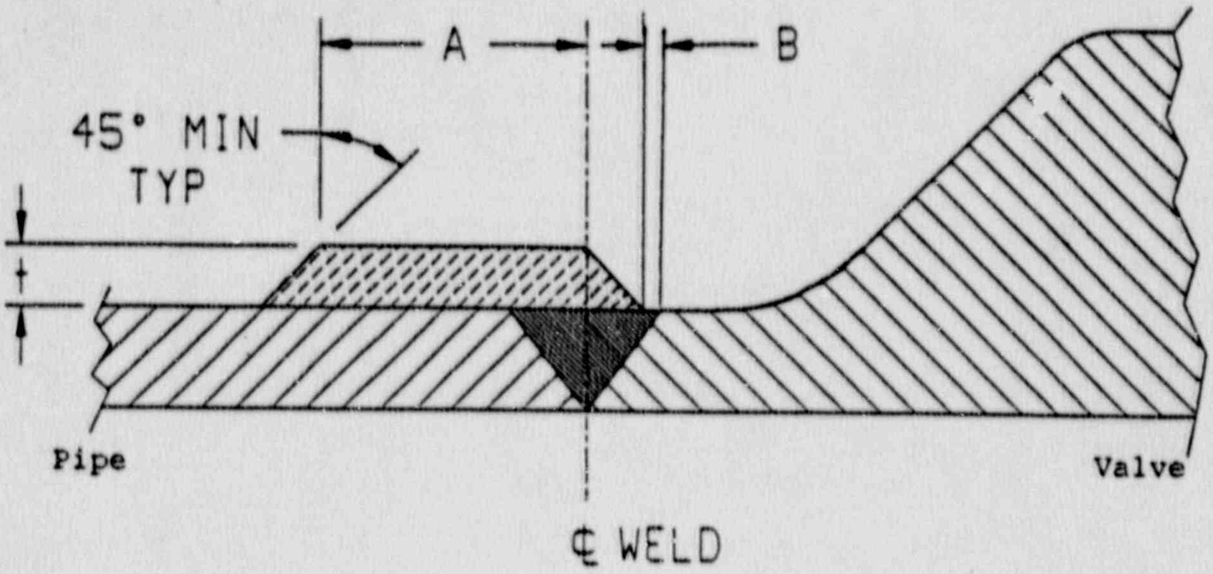
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.

5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28B-9		0.44"	3.5"	≥0.125"	

PREPARED BY: [signature]	DATE 4/16/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28B-9 (per NUREG-0313, Revision 2)
CHECKED BY: J.F. Copeland	DATE 4-16-90	

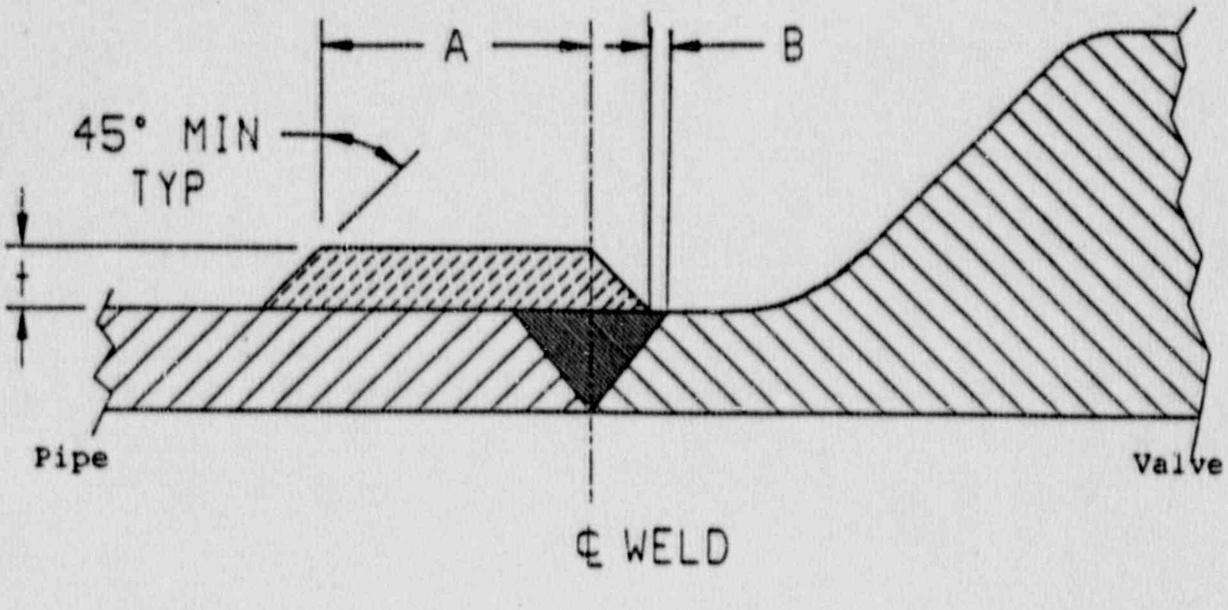
JOB NO:	PLANT / UNIT:		REV
GPCO-18Q	Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.	1
FILE NO: GPCO-18Q-311	DWG NO: GPCO-18Q-013		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.
2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.
4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.
5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.
6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

GPCO-18Q-013, Rev. 1, Page 2 of 2

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28B-13		0.52"	3.5"	≥0.125"	

PREPARED BY: [signature]	DATE: 4/16/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28B-13 (per NUREG-0313, Revision 2)
CHECKED BY: J.F. Copeland	DATE: 4-16-90	

JOB NO: GPCO-18Q	PLANT / UNIT: Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES, INC.	REV 1
FILE NO: GPCO-18Q-312	DWG NO: GPCO-18Q-014		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.

2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

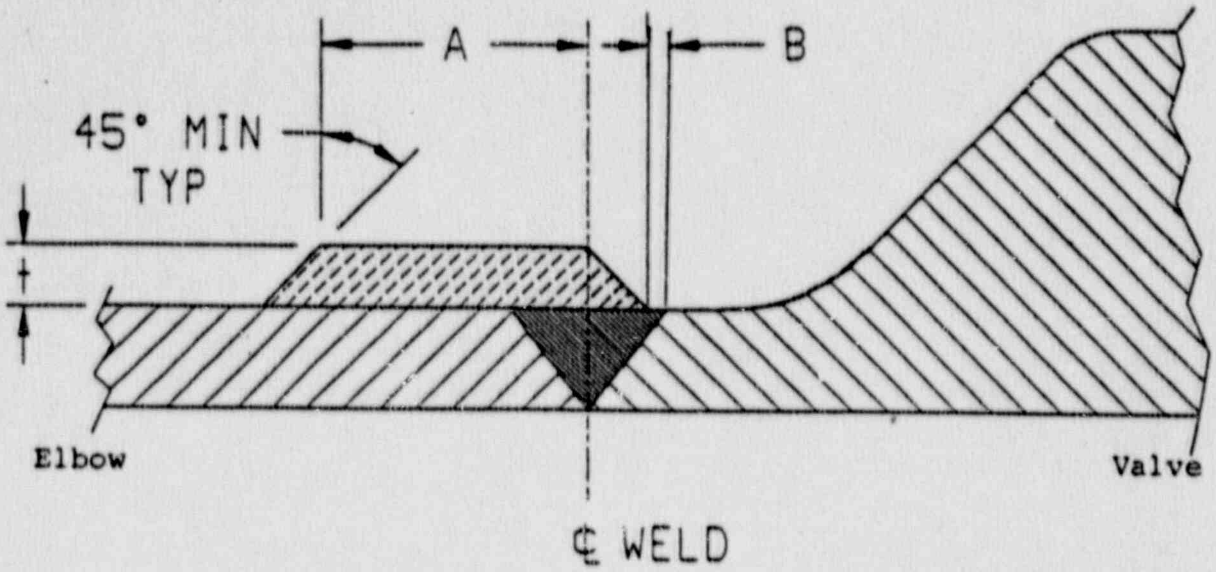
4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.

5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

GPCO-18Q-014, Rev. 1, Page 2 of 2

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28B-14		0.52"	3.5"	≥0.125"	

PREPARED BY: [signature]	DATE 4/16/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28B-14 (per NUREG-0313, Revision 2)
CHECKED BY: J. F. Copeland	DATE 4-16-90	

JOB NO: GPCO-18Q	PLANT / UNIT: Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES INC.	REV 1
FILE NO: GPCO-18Q-313	DWG NO: GPCO-18Q-015		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.

2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.

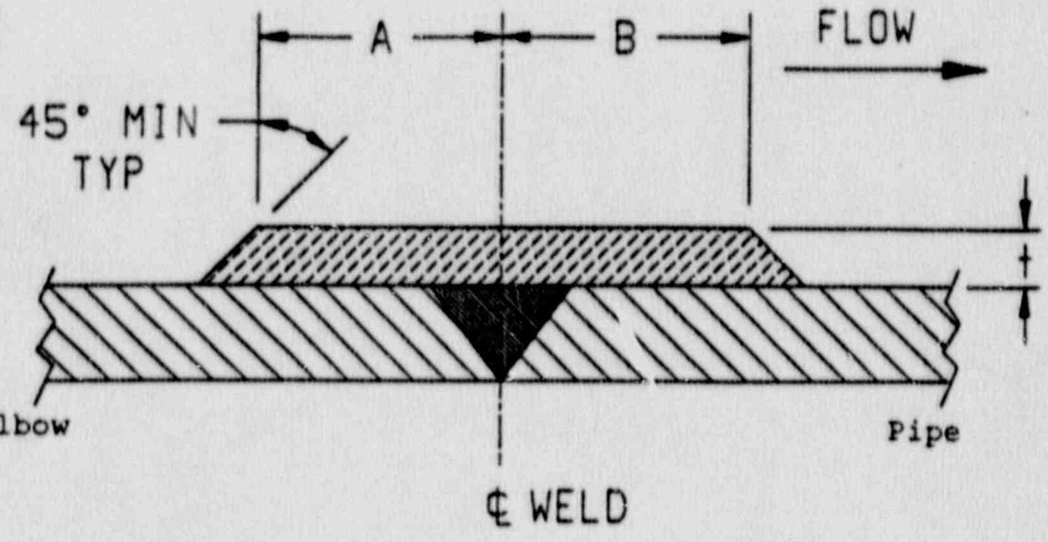
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.

4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.

5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.

6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

STRUCTURAL INTEGRITY ASSOCIATES, INC.



WELD OVERLAY

REPAIR DETAILS

WELD NUMBER	FLAW CHARACTERIZATION	DESIGN DIMENSIONS			COMMENTS
		t	A	B	
1B31-1RC-28B-15		0.52"	3.35"	3.35"	

PREPARED BY: [signature]	DATE 4/16/90	DESCRIPTION: Standard Weld Overlay Repair Design for Weld 1B31-1RC-28B-15 (per NUREG-0313, Revision 2)
CHECKED BY: J.F. Copeland	DATE 4-16-90	

JOB NO: GPCO-18Q	PLANT / UNIT: Georgia Power Plant Hatch Unit 1	STRUCTURAL INTEGRITY ASSOCIATES INC	REV 1
FILE NO: GPCO-18Q-314	DWG NO: GPCO-18Q-016		SHT 1 OF 2

NOTES

1. Weld overlay material is to be type 308L or equivalent, with as-deposited delta ferrite content greater than 7.5 FN.
2. Component surface is to be examined by dye penetrant method and accepted as clean prior to overlay application in order to include the entire deposited overlay thickness in meeting the design thickness requirement, per NUREG-0313, Revision 2.
3. In the event that the original component surface does not pass the note 2 requirements, the first deposited weld layer is to be examined by dye penetrant method and accepted as clean before proceeding with subsequent layers.
4. First weld layer is to have a measured delta ferrite content greater than 7.5 FN.
5. Design thickness includes no allowance for surface conditioning operations to facilitate UT inspections.
6. Design length is that required for structural reinforcement; greater length may be required for effective UT inspection. This is to be determined in the field.

GPCO-18Q-016, Rev. 1, Page 2 of 2

STRUCTURAL INTEGRITY ASSOCIATES, INC.

APPENDIX C

Revised Fracture Mechanics Evaluation
for Unoverlayed Welds

tm
pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 2.0

Date: 21-Jun-1990
Time: 16:46:50.90

STRESS CORROSION CRACK GROWTH ANALYSIS

GPCO-18Q, WELD 12AR-G-4

INITIAL CRACK SIZE= 0.1390
WALL THICKNESS= 0.6930
MAX CRACK SIZE FOR SCCG= 0.5544

STRESS CORROSION CRACK GROWTH LAW

LAW ID	C	N	Kthres	K1C
NRC	3.590E-08	2.1610	0.0000	200.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
IHSI10F	-30.7058	-212.1766	1411.8703	-1505.4352
12AR-G-4	19.1400	0.0000	0.0000	0.0000
12BR-A-4	17.4900	0.0000	0.0000	0.0000
12BR-E-4	21.9400	0.0000	0.0000	0.0000

CASE ID	Kmax SCALE FACTOR
IHSI10F	1.00
12AR-G-4	1.00

TIME	TIME INCREMENT	PRINT INCREMENT
50000.0	25000.0	25000.0

crack model:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

CRACK SIZE	STRESS INTENSITY FACTOR CASE IHSI10F	CASE 12AR-G-4	CASE 12BR-A-4	CASE 12BR-E-4
0.0111	-6.625	3.962	3.621	4.542
0.0222	-9.748	5.629	5.144	6.452
0.0333	-12.353	6.925	6.328	7.938
0.0444	-14.686	8.032	7.339	9.207
0.0554	-16.832	9.020	8.242	10.339
0.0665	-18.826	9.924	9.069	11.376
0.0776	-20.800	10.826	9.892	12.409
0.0887	-22.711	11.708	10.698	13.420

0.0998	-24.527	12.561	11.478	14.398
0.1109	-26.248	13.391	12.236	15.350
0.1220	-27.873	14.202	12.978	16.280
0.1331	-29.402	14.999	13.706	17.193
0.1441	-30.912	15.826	14.461	18.141
0.1552	-32.408	16.690	15.252	19.132
0.1663	-33.810	17.553	16.040	20.121
0.1774	-35.113	18.414	16.827	21.108
0.1885	-36.315	19.276	17.614	22.095
0.1996	-37.412	20.138	18.402	23.083
0.2107	-38.474	21.046	19.232	24.125
0.2218	-39.652	22.099	20.194	25.332
0.2328	-40.723	23.163	21.167	26.552
0.2439	-41.685	24.239	22.150	27.785
0.2550	-42.535	25.327	23.144	29.032
0.2661	-43.270	26.426	24.148	30.292
0.2772	-43.887	27.537	25.163	31.565
0.2883	-44.544	28.720	26.244	32.921
0.2994	-45.091	29.916	27.337	34.293
0.3105	-45.528	31.127	28.443	35.680
0.3216	-45.855	32.351	29.562	37.083
0.3326	-46.073	33.588	30.693	38.502
0.3437	-46.183	34.840	31.836	39.936
0.3548	-46.339	36.180	33.061	41.473
0.3659	-46.443	37.562	34.324	43.057
0.3770	-46.447	38.960	35.601	44.659
0.3881	-46.354	40.374	36.893	46.280
0.3992	-46.168	41.804	38.200	47.920
0.4103	-45.892	43.250	39.521	49.577
0.4213	-45.492	44.766	40.907	51.315
0.4324	-44.958	46.356	42.359	53.137
0.4435	-44.334	47.963	43.828	54.980
0.4546	-43.626	49.588	45.314	56.843
0.4657	-42.841	51.231	46.815	58.726
0.4768	-41.989	52.892	48.332	60.630
0.4879	-41.082	54.610	49.902	62.598
0.4990	-40.103	56.465	51.597	64.725
0.5100	-39.035	58.340	53.311	66.875
0.5211	-37.889	60.236	55.044	69.048
0.5322	-36.675	62.152	56.794	71.245
0.5433	-35.405	64.088	58.564	73.464
0.5544	-34.093	66.044	60.351	75.706

TIME	KMAX	DA/DT	DA	A	A/THK
25000.0	-14.77	0.000E+00	0.0000	0.1390	0.201

END OF pc-CRACK

pc-CRACK[tm]
(C) COPYRIGHT 1984, 1988
STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 2.0

Date: 21-Jun-1990
Time: 16:45:32.52

STRESS CORROSION CRACK GROWTH ANALYSIS

GPCO-180, WELD 12BR-A-4

INITIAL CRACK SIZE= 0.1800
WALL THICKNESS= 0.6930
MAX CRACK SIZE FOR SCCG= 0.5544

STRESS CORROSION CRACK GROWTH LAW

LAW ID	C	N	Kthres	K1C
NRC	3.590E-08	2.1610	0.0000	200.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
IHSI10F	-30.7050	-212.1766	1411.8703	-15[illegible].4352
12AR-G-4	19.1400	0.0000	0.0000	0.0000
12BR-A-4	17.4900	0.0000	0.0000	0.0000
12BR-E-4	21.9400	0.0000	0.0000	0.0000

Kmax CASE ID	SCALE FACTOR
IHSI10F	1.00
12BR-A-4	1.00

TIME	TIME INCREMENT	PRINT INCREMENT
50000.0	25000.0	25000.0

crack model:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

CRACK SIZE	STRESS INTENSITY FACTOR CASE IHSI10F	CASE 12AR-G-4	CASE 12BR-A-4	CASE 12BR-E-4
0.0111	-6.625	3.962	3.621	4.542
0.0222	-9.748	5.629	5.144	6.452
0.0333	-12.353	6.925	6.328	7.938
0.0444	-14.686	8.032	7.339	9.207
0.0554	-16.832	9.020	8.242	10.339
0.0665	-18.826	9.924	9.069	11.376
0.0776	-20.800	10.826	9.892	12.409
0.0887	-22.711	11.708	10.698	13.420

0.0998	-24.527	12.561	11.478	14.398
0.1109	-26.248	13.391	12.236	15.350
0.1220	-27.873	14.202	12.978	16.280
0.1331	-29.402	14.999	13.706	17.193
0.1441	-30.912	15.826	14.461	18.141
0.1552	-32.408	16.690	15.252	19.132
0.1663	-33.810	17.553	16.040	20.121
0.1774	-35.113	18.414	16.827	21.108
0.1885	-36.315	19.276	17.614	22.095
0.1996	-37.412	20.138	18.402	23.083
0.2107	-38.474	21.046	19.232	24.125
0.2218	-39.652	22.099	20.194	25.332
0.2328	-40.723	23.163	21.167	26.552
0.2439	-41.685	24.239	22.150	27.785
0.2550	-42.535	25.327	23.144	29.032
0.2661	-43.270	26.426	24.148	30.292
0.2772	-43.887	27.537	25.163	31.565
0.2883	-44.544	28.720	26.244	32.921
0.2994	-45.091	29.916	27.337	34.293
0.3105	-45.528	31.127	28.443	35.680
0.3216	-45.855	32.351	29.562	37.083
0.3326	-46.073	33.588	30.693	38.502
0.3437	-46.183	34.840	31.836	39.936
0.3548	-46.339	36.180	33.061	41.473
0.3659	-46.443	37.562	34.324	43.057
0.3770	-46.447	38.960	35.601	44.659
0.3881	-46.354	40.374	36.893	46.280
0.3992	-46.168	41.804	38.200	47.920
0.4103	-45.892	43.250	39.521	49.577
0.4213	-45.492	44.766	40.907	51.315
0.4324	-44.958	46.356	42.359	53.137
0.4435	-44.334	47.963	43.828	54.980
0.4546	-43.626	49.588	45.314	56.843
0.4657	-42.841	51.231	46.815	58.726
0.4768	-41.989	52.892	48.332	60.630
0.4879	-41.082	54.610	49.902	62.598
0.4990	-40.103	56.465	51.597	64.725
0.5100	-39.035	58.340	53.311	66.875
0.5211	-37.889	60.236	55.044	69.048
0.5322	-36.675	62.152	56.794	71.245
0.5433	-35.405	64.088	58.564	73.464
0.5544	-34.093	66.044	60.351	75.706

TIME	KMAX	DA/DT	DA	A	A/THK
25000.0	-18.38	0.000E+00	0.0000	0.1800	0.260

END OF pc-CRACK

tm
pc-CRACK
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STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 2.0

Date: 21-Jun-1990
Time: 16:44: 8.65

STRESS CORROSION CRACK GROWTH ANALYSIS

GPCO-18Q, WELD 12BR-E-4

INITIAL CRACK SIZE= 0.1730
WALL THICKNESS= 0.6930
MAX CRACK SIZE FOR SCCG= 0.5544

STRESS CORROSION CRACK GROWTH LAW

LAW ID	C	N	Kthres	K1C
NRC	3.590E-08	2.1610	0.0000	200.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
IHSI10F	-30.7058	-212.1766	1411.8703	-1505.4352
12AR-G-4	19.1400	0.0000	0.0000	0.0000
12BR-A-4	17.4900	0.0000	0.0000	0.0000
12BR-E-4	21.9400	0.0000	0.0000	0.0000

Kmax CASE ID	SCALE FACTOR
IHSI10F	1.00
12BR-E-4	1.00

TIME	TIME INCREMENT	PRINT INCREMENT
50000.0	25000.0	25000.0

crack model:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

CRACK SIZE	STRESS INTENSITY FACTOR CASE IHSI10F	CASE 12AR-G-4	CASE 12BR-A-4	CASE 12BR-E-4
0.0111	-6.625	3.962	3.621	4.542
0.0222	-9.748	5.629	5.144	6.452
0.0333	-12.353	6.925	6.328	7.938
0.0444	-14.686	8.032	7.339	9.207
0.0554	-16.832	9.020	8.242	10.339
0.0665	-18.826	9.924	9.069	11.376
0.0776	-20.800	10.826	9.892	12.409
0.0887	-22.711	11.708	10.698	13.420

0.0998	-24.527	12.561	11.478	14.398
0.1109	-26.248	13.391	12.236	15.350
0.1220	-27.873	14.202	12.978	16.280
0.1331	-29.402	14.999	13.706	17.193
0.1441	-30.912	15.826	14.461	18.141
0.1552	-32.408	16.690	15.252	19.132
0.1663	-33.810	17.553	16.040	20.121
0.1774	-35.113	18.414	16.827	21.108
0.1885	-36.315	19.276	17.614	22.095
0.1996	-37.412	20.138	18.402	23.083
0.2107	-38.474	21.046	19.232	24.125
0.2218	-39.652	22.099	20.194	25.332
0.2328	-40.723	23.163	21.167	26.552
0.2439	-41.685	24.239	22.150	27.785
0.2550	-42.535	25.327	23.144	29.032
0.2661	-43.270	26.426	24.148	30.292
0.2772	-43.887	27.537	25.163	31.565
0.2883	-44.544	28.720	26.244	32.921
0.2994	-45.091	29.916	27.337	34.293
0.3105	-45.528	31.127	28.443	35.680
0.3216	-45.855	32.351	29.562	37.083
0.3326	-46.073	33.588	30.693	38.502
0.3437	-46.183	34.840	31.836	39.936
0.3548	-46.339	36.180	33.061	41.473
0.3659	-46.443	37.562	34.324	43.057
0.3770	-46.447	38.960	35.601	44.659
0.3881	-46.354	40.374	36.893	46.280
0.3992	-46.168	41.804	38.200	47.920
0.4103	-45.892	43.250	39.521	49.577
0.4213	-45.492	44.766	40.907	51.315
0.4324	-44.958	46.356	42.359	53.137
0.4435	-44.334	47.963	43.828	54.980
0.4546	-43.626	49.588	45.314	56.843
0.4657	-42.841	51.231	46.815	58.726
0.4768	-41.989	52.892	48.332	60.630
0.4879	-41.082	54.610	49.902	62.598
0.4990	-40.103	56.465	51.597	64.725
0.5100	-39.035	58.340	53.311	66.875
0.5211	-37.889	60.236	55.044	69.048
0.5322	-36.675	62.152	56.794	71.245
0.5433	-35.405	64.088	58.564	73.464
0.5544	-34.093	66.044	60.351	75.706

TIME	KMAX	DA/DT	DA	A	A/THK
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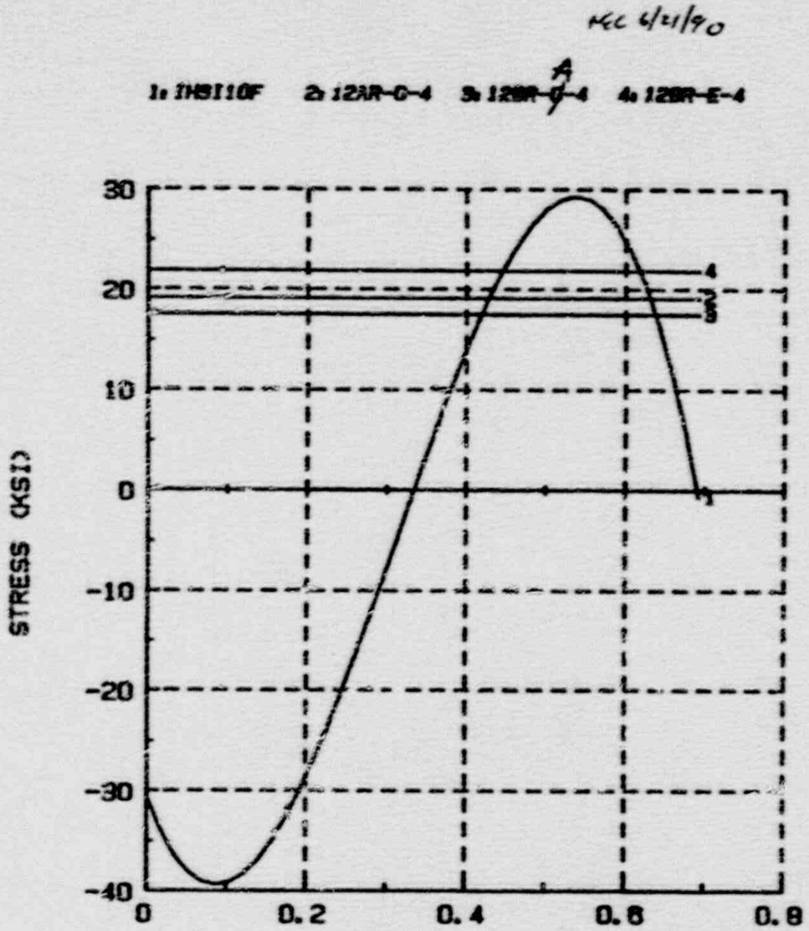
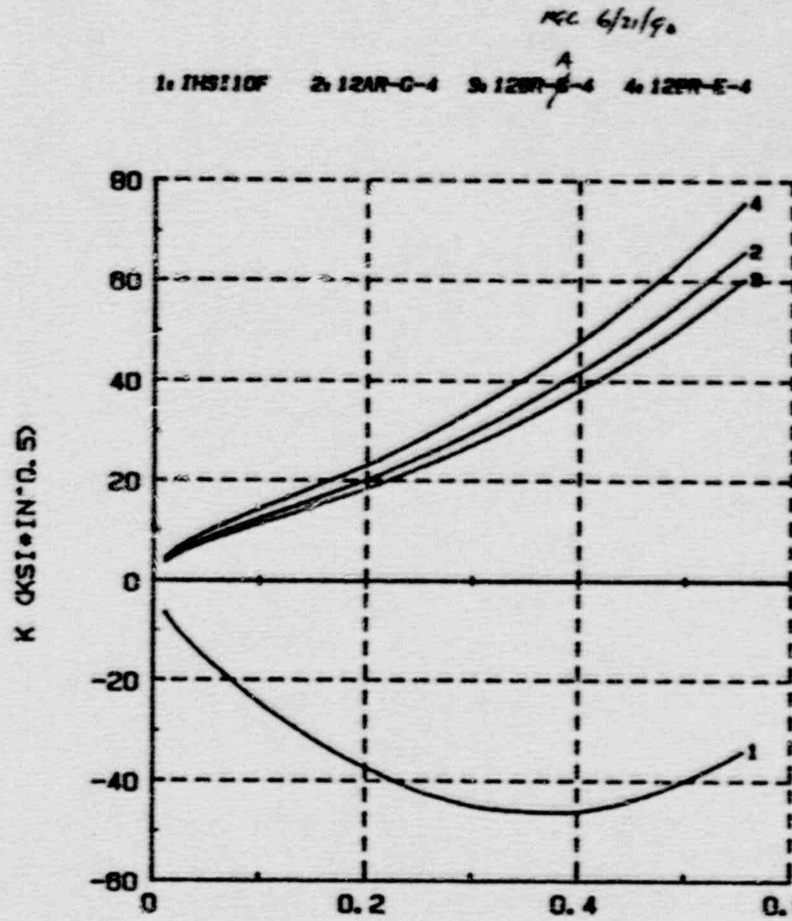


X (IN)
THROUGH WALL DISTANCE FROM INSIDE RADIUS (IN)



CRACK SIZE (IN)
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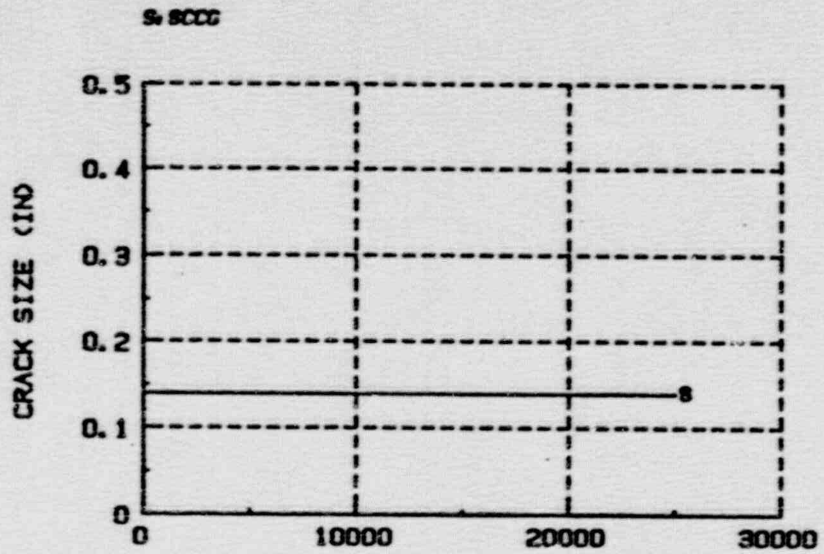
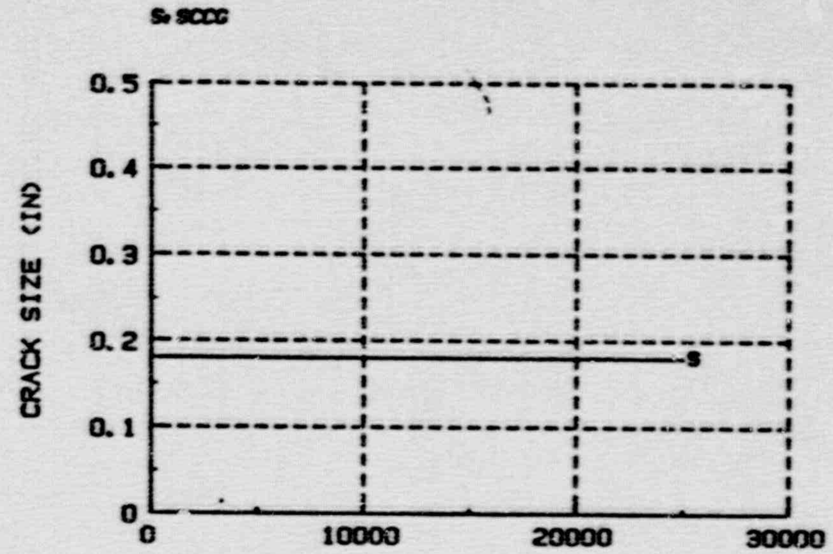
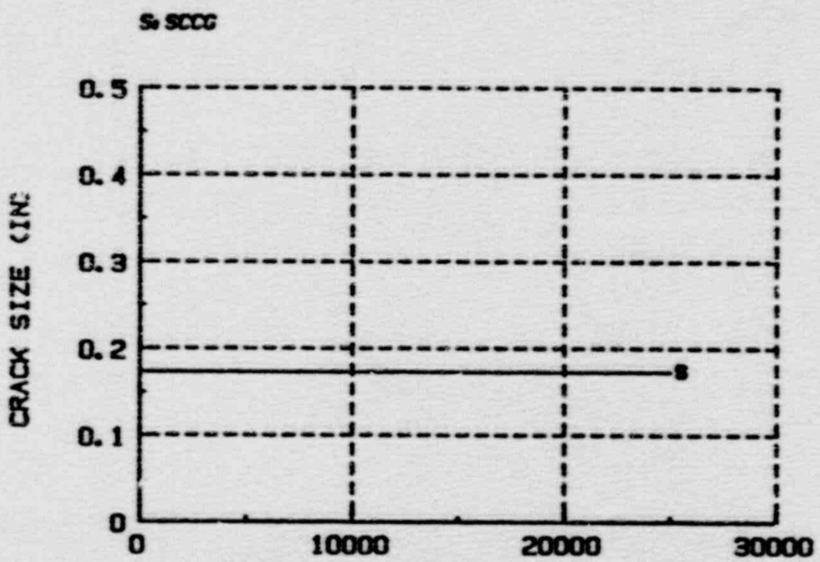


TIME (HRS)
STRESS CORROSION CRACK GROWTH FOR WELD (12AR-G-4)



TIME (HRS)
STRESS CORROSION CRACK GROWTH FOR WELD 12BR-A-4



TIME (HRS)
STRESS CORROSION CRACK GROWTH FOR WELD 12BR-E-4