Georgia Power Company
333 Piedmont Avenue
Atlanta, Georgia 30308
Telephone 404 526-6526

Mailing Address:
Post Office Box 4545
Atlanta, Georgia 30302

Georgia Power
the southern electric system

L. T. Gucwa
Manager Nuclear Engineering
and Chief Nuclear Engineer

NED-84-605

December 10, 1984

Director of Nuclear Reactor Regulation
Attention: Mr. John F. Stolz, Chief
Operating Reactors Branch No. 4
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

NRC DOCKET 50-321
OPERATING LICENSE DPR-57
EDWIN I. HATCH NUCLEAR PLANT UNIT 1
INSERVICE INSPECTION OF STAINLESS STEEL PIPING -
1984 REFUELING OUTAGE

Gentlemen:

Georgia Power Company (GPC) herein submits the results of the inservice inspection of stainless steel piping and the corrective actions taken for those welds reported to have crack-like indications during the Fall 1984 maintenance/refueling outage. Enclosed is a report which details, but is not limited to, 1) the scope of examinations, 2) procedure and personnel qualification related to IGSCC detection and sizing, 3) inspection results, 4) flaw evaluations and repairs, and 5) future plans. The greater part of the information contained in the enclosed report was discussed previously, although some was in preliminary form, with NRC on November 9, 1984 and November 15, 1984 during meetings in your offices located in Atlanta and Bethesda, respectively.

Pursuant to the requirements of the NRC's Safety Evaluation Report issued following repairs of stainless steel recirculation piping at Hatch Unit 1 during the Fall 1982 maintenance/refueling outage, GPC submitted by letter dated May 31, 1984 for your review and approval our proposed plans for the inservice inspection of the subject piping during the Fall 1984 maintenance/refueling outage. Based on your reviewer's comments concerning examination sample size by weld category as defined in NRC Generic Letter 84-11, the aforementioned submittal was supplemented, as appropriate, by letter dated September 26, 1984. While an additional question concerning weld sample size was later raised by your reviewer, it is academic now since

A047
1/1

one hundred percent of the stainless steel circumferential and branch connection welds in the Recirculation, Residual Heat Removal (RHR), and Reactor Water Cleanup (RWCU) systems were ultimately examined as a result of observing reportable, crack-like indications during the current outage.

Included as part of the May 31, 1984 submittal was a justification for continued service with six weld overlays which were applied during the previous maintenance/refueling outage. The justification provided in the aforementioned submittal and the favorable inspection results of the overlaid welds inspected during the current outage should aid in your granting approval for another cycle's service with those overlays.

A sweepolet weld (1B31-1RC-22AM-1BC-1) in the Recirculation System was found to have seven short, shallow axial ultrasonic indications when the weld was examined during the Fall 1982 maintenance/refueling outage. Analysis showed that this weld could be left unrepaired. GPC voluntarily installed an acoustic emissions device to monitor for any leakage from this unrepaired sweepolet weld. GPC intends to remove the device during the current outage based on the results of the weld's reexamination, the leak-before-break concept, and the augmented reactor coolant leakage surveillance requirements currently in place. While installation of the device is not a licensing condition, your concurrence with its removal is requested since it was discussed rather extensively in the safety evaluation report issued after the 1982 outage. Details of the reexamination of the subject weld and our justification for removal of the acoustic emissions leakage detection device are discussed in the enclosed report.

GPC intends to return the unit to power operation upon completion of the necessary repairs, analyses, baseline examinations of the new weld overlays, hydrostatic testing, your approval for continued service for another cycle with the existing weld overlays, and your concurrence with the removal of the acoustic emissions device on the unrepaired sweepolet weld from the previous outage. Return to power operation is currently scheduled for December 28, 1984. While your review and approval of the scope of our inspection plan was a condition specified in the aforementioned safety evaluation report, it may be a moot point since all stainless steel circumferential and branch connection piping welds in the Recirculation, RHR, and RWCU systems were ultimately examined during the outage. Criteria for flaw evaluation, weld overlays, leakage limits, and leakage detection as they pertained to our May 31, 1984 submittal were consistent with the intent of NRC Generic Letter 84-11 and should therefore be acceptable to you. We

Georgia Power

believe the results of the inspections and repairs program provide an adequate basis for the safe operation of the unit.

Seven copies of this letter and enclosed report are provided for your convenience. Since the final version of the design report will not be available until all repairs are complete, the enclosed NUTECH design report is a preliminary draft version. The final design report will be provided for your review when it becomes available to GPC.

By copy of this letter, NRC Region II is concurrently being provided this report to assist you, as appropriate, in your review.

Should you have any questions in this regard, please contact this office.

Sincerely yours,

William E. Burns /for

L. T. Gucwa

JAE/mb
Attachments
xc: J. T. Beckham, Jr.
H. C. Nix, Jr.
J. P. O'Reilly (NRC- Region II)
Senior Resident Inspector

ENCLOSURE 1

Inspection of Hatch Unit 1 Recirculation, RHR, And RWCU Piping Welds - 1984 Maintenance/Refueling Outage

December 10, 1984

TABLE OF CONTENTS

December 10, 1984

1.0 INTRODUCTION

During the inservice inspection conducted during the Fall 1984 maintenance/refueling outage at Hatch Unit 1, several stainless steel piping welds in the Recirculation and Residual Heat Removal (RHR) systems were found by ultrasonic examination to have reportable, crack-like indications. Georgia Power Company (GPC) hereby submits the following information concerning the inservice inspection of stainless steel welds, inspection procedures and personnel qualifications, weld repairs and flaw evaluations, and future plans.

2.0 SCOPE OF EXAMINATIONS

2.1 Original Scope

The original scope of examinations at Hatch Unit 1 during the Fall 1984 maintenance/refueling outage included the ultrasonic inspection of approximately seventy five (75) stainless steel welds (included several longitudinal seam welds) in the Recirculation, RHR, and Reactor Water Cleanup (RWCU) systems. Core Spray piping and Control Rod Drive (CRD) hydraulic return line piping were not required to be examined in the original scope of examination of stainless steel welds since they were either of a different material type (Core Spray-carbon steel) or had been capped at the reactor vessel nozzle and rerouted to another system outside primary containment (CRD capped and rerouted to RWCU return).

The examinations were conducted for GPC by Southern Company Services (SCS) and its contractor, Sonics Systems International (SSI). Procedures and personnel qualifications relative to the detection of intergranular stress corrosion cracking (IGSCC) and depth sizing of any such cracking will be discussed later in this report.

Basically, the welds examined during the original scope of stainless steel weld examinations were comprised of three groups. The three groups involved were as follows:

1) Welds normally scheduled to be examined throughout the ten-year inservice inspection interval to meet ASME Section XI Code requirements,

2) Welds (e.g., weld overlays, unrepaired weld) required by the Hatch Unit 1 Safety Evaluation Report (SER) issued following analyses/repairs during the Fall 1982 maintenance/refueling outage and by NRC Generic Letter 84-11, and

3) Examinations committed to NRC as a result of cracking observed at other boiling water reactors, (e.g., inconel-buttered Recirculation safe ends/nozzles, Recirculation jet pump instrumentation nozzles).

Circumferential welds examined in the original scope typically were chosen based on crack experience, where available. Where such information was not available, high stress rule index number and/or high carbon content was used for selecting the welds to be examined. The welds in the original scope of examinations included the following sizes of stainless steel piping by system:

Ultimately, 136 circumferential and branch connection welds (includes the 4 safe end-to-nozzle welds and 2 jet pump instrumentation nozzle penetration seal-to-safe end welds) in the Recirculation, RHR, and RWCU systems were examined as a result of observing reportable, crack-like indications. Of that number examined, 21 piping welds in the Recirculation and RHR systems were found by ultrasonic inspection to have reportable, crack-like indications. As noted in the previous section, examination results of those welds found to have reportable, crack-like indications will be discussed in Section 4.0.

Since reportable, crack-like indications were not observed in the inconel-buttered Recirculation safe end-to-nozzle welds examined in the original scope of examinations, the scope of examinations was not expanded for that particular ASME category weld (i.e , Category B-F). Both of the Recirculation jet pump instrumentation nozzle penetration seal-to-safe end welds were examined with acceptable results; consequently, scope expansion for those welds was not necessary. The Recirculation jet pump instrumentation nozzle safe end-to-nozzle welds had been examined during the previous maintenance/refueling outage with acceptable results.

The examination scope during the Fall 1984 maintenance/refueling outage was expanded, as appropriate, to meet or exceed ASME Section XI Code and NRC requirements.

3.0 INSPECTION PROCEDURES AND PERSONNEL QUALIFICATIONS

3.1 Procedures

3.1.1 IGSCC Detection

SCS NDE procedure UT-H-400 was qualified in October 1982 at Battelle Columbus Laboratories in Columbus, Ohio. This procedure was qualified under the guidelines of NRC I&E Bulletin 82-03 (for Hatch Unit 1) and later approved for use under NRC I&E Bulletin 83-02. In addition, IGSCC detection methods and techniques used during the 1982 refueling outage were essentially the same as those used during the 1984 refueling outage. Ultrasonic examiners were required to record all flaw indications regardless of amplitude and all geometry 50% DAC and greater.

NOTE: SCS Procedure UT-H-400 is essentially the same procedure as that used for detection qualification at the EPRI NDE Center.

3.1.2 IGSCC Sizing

SCS NDE Planar Flaw Sizing procedure UT-H-470 was developed incorporating techniques and methods demonstrated and approved for use at the EPRI NDE Center in Charlotte, North Carolina. Such methods include SLIC-40 (Multi-pulse Observation Sizing Technique-MOST), 45^{o} and 52^{o} Shear Wave-Pulse Arrival Travel Time (PATT), Satellite Pulse Observation Technique (SPOT), 50^{o} and 70^{o} Refracted Longitudinal Wave, and the "I.D. Creeping" Longitudinal Wave.

3.2 Personnel Qualification

3.2.1 IGSCC Detection

Level II and III personnel performing ultrasonic examinations and/or evaluations were qualified at the EPRI NDE Center for detection of IGSCC. In addition, Level I, II, and III contractor (SSI) personnel were administered SCS NDE procedure examinations on site. Also, an EPRI IGSCC Pipe Crack Sample was provided for Level I personnel to ensure an understanding of procedure requirements, e.g. scanning, detection, and search unit location requirements, and to build confidence.

3.2.2 IGSCC Sizing

Personnel performing ultrasonic sizing of indications were qualified at the EPRI NDE Center in Planar Flaw Sizing and were certified to Level III in ultrasonics. In all, five such individuals were used on Hatch Unit 1; three from SCS and two from Nuclear Energy Services (NES). Third-party examiners were used for their opinion as discussed in Section 4.3 of this report. However, their results were not used as a basis for repair decisions.

Initially, sizing was performed by SCS AND SSI. If GPC Plant Hatch engineering determined that the weld may not require repair, then finite flaw sizing was performed by NES to provide more detailed information for disposition. Finite flaw sizing was performed at random locations around the weld. This approach was taken to minimize personnel radiation exposure on welds that absolutely required repair.

4.0 INSPECTION RESULTS

4.1 Welds with Reportable Indications

Of the 136 circumferential and branch connection (sweepolets, etc.) welds examined, 21 welds (19 circumferential and 2 branch connection) were found to have reportable, crack-like indications. These welds and their results are tabulated in Table 4.1.

4.2 Nature of Reportable Indications

Of the 21 welds identified with reportable indications, 18 welds contained circumferentially oriented indications and 3 contained axially oriented indications. The circumferential indications were detected essentially 360° intermittent around the circumference.

4.3 Third-Party Review

Based on the scope of reportable indications detected during the early stages of the outage, the SCS Inspection, Testing, & Engineering (ITE) Department decided to obtain third-party review of a specific scope of welds. The third-party vendors were as follows: One company identified as Team #1, Kraftwerk Union (KWU), and NES. This third-party review was to confirm evaluations of crack-like indications and estimate depth of the

indications. However, final evaluation and disposition of sizing results was made by SCS and/or NES. The most conservative estimate was reported to GPC by SCS and was used in analysis for decisions concerning repairs. It should be noted that this was not a research effort but a means to show that results were conservative. Some examples of the third-party review results are shown in Figures 4.3 and 4.4.

4.4 Examination of Existing Weld Overlays and Unrepaired Sweepolet Weld

During the Fall 1982 maintenance/refueling outage at Hatch Unit 1, 7 welds (6 circumferential welds and 1 sweepolet weld) were identified as having reportable, crack-like indications. Analysis revealed that the 6 circumferential welds required repair by weld overlay while the sweepolet weld could be left unrepaired. The welds are as follows:

SYSTEM	WELD NO.
Recirculation	1B31-1RC-22AM-1
"	1B31-1RC-22AM-4
"	1B31-1RC-22BM-1
"	1B31-1RC-22BM-4
"	1B31-1RC-22AM-1BC-1 (sweepolet)
RHR	1E11-1RHR-20B-D-3
"	1E11-1RHR-24B-R-13

The existing weld overlays were examined during the Fall 1984 maintenance/refueling outage and showed no evidence of cracking in the overlay material. They were ultrasonically examined to verify the integrity of both the weld metal and its bond to the pipe base material, in a manner consistent wih ASME Code, Section V, Paragraph T550. In addition, a liquid penetrant examination was conducted on the weld overlay and 1" of base material on either size of the weld overlay. Any new weld overlays to be applied during the 1984 outage were to be examined in a similar manner.

As part of our letter dated May 31, 1984, GPC provided NRC justification for an additional cycle of operation with the existing six weld overlays in the Recirculation and RHR systems. The six weld overlays applied previously at Hatch Unit 1 were full structural overlays. Five of the six overlayed welds contained only axially oriented flaws. Since the flaws are due to IGSCC and thus depend on the presence of sensitized material for continued growth, their growth in the axial direction is restricted to the heat affected zone. This means that axial flaws cannot grow axially and thus will never present a significant pipe break threat. The overlay welds consist of 308L weld metal with controlled ferrite which has been demonstrated to be highly resistant to IGSCC. With this barrier to continued IGSCC at the outer pipe surface and the resistant 304 stainless steel base metal limiting the axial growth, the axial flaws are effectively contained. With regard to the sixth overlayed weld, it had two relatively short circumferential flaws on the order of 1 1/2" in length with the deepest indication having a maximum depth of 33% of the unrepaired pipe wall. With the beneficial effect of the weld

overlay induced residual stress, calculations predict that these circumferential cracks will have essentially no growth during their five-year design life. However, even if these calculations of the 33% through wall sizing are significantly in error, the overlay for the joint is substantially overdesigned and would accommodate much longer, deeper circumferential flaws with no loss in safety margin. (Reference: Section 3.1.2 of Attachment 1 to GPC May 31, 1984 letter). Therefore, GPC requests that NRC grant approval for an additional cycle of operation for the existing six weld overlays in the Recirculation and RHR systems in light of their successful examination during the Fall 1984 maintenance/refueling outage and our having provided in the aforementioned letter justification for their continued service.

With regard to the sweepolet weld, 1B31-1RC-22AM-1BC-1; it was examined during the Fall 1984 maintenance/refueling outage and found to have reportable, crack-like indications other than those observed during the previous outage. The indications observed during the previous outage were shallow, axially oriented, and lay outside of the heat affected zone of the weld. The indications observed during the Fall 1982 maintenance/refueling outage were not observed during the current outage. The area of the indications was reexamined with advanced techniques (e.g., sizing techniques) to try to confirm cracking; however, no cracking was detected and the previous indications were thought to be I.D. roll (noise) rather than IGSCC. The new indications were observed to be two circumferential indications totaling approximately 9 inches in length with a maximum through wall depth of 11%. In addition, several spot indications were observed with the deepest indiction being 18% through-wall. Analyses conducted by the primary contractor and a third party indicated that the subject weld could be left unrepaired for a period of at least one fuel cycle based on flaw limits imposed by ASME Section XI Code, Paragraph IWB-3640 and NRC Generic Letter 84-11. Based on these examination results and analyses, it is the intention of GPC to remove the acoustic emissions leakage device installed on this solution annealed sweepolet weld joint during the current outage. While the device was voluntarily installed by GPC and was not a licensing condition, NRC's concurrence with its removal is requested since the device is discussed rather extensively in the Hatch Unit 1 SER issued for the analyses/repairs conducted during the previous outage. It is the opinion of GPC that local leakage detection is no longer required for this weld. The extremely high inherent toughness and ductility of the stainless steel piping material; the tendency of cracks in such piping to grow through-wall and leak before affecting its structural load carrying capacity (i.e., "Leak-before-break" concept); and augmented reactor coolant leakage surveillance requirements currently in effect support our desired removal of the acoustic emissions leakage detection device on the subject weld.

Table 4.1
Edwin I. Hatch Nuclear Plant Unit 1
Results of Examinations
1984 Examination of Stainless Steel Piping

Weld No.	Last Exam	Results- Fall 1982 Outage	Current Results
Recirculation System			
12AR-F-2	Baseline	Not examined	Elbow - 20-30%*
12AR-F-3	11/82	Pipe-360° I.D. Geo. Elbow-360° O.D. Geo.	Pipe/Elbow 20-30%*
12AR-H-2	11/82	Pipe-No Indication Elbow-O.D. Geo. due to Counterbore	Elbow 20-30%*
12AR-H-3	11/82	Pipe-No Indication Elbow-O.D. Geo. due to Counterbore	Elbow 20-30%*
12AR-J-3	11/82	Pipe - No Indication Elbow - I.D. Geo. 360°	Elbow 20 - 30%*
12AR-K-2	5/79	Not examined	Elbow - 30%*
12AR-K-3	Baseline	Not examined	Elbow 30%*
12BR-C-2	11/82	Pipe - No Recordable Indication Elbow-360° I.D. Geo. Counterbore	Pipe/Elbow-49%*
12BR-C-3	Baseline	Not examined	Elbow - 66%*
12BR-D-3	11/82	Elbow O.D. Geo. due to I.D. Counterbore	Elbow 20%*
12BR-E-2	Baseline	Not examined	Elbow - 25%*
12BR-E-3	11/82	Elbow-360° I.D. Geo. Counterbore	Elbow -30%*
22AM-1BC-1	11/82	7 Axial Indications No Overlay	18% Spot indication, max. circ. indication 11%

* Maximum detected depth - 360° intermittent

Table 4.1
Edwin I. Hatch Nuclear Plant Unit 1
Results of Examinations
1984 Examination of Stainless Steel Piping
(Cont'd)

Weld No.	Last Exam	Results- Fall 1982 Outage	Current Results
22BM-1BC-1	11/82	I.D. Geo.	29% Circ.
28A-6	Baseline	Not examined	Elbow 16% Axial
28A-10	Baseline	Not examined	Elbow 50%*
28B-3	11/82	Pipe I.D. Geo. 360° Elbow I.D. & O.D. Geo. 360°	Elbow 32%*
28B-4	3/81	Not examined	Elbow 31%*
28B-11	Baseline	Not examined	Elbow 49%*
28B-16	Baseline	Not examined	Pipe 17% Axial
RHR System			
24B-R-13	11/82	Axial Scan No Indication Circ. Scan I.D. Geo. 360°	Pipe 50% Axial

* Maximum detected depth - 360° intermittent

FIGURE 4.1

"A" Loop - Recirculation & Attached System

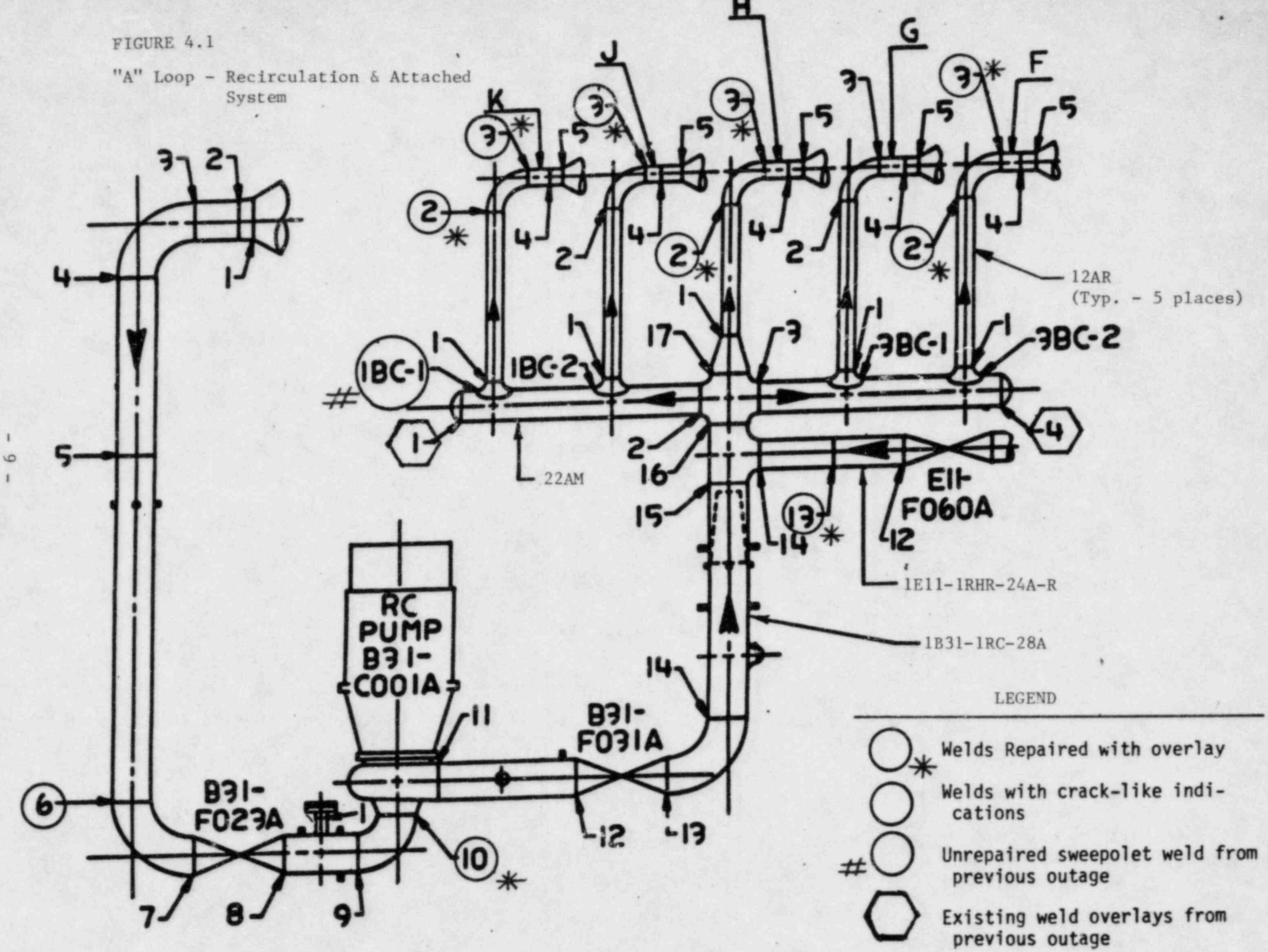


FIGURE 4.2

"B" Loop - Recirculation & Attached Systems

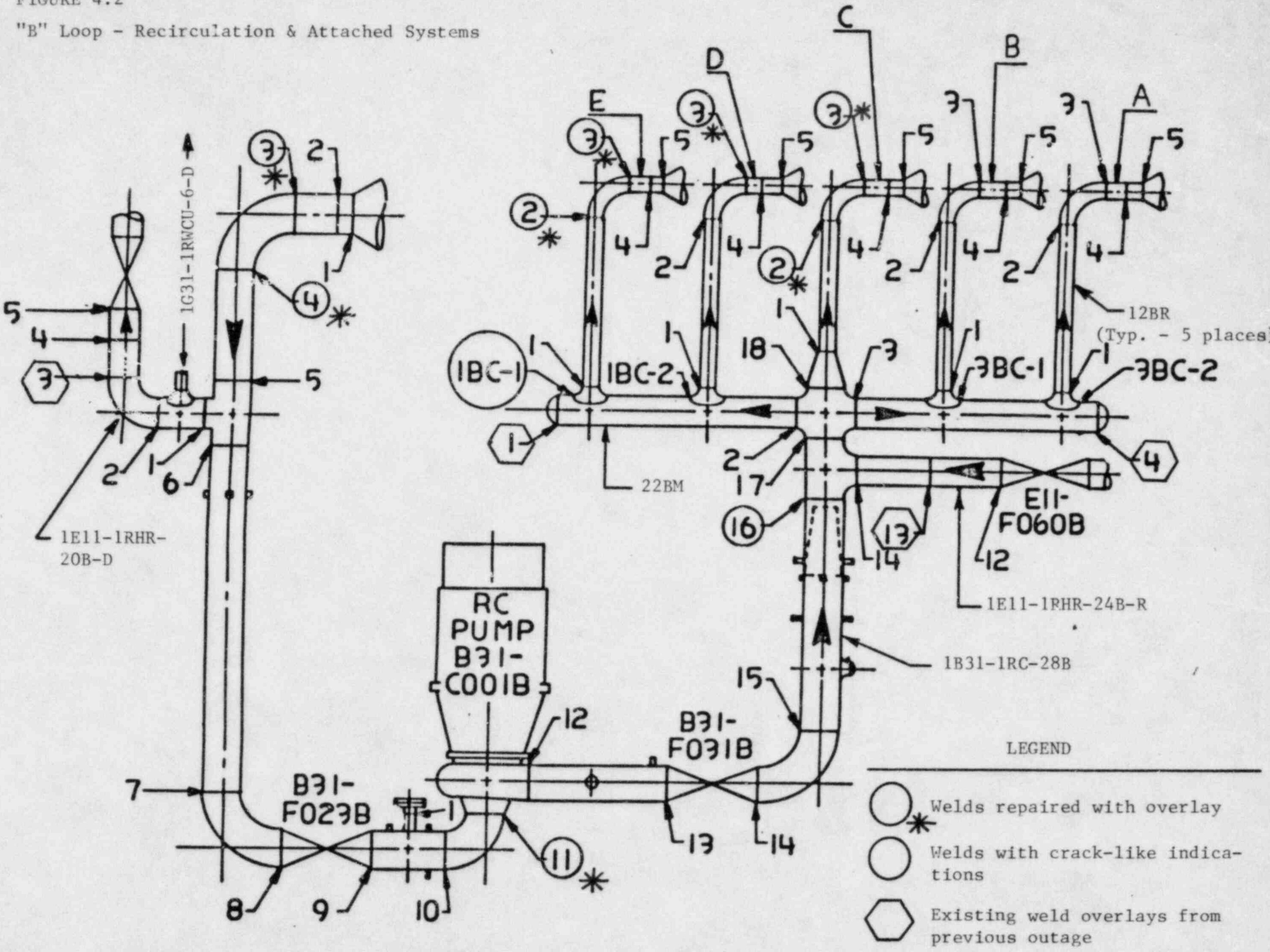
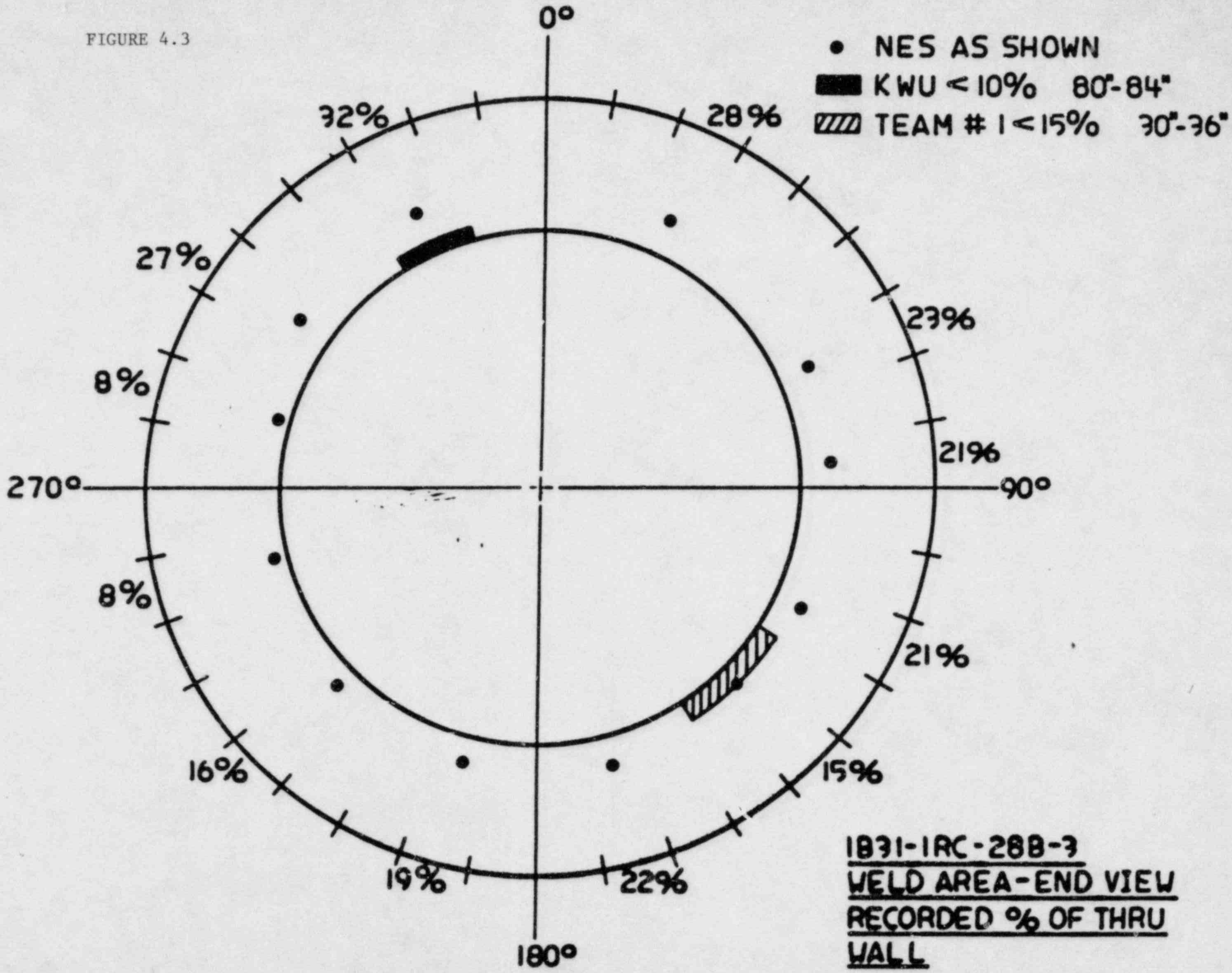
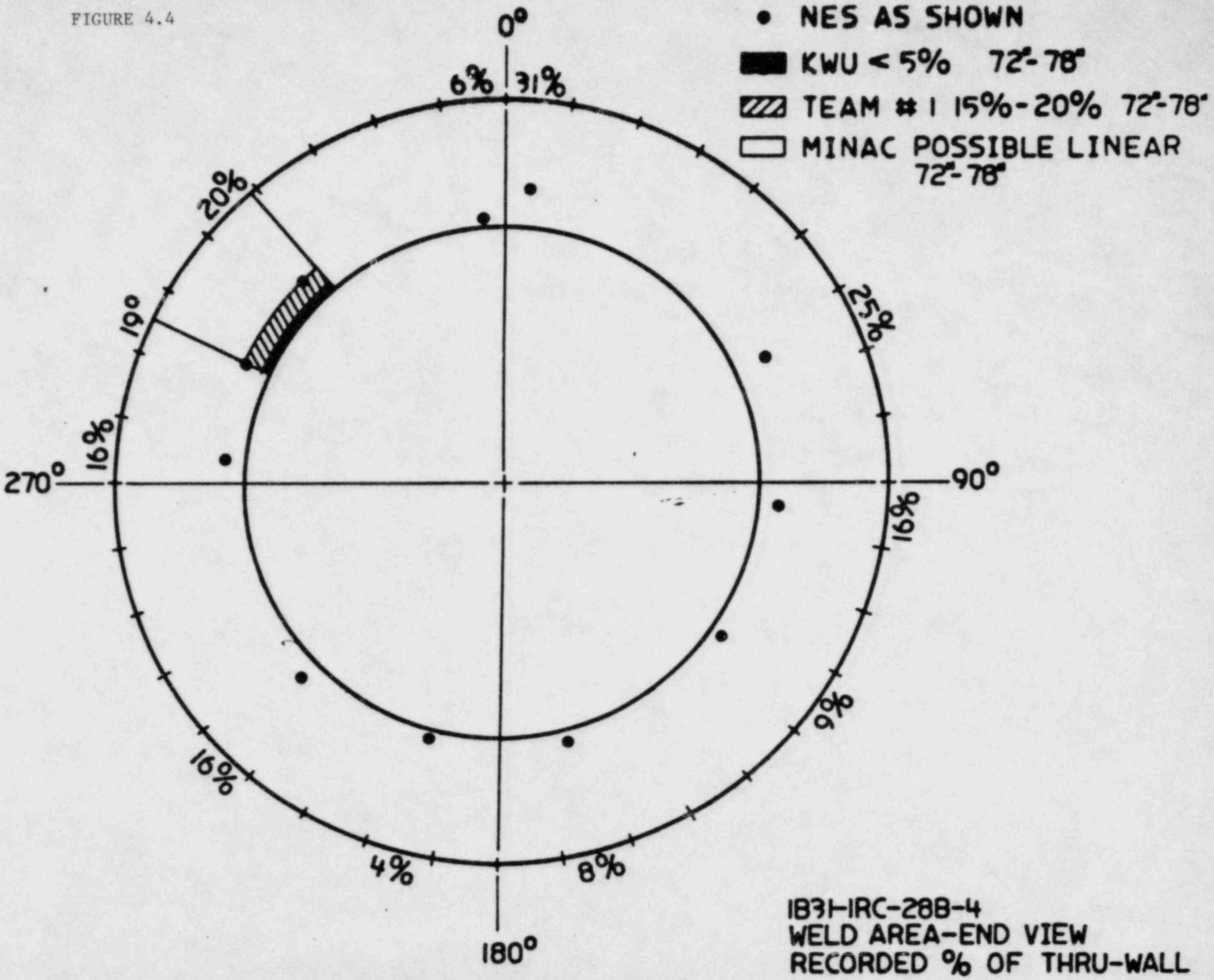


FIGURE 4.3



1B31-1RC-28B-3
WELD AREA-END VIEW
RECORDED % OF THRU WALL

FIGURE 4.4



IB31-IRC-28B-4
WELD AREA-END VIEW
RECORDED % OF THRU-WALL

5.0 REPAIRS AND FLAW EVALUATIONS

Prior to the Fall 1984 maintenance/refueling outage, GPC contracted with NUTECH to perform design activities and overlay welding repairs of piping at Hatch Unit 1 should reportable, crack-like indications be detected during the inservice inspection of the stainless steel piping in the Recirculation, RHR, and RWCU systems. Application of any required overlays was subcontracted to Welding Services, Inc. by NUTECH. Activities under the NUTECH scope of work included, but was not limited to, fracture mechanics analysis, overlay sizing calculations, preparation of the ASME Section XI repairs program, and preparation of a final design report and analysis. GPC instructured NUTECH that flaw evaluations and repairs performed would be consistent with the criteria specified in NRC Generic Letter 84-11 and were performed accordingly by them. The following sections discuss the analyses and repairs performed by NUTECH and review thereof by a third-party.

5.1 Flaw Evaluations and Overlay Design

As noted in Section 4.0, 21 piping welds in the Recirculation and RHR systems were found to have reportable, crack-like indications. Analyses performed by NUTECH have demonstrated the need to repair 17 welds at this time in the form of a weld overlay. The welds requiring repair at this time are:

SYSTEM	WELD NO.
Recirculation	1B31-1RC-12AR-F-2
"	1B31-1RC-12AR-F-3
"	1B31-1RC-12AR-H-2
"	1B31-1RC-12AR-H-3
"	1B31-1RC-12AR-J-3
"	1B31-1RC-12AR-K-2
"	1B31-1RC-12AR-K-3
"	1B31-1RC-12BR-C-2
"	1B31-1RC-12BR-C-3
"	1B31-1RC-12BR-D-3
"	1B31-1RC-12BR-E-2
"	1B31-1RC-12BR-E-3
"	1B31-1RC-28A-10
"	1B31-1RC-28B-3
"	1B31-1RC-28B-4
"	1B31-1RC-28B-11
RHR	1E11-1RHR-24A-R-13

In addition, the indications in 4 piping welds in the Recirculation System were analyzed by NUTECH and were determined not to require repairs at this time. The welds dispositioned by analysis are as follows: 1B31-1RC-22AM-1BC-1, 1B31-1RC-22BM-1BC-1, 1B31-1RC-28A-6, and 1B31-1RC-28B-16.

Included as an attachment to this report is a copy of the preliminary draft NUTECH design report on the Recirculation and RHR systems weld overlay repairs and flaw evaluations for your review. The draft report is

incomplete since weld overlay repairs were still being performed at the time of this writing. The final version of the NUTECH design report will be submitted for your review upon its completion.

5.2 Third-Party Review

Structural Integrity Associates, Inc. (SI) was contracted by GPC to provide an independent third-party review of crack-like indications identified during the inservice inspection of the primary pressure boundary austenitic stainless steel piping at Hatch Unit 1 (see Section 4.0). SI has performed similar third party reviews for weld overlay designs at Peach Bottom 2 and 3 and at the Caorso Nuclear Power Stations. SI has also been the principal weld overlay design and flaw evaluation contractor for several other utilities including New York State Power Authority (Fitzpatrick), Yankee Atomic Electric Corporation (Vermont Yankee), Northeast Utilities (Millstone 1) and Tennessee Valley Authority (Browns Ferry 1, 2, 3). In addition, SI has been a consultant to GPC for IGSCC concerns at both Hatch units during the past two years.

The following sections describe the third-party review function provided by SI for GPC in support of the current Hatch Unit 1 outage.

5.2.1 Review Process

The principal subject area of SI's independent review as the evaluation and disposition of all crack-like indications in the piping resulting from the ultrasonic inservice inspections. This included evaluation of the ultrasonic results, fracture mechanics analysis of the flaws to determine potential for crack growth, comparison of final flaw sizes to allowable flaw size, design of weld overlay repairs where such repairs are deemed necessary, and metallurgical/welding consultation with regard to the application of weld overlay repairs. The criteria for the review consisted of the flaw evaluation procedures for austenitic piping components of ASME Section XI, IWB-3640, supplemented by the recommendations of NRC Generic Letter 84-11. The independent review included an independent verification of the design input to the flaw evaluation or overlay design. Stresses were obtained from a recently completed design stress report for the Hatch Unit 1 recirculation system, prepared by General Electric Company to the NRC I&E Bulletin 79-14 requirements (Reference 1). Material properties used in the evaluation were independently verified, and conservative, bounding interpretations of the ultrasonic results were used in sizing of the defects for analysis and repair.

The flaw evaluation process for both axial and circumferential defects used representative weld residual stresses for both axial and circumferential stresses for each pipe size. Upper bound crack growth rates for weld

sensitized material were utilized in the analysis and all normal operational loads, including thermal expansion loads, were used for crack growth. The allowable flaw size and weld overlay thickness calculations included use of all design basis (pressure, dead weight and seismic) primary stresses.

As recommended in NRC Generic Letter 84-11, no credit was taken for the initial weld overlay layer for structural reinforcement, and any circumferential indications with substantial length were overlay repaired regardless of their depth. Care was taken in selection of the weld material to obtain Type 308L stainless steel weld wire containing a minimum of 10 FN ferrite and in welding by using the high quality machine Gas Tungsten Arc Process (GTAW), with controlled heat input. No credit was assumed for part-through defects in the overlay sizing, all defects were assumed to be through-wall for the entire crack length. Thus, all overlays are full structural overlays with the exception of the RHR weld overlay as discussed in Section 5.2.2.4.

As a final step in the evaluation, weld overlay shrinkage stresses will be considered when as-built shrinkage measurements are available. Details of the flaw evaluations and the weld overlay sizing calculations are summarized below.

5.2.2 Results of Third-Party Review

5.2.2.1 12 Inch Diameter Riser Welds

Crack-like indications were identified in a total of twelve welds in the recirculation riser piping at Hatch Unit 1 (see Section 4.0 for inspection details). Since the indications were identified as 360^{o} intermittent indications for all joints, NRC Generic Letter 84-11 recommendations result in full structural overlays for all affected 12 inch riser piping weld joints. The resulting SI weld overlay designs for the 12 inch welds are presented in Table 5.1. These overlays, as with all the Hatch Unit 1 overlays, have been reconciled with the overlay sizes specified by NUTECH Engineers, the overlay design contractor, and any differences were resolved by taking the more conservative of the two approaches. The overlays have been installed using machine GTAW technique and Type 308L SS filler containing 10 FN minimum. Table 5.1 also presents overlay thickness requirements for the conservative case in which thermal expansion stresses are included as a primary stress component. Note that in this case, the design overlay thickness is sufficient if the first layer of overlay is included.

5.2.2.2 28 Inch Diameter Suction and Discharge Welds

The ultrasonic examination of the 28 inch diameter recirculation suction and discharge welds at Hatch Unit 1 revealed circumferential crack-like indications in four joints and axial crack-like indications in two joints.

Due to the depth and length of the circumferential indications and the recommendations of NRC Generic Letter 84-11, it was decided to overlay these four joints using full structural overlays. As is the case of the 12 inch diameter riser welds, the welding was performed using the machine GTAW

technique and Type 308L SS filler wire containing 10 FN minimum ferrite. The SI overlay sizes were again compared to the NUTECH Engineers design and the designs were in essential agreement. Table 5.2 presents the overlay sizes for these four welds. Once again, if the first layer of weld overlay is included, the overlay designs are of sufficient thickness to include thermal expansion stress as a primary stress component.

The two axial crack-like indications were of a depth so that flaw evaluation was able to demonstrate continued successful operation for at least one additional fuel cycle with these joints unrepaired. The crack growth analysis utilized representative circumferential residual stress data and analysis for this pipe size obtained from EPRI reports (Refs. 2, 3, 4). The analysis technique and results were again compared to the NUTECH Engineers results and agreement was obtained. Crack growth curves versus allowable flaw size for the two joints are presented in Figures 5.1 and 5.2. It is seen that in both cases the indications are acceptable for a period well in excess of one fuel cycle.

5.2.2.3 22 Inch Diameter Sweepolet to Ring Header Welds

Crack-like circumferential indications were also observed in two of the sweepolet to ring header welds during the inservice inspection of these welds. These crack-like indications were evaluated using the flaw evaluation methodology described above. The weld residual stress used assumed that the sweepolet to header joints had been solution annealed following welding, (a condition which was verified as a result of a review of shop fabrication records) and therefore produced a zero through thickness residual stress state. The flaw evaluation results indicated that all of the flaws would remain within the limits imposed by the ASME Code, Section XI, Paragraph IWB-3640 and NRC Generic letter 84-11 for a period of at least one fuel cycle (see Figures 5.3 and 5.4). These results were compared to those developed by NUTECH Engineers and were essentially in agreement.

5.2.2.4 24 Inch Diameter Residual Heat Removal Weld

One axially oriented indication was discovered in a 24 inch RHR weld. The depth of this indication was such that crack growth calculations could not demonstrate acceptable crack growth in one fuel cycle. Thus, even though such an indication does not result in a reduction in piping system structural safety margins, a weld overlay repair was applied to this joint. This overlay repair was not a full structural overlay, but instead was used merely to arrest further crack growth and prevent potential leakage from the joint. Therefore, detailed structural design calculations were not performed, and an overlay of two weld layers with a width sufficient to cover both weld heat affected zones was specified by NUTECH Engineers. This overlay was also installed using machine GTAW technique and Type 308L SS filler containing 10 FN minimum. SI is in agreement with this overlay concept for short axial flaw indications, and has used an essentially similar procedure in the past at other plants.

REFERENCES

1. GE Report "Results of Seismic Evaluation: 'As-Built' Recirculation Piping Including Replacement Actuator for F031 Discharge Valve", Hatch Unit 1 Plant Piping Analysis, Design Memo 170-113, September 26, 1984.

2. R. J. Demuth & B. Doll, "Last Past Heat Sink Welding Process Development", EPRI report NP-3414, January 1984.

3. F. W. Brust & R. B. Stonesifer, "Effect of Weld Parameters on Residual Stresses in BWR Piping Systems", EPRI report NP-1743, March, 1981.

4. E. F. Rybicki, et al, "Computational Residual Stress Analysis for Induction Heating of Welded BWR Pipes", EPRI report NP-2662-LD, December, 1982.

TABLE 5.1

Results of Independent Review Calculations
for 12 Inch Riser Weld Overlays

Weld	Required Overlay Thickness (inches)		Minimum Overlay Length (inches)
	w/o Thermal Stresses	w/Thermal Stresses	
F2	0.19	0.24	2.85
H2	0.19	0.24	2.85
J3	0.19	0.23	2.85
K2	0.19	0.22	2.85
K3	0.20	0.27	2.85
C2	0.20	0.25	2.85
C3	0.20	0.32	2.85
E2	0.20	0.23	2.85
D3	0.20	0.29	2.85
F3	0.20	0.29	2.85
H3	0.20	0.31	2.85
E3	0.20	0.30	2.85

TABLE 5.2

Results of Independent Review Calculations
for 28 Inch Weld Overlays

Weld	Required Overlay Thickness (inches)		Minimum Overlay Length (Inches)
	w/o Thermal	w/Thermal	
28-A10	.40	.43	5.8 *
28-B11	.40	.42	5.8 *
28-B3	.40	.44	5.8
28-B4	.39	.42	5.8

* Actual length should be half of this length because cast stainless steel pump side of weld was not overlay repaired.

STRESS CORROSION CRACK GROWTH

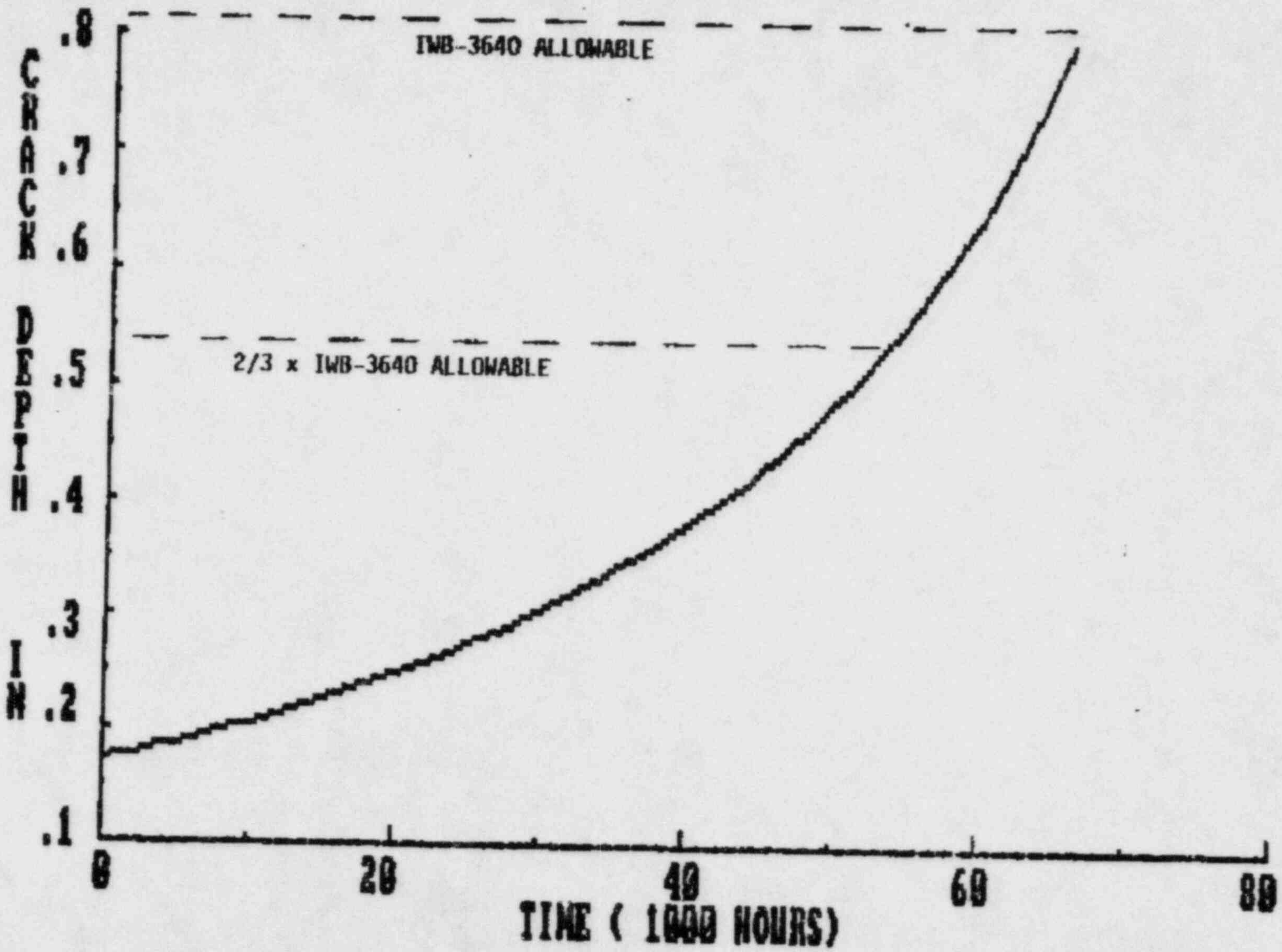


FIGURE 5.1 Projected Crack Growth Versus Allowable For Weld 28-A6

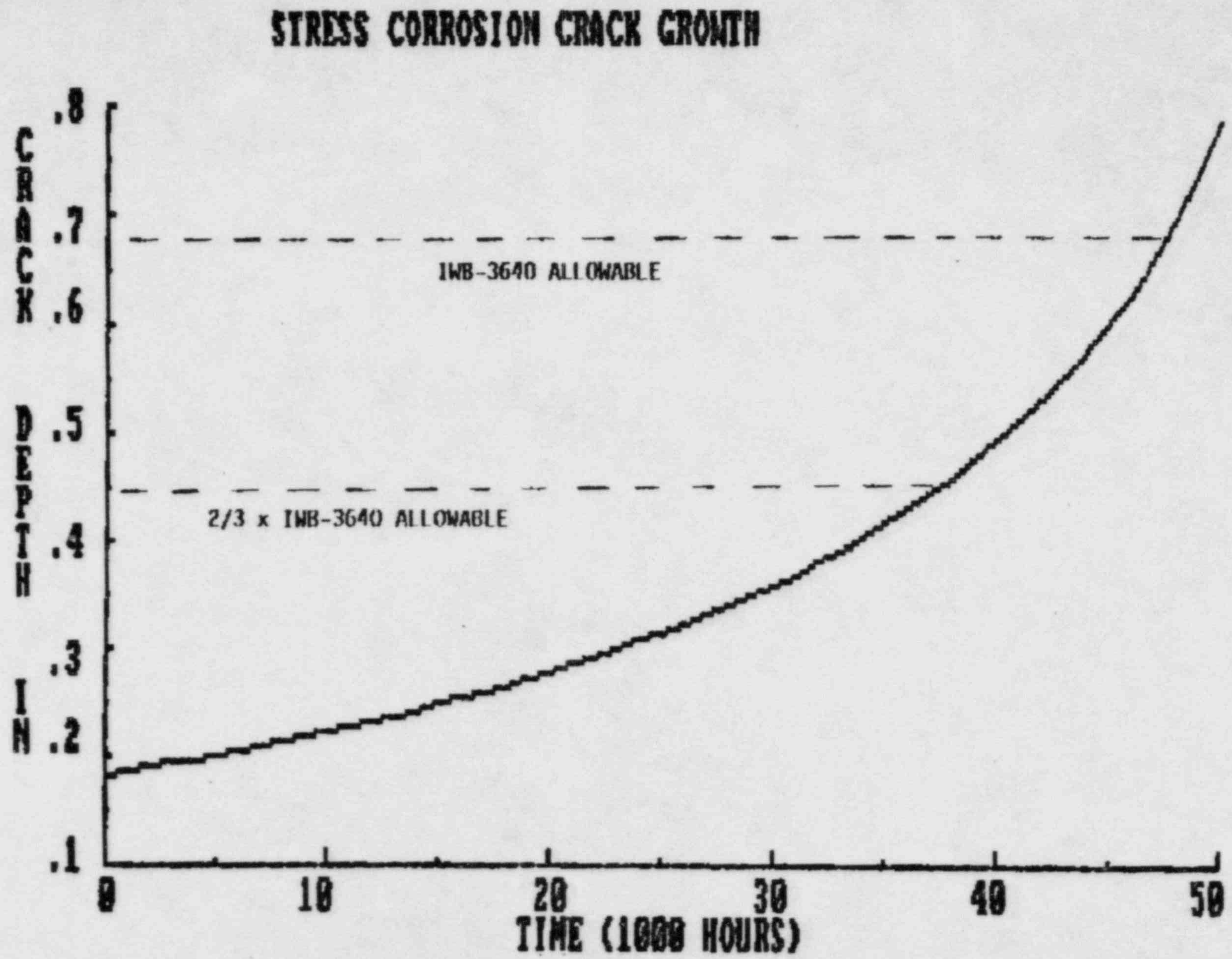


FIGURE 5.2 Projected Crack Growth Versus Allowable For Weld 28-816

STRESS CORROSION CRACK GROWTH

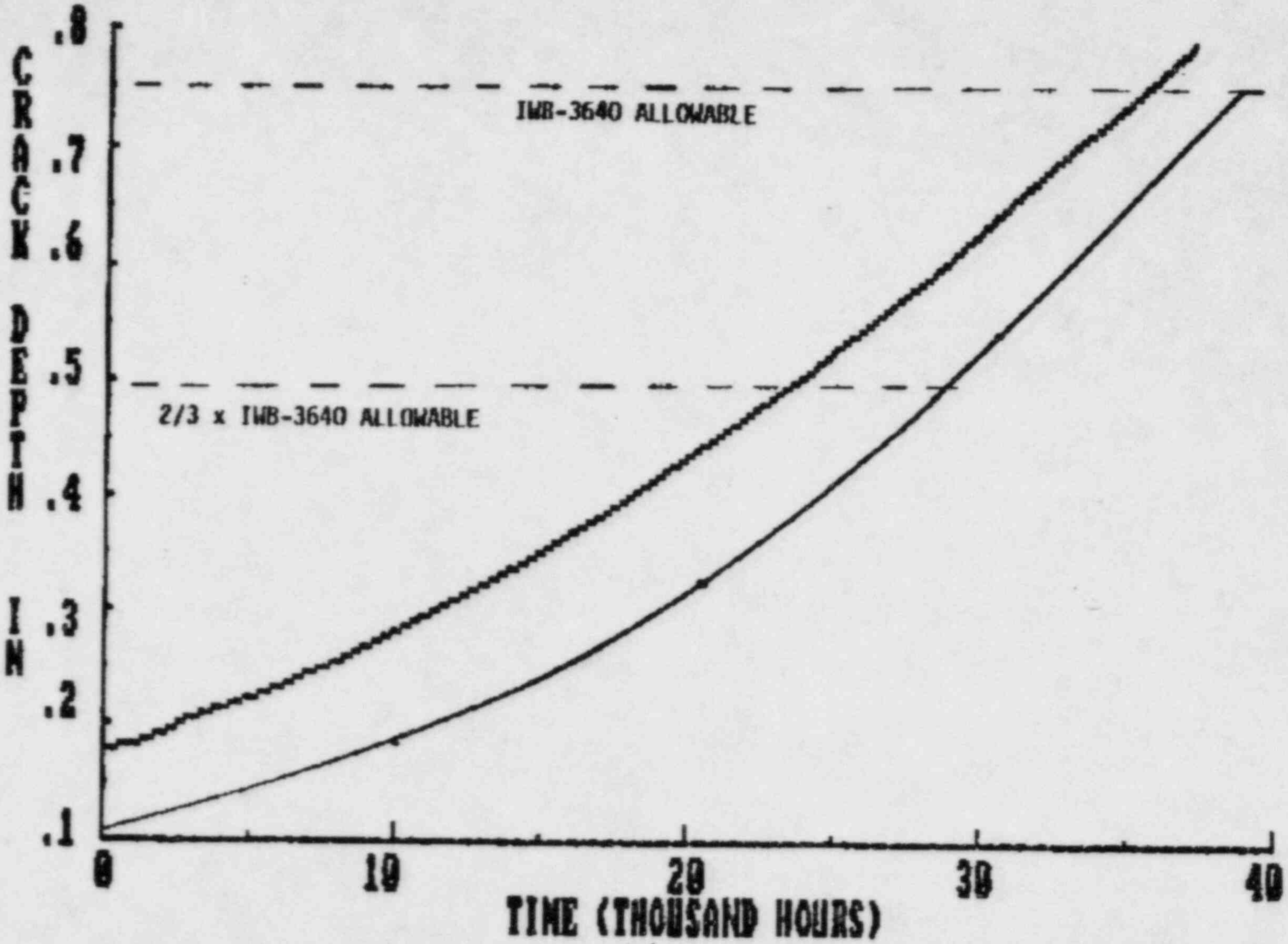


FIGURE 5.3 Projected Crack Growth Versus Allowable For Sweep-o-let Weld 22-1BC1-AM1

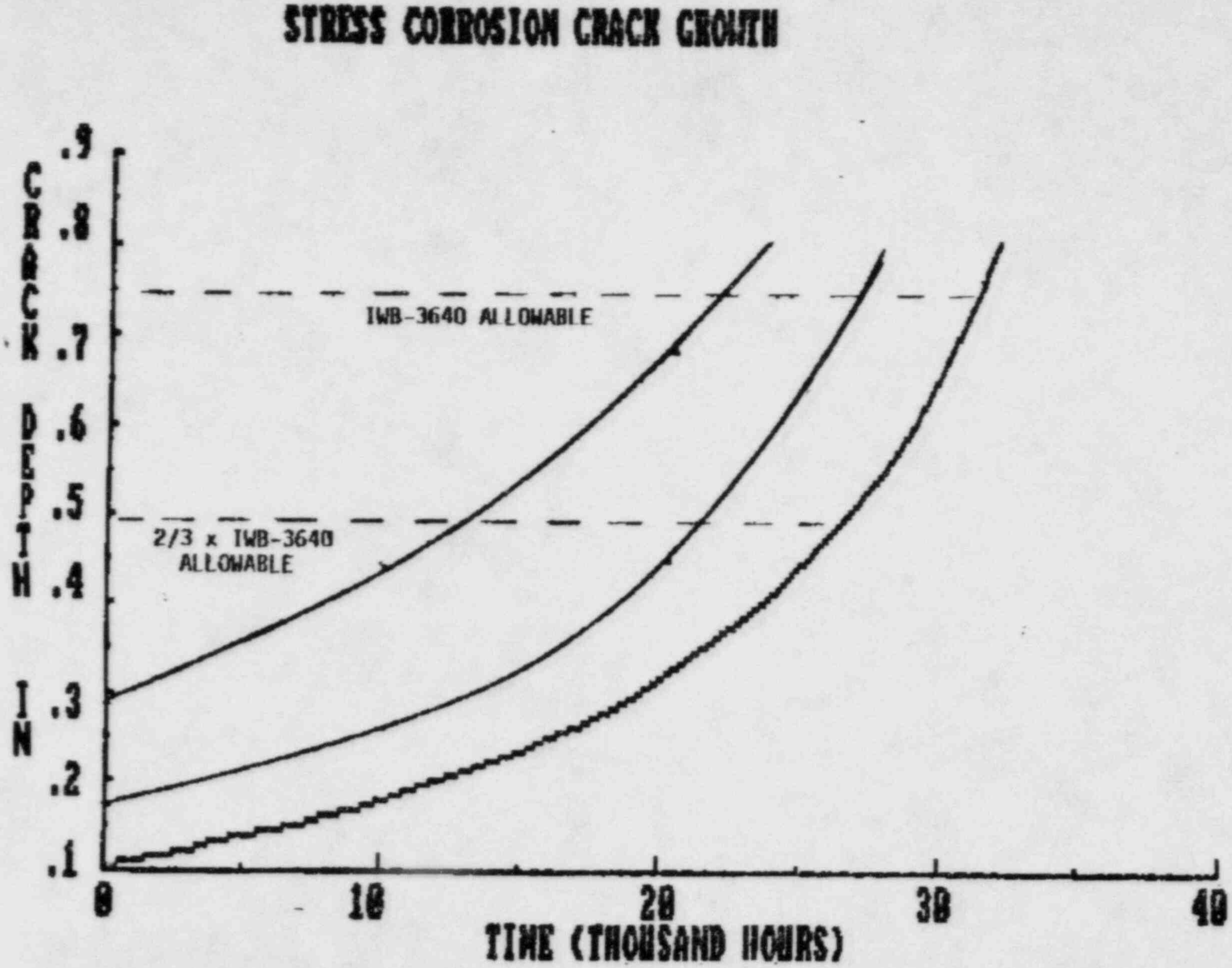


FIGURE 5.4 Projected Crack Growth Versus Allowable For Sweep-o-let Weld 22-1BC1-BM1

6.0 FUTURE PLANS

6.1 Modifications/Replacement

GPC has no firm plans at this time with regard to modification/replacement. NRC is advised that GPC has procurred piping for the Recirculation, RHR, and RWCU systems should it be decided to replace the existing piping at some point in the future. Should replacement be undertaken, the new piping would be of a similar configuration to that installed at Hatch Unit 2 during the 1984 maintenance/refueling outage for that particular unit.

6.2 Leakage Limits and Detection

Our May 31, 1984 and September 26, 1984 submittals addressed this point. Proposed Technical Specification changes to augment then existing reactor coolant leakage detection requirements were submitted to NRC by letters dated February 10 and 11, 1983. The proposed changes submitted as a result of crack-like indications being observed during the Fall 1982 maintenance/refueling outage were subsequently reviewed and approved as discussed in the NRC Hatch Unit 1 SER dated February 11, 1983. The proposed changes meet the intent of the leak detection and leakage limits discussed in Attachment 1 to NRC Generic Letter 84-11. With the exception of our requesting your concurrence of our desired removal of the acoustic emission leakage detection devices installed during the previous maintenance/refueling outage as discussed above in Section 4.4, no changes other than those discussed in Section 2.5 of Attachment 1 to our May 31, 1984 submittal are planned.

7.0 SUMMARY AND CONCLUSIONS

- o Inspections proposed for the Recirculation, RHR, and RWCU systems piping during the Fall 1984 maintenance/refueling outage meets the intent of the Hatch Unit 1 SER, NRC I&E Bulletin 83-02, NRC letter SECY 83-267C, and NRC Generic Letter 84-11.

- o As a result of observing reportable, crack-like indications in the original scope of examinations, the examination scope was expanded to include 100% of the 136 circumferential and branch connection welds in the Recirculation, RHR, and RWCU systems.

- o The detection and sizing of IGSCC was performed by qualified inspection personnel.

- o Twenty one (21) welds were observed to have reportable crack-like indications in the Recirculation and RHR systems.

- o Analyses revealed that 17 of the 21 welds required repair at this time in the form of a weld overlay while the remaining four welds were left unrepaired. A summary of weld disposition is as follows:

PIPING	NUMBER	DISPOSITION
12" Recirculation Risers	12-Circs.	Weld Overlay
22" Recirculation Sweepolets	2-Circs	Evaluation, left unrepaired
28" Recirculation	4-Circs 2-Axial	Weld Overlay Evaluation, left unrepaired
24" RHR	1-Axial	Weld Overlay

- o Flaw evaluations and repairs were performed consistent with the criteria specified in NRC Generic Letter 84-11.

- o Third-party reviews were conducted in the areas of nondestructive examination (detection/sizing) and flaw evaluations/repairs.

- o Continued operation with the existing six weld overlays in the Recirculation and RHR systems is requested and justified based on their acceptable examination results during the current outage and GPC's justification provided in our May 31, 1984 submittal to NRC.

- o While crack-like indications were observed in unrepaired sweepolet weld 22AM-1BC-1 during the current outage, the indications were other than those observed previously. The previously observed indications were no

longer present. The area of the indications was reexamined with advanced techniques (e.g., sizing techniques) to try to confirm the cracking; however, no cracking was detected and the previous indications were thought to be I.D. roll (noise) rather than IGSCC. The new indications were circumferential totaling approximately 9 inches in length with a through-wall depth of 11%. Several spot indications were observed the deepest of which was 18%.

- Based on the unrepaired sweepolet examination results discussed above, the leak before break concept, and augmented reactor coolant leakage surveillance requirements currently in place, GPC intends to remove the acoustic emissions device installed on the subject weld during the current outage and requests NRC's concurrence in its removal.

- Regarding future plans, there are no firm plans at this time for modification/replacement, however, piping has been procurred should it be decided to replace the existing Recirculation, RHR, and RWCU systems piping at some point in time.

- With the exception of our requesting NRC concurrence of our desired removal of the acoustic emissions device on the previously discussed unrepaired sweepolet weld, no changes to leakage limits and detection other than those discussed in our May 31, 1984 submittal are planned.

- Upon completion of the necessary repairs, analyses, baseline examination of the new weld overlays, successful completion of the hydrostatic test, and granting of requested approvals and/or concurrence by NRC concerning continued service with existing weld overlays and removal of the acoustic emissions leakage detection device, it is the intention of GPC to return the unit to power operation on or about December 28, 1984.

- GPC concludes that the inspections and repairs program conducted during the Hatch Unit 1 1984 maintenance/refueling outage provides an adequate basis for the safe operation of the unit.

XGP-09-106
Revision A
December 1984
XGP009.0106

DESIGN REPORT FOR EVALUATION AND DISPOSITION OF IGSCC FLAWS AT PLANT E. I. HATCH UNIT 1

Prepared for:
Georgia Power Company

Prepared by:
NUTECH Engineers, Inc.
San Jose, California

Prepared by:

____
H. L. Gustin, P.E.
Technical Leader
Applied Mechanics

Issued by:

Ben D. Acojido
B. D. Acojido, P.E.
Project Manager

Approved by:

____
T. J. Wenner, P.E.
Engineering Manager
Structures & Materials Engineering

Date: 12/5/84

nutech ENGINEERS

REVISION CONTROL SHEET

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

This report summarizes the analyses performed by NUTECH to establish the basis for weld overlay repairs and to evaluate unrepaired flaw indications in the Recirculation System at Georgia Power Company's Plant E. I. Hatch Unit 1. Ultrasonic (UT) examination of the welds in this system during both the Fall 1982 and Fall 1984 outages identified flaws which were judged to be intergranular stress corrosion cracking (IGSCC).

Weld overlays have been applied to 17 of these welds during the Fall 1984 Outage. The purpose of each overlay is to arrest any further propagation of the cracking and to restore the original design safety margin to the weld. All of the flaws are in Type 304 stainless steel material. Tables 1.1 and 1.2 contain a description of each flaw indication as well as its disposition.

Flaw evaluations have been performed for 4 welds during this outage which were determined not to require weld overlay repair. The purpose of the evaluations is to assure that the original design safety margins for these welds has not been degraded. Tables 1.1 and 1.2 contain a description of these flaw indications.

Table 1.1

PLANT E. I. HATCH UNIT 1
FLAW DISPOSITION
FALL 1984 OUTAGE

Weld Number	Flaw Description	Overlay Design t	Overlay Design L/2(2)
1-B31-1RC-12AR-F-2	Circ. 20-30% x 360°	0.23	2.0
1-B31-1RC-12AR-F-3	Circ. 20-30% x 360°	0.23	2.0
1-B31-1RC-12AR-H-2	Circ. 20-30% x 360°	0.23	2.0
1-B31-1RC-12AR-H-3	Circ. 20-30% x 360°	0.23	2.0
1-B31-1RC-12AR-K-2	Circ. 30% x 360°	0.23	2.0
1-B31-1RC-12AR-K-3	Circ. 30% x 360°	0.23	2.0
1-B31-1RC-12AR-J-3	Circ. 20-30% x 360°	0.23	2.0
1-B31-1RC-12BR-C-2	Circ. 20-30% x 360°	0.23	2.0
1-B31-1RC-12BR-C-3	Circ. 25% x 360°	0.23	2.0
1-B31-1RC-12BR-D-3	Circ. 20% x 360°	0.23	2.0
1-B31-1RC-12BR-E-2	Circ. 25% x 360°	0.23	2.0
1-B31-1RC-12BR-E-3	Circ. 30% x 360°	0.23	2.0
1-E11-1RHR-24AR-13	Axial 50% x 1.75"	two layers (2)	
1-B31-1RC-28A-10	Circ. 50% x360°	0.42	4.25(3)
1-B31-1RC-28B-11	Circ. 49% x360°	0.42	4.25(3)
1-B31-1RC-28B-3	Circ. 32% x 360°	0.44	3.0
1-B31-1RC-28B-4	Circ. 31% x 360°	0.44	3.0
1-B31-1RC-28B-16	Axial 17% x 1"	No Overlay	
1-B31-1RC-28A-6	Axial 16% x 0.5"	No Overlay	
1-B31-1RC-22AM-1BC-1	Circ. Under 10%	No Overlay	
1-B31-1RC-22BM-1BC-1	Intermittent Circ.; Max. 30%	No Overlay	

Notes:
1. The effective thickness, t, is exclusive of the thickness of the initial layer.
2. L/2 = C/2 + 0.75" on valve side; L/2 = C/2 + 2.25" on tee side.
3. L/2 is entirely on the elbow side of the groove weld centerline.

Table 1.2

PLANT E. I. HATCH UNIT 1

FLAW DISPOSITION

FALL 1982 OUTAGE

Weld Number	Flaw Description	Overlay Design t	Overlay Design L/2
1-B31-1RC-22-AM-1	Axial 63% x 1/2"	0.25	*
1-B31-1RC-22-AM-4	Axial 72% x 1/2"	0.25	*
1-B31-1RC-22-BM-1	Axial 64% x 1/2"	0.25	*
1-B31-1RC-22-BM-4	Axial 67% x 1/2"	0.25	*
1-E11-1RHR-20-BD-3	Axial 94% x 3/8"	0.4	3.5
	Circ. 33% x 1-1/2"	0.4	3.5
1-E11-1RHR-24-BR-13	Axial 47% x 1/2"	0.3	4.0

* L/2 = 3.0" on pipe side; L/2 = 3.5" on end cap side

2.0 REPAIR DESCRIPTION

The UT flaw indications requiring repair have been remedied by increasing the pipe wall thickness through the deposition of weld metal 360° around and to either side of the existing weld. This is shown for a typical geometry in Figure 2.1. The weld-deposited band provides additional wall thickness to restore the original design safety margin. In addition, the welding process produces a strong compressive residual stress pattern on the inside portion of the pipe wall which prevents further crack growth. The deposited weld metal is Type 308L with controlled delta ferrite content so as to be resistant to propagation of IGSCC. Design and as-built information for all overlays is shown in Tables 1.1 and 2.1.

The nondestructive examination of each weld overlay consisted of:

1) Delta ferrite content measurement of the first overlay layer.

2) Surface examination of the completed weld overlay by the liquid penetrant examination technique in accordance with ASME Section XI (Reference 1).

3) Volumetric examination of the completed weld overlay by the ultrasonic examination technique in accordance with Plant E. I. Hatch Procedure.

Table 2.1

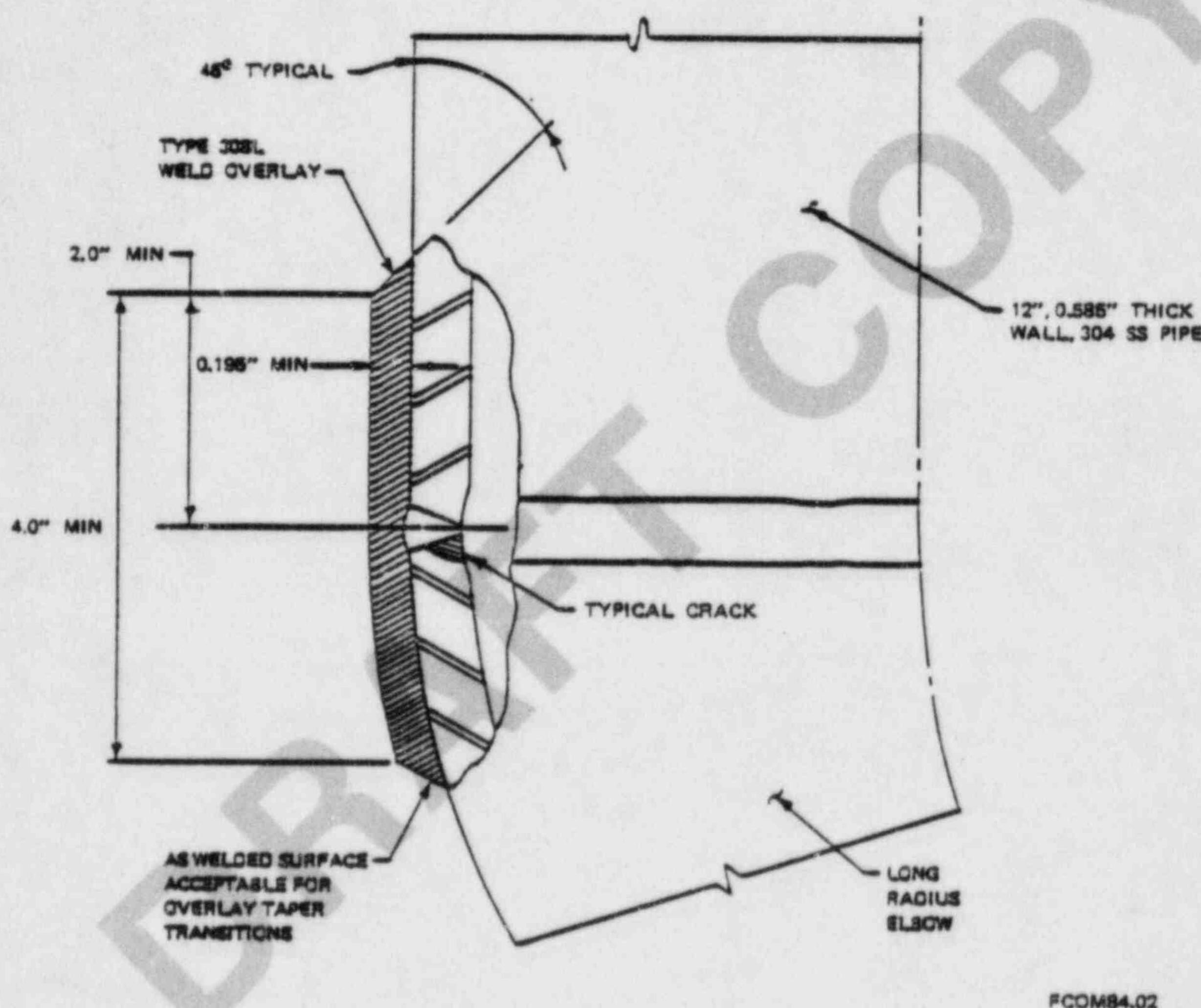
WELD OVERLAY AS-BUILT DIMENSIONS

Weld I.D.	As-Built Thickness	As-Built Length
1-B31-1RC-12AR-F-2	Later	Later
1-B31-1RC-12AR-F-3		
1-B31-1RC-12AR-H-2		
1-B31-1RC-12AR-H-3		
1-B31-1RC-12AR-K-2		
1-B31-1RC-12AR-K-3		
1-B31-1RC-12AR-J-3		
1-B31-1RC-12BR-C-2		
1-B31-1RC-12BR-C-3		
1-B31-1RC-12BR-D-3		
1-B31-1RC-12BR-E-2		
1-B31-1RC-12BR-E3		
1-E11-1RHR-24AR-13		
1-B31-1RC-28A-10		
1-B31-1RC-28B-11		
1-B31-1RC-28B-3		
1-B31-1RC-28B-4		

Figure 2.1

TYPICAL CONFIGURATION OF 12"

ELBOW-TO-PIPE WELD OVERLAY



PATENT APPLIED FOR

3.0 EVALUATION CRITERIA

This section describes the criteria used to establish the acceptability of the weld overlay repairs and flawed pipe analyses. All evaluations and repairs were performed in accordance with NRC Generic Letter 84-11, dated March, 1984.

3.1 Weld Overlay Repair Criteria

Because of the nature of these repairs, the geometric configuration is not specifically covered by Section III of the ASME Boiler and Pressure Vessel Code, which is intended for new construction. However, the materials, fabrication procedures, and quality assurance requirements used for weld overlay repairs are in accordance with applicable sections of this Code. The intent of the design criteria is to assure equivalent margins of safety for strength and fatigue considerations as provided in the ASME Section III Design Rules. In addition, because of the IGSCC conditions that led to the need for repairs, IGSCC resistant materials have been selected for the weld overlay. As a further means of assuring structural adequacy, criteria are also provided for fracture mechanics evaluation of the repairs.

Highly conservative assumptions were used for all evaluations. Axial and circumferential flaws in pipes with diameters less than or equal to 12" were assumed to be through-wall for the measured length and were evaluated in accordance with the criteria of References 1 and 2. Flaws in larger pipes were evaluated in accordance with the requirements of NRC Letter 84-11.

3.1.1 Strength Evaluation

The structural adequacy of the weld overlay repairs from a strength viewpoint with respect to applied mechanical loads was demonstrated by performing ASME Boiler and Pressure Vessel Code, Section III, Class 1 (Reference 3) analyses. These analysis bounded each weld overlay repair.

3.1.2 Fatigue Evaluation

The stress values obtained from the above strength evaluation were combined with thermal and other secondary stress conditions to demonstrate adequate fatigue resistance for the design life of each repair. The criteria for fatigue evaluation include:

1. The maximum range of primary plus secondary stress was compared to the secondary stress limits of Reference 3.

2. The peak alternating stress intensity, including all primary and secondary stress terms and a fatigue strength reduction factor of 5.0 to account for the existing crack, was determined using conventional fatigue analysis techniques. The total fatigue usage factor, defined as the sum of the ratios of applied number of cycles to allowable number of cycles at each stress level, must be less than 1.0 for the design life of each repair. The allowable number of cycles was determined from the stainless steel fatigue curve of Appendix I of Reference 3.

3.1.3 Fracture Mechanics Evaluation

A highly conservative method was used to demonstrate the adequacy of the weld overlay repair. The growth of the assumed flaw was calculated using a conservative crack growth correlation combined with the predicted residual stress and applied stress distribution. The weld overlay was designed such that the net section limit

would be satisfied for the predicted flaw size.

3.2 Flawed Pipe Analysis Criteria

The flawed welds which were determined not to require weld overlay repair meet the criteria given in Paragraph IWB-3600 of Reference 1 and Reference 4. A highly conservative crack growth law has been used to demonstrate that IGSCC induced flaws will not grow to a critical flaw size during the next fuel cycle.

4.0 LOADS

The loads considered in the evaluation of the UT flaw indications included mechanical loads, internal pressure, differential thermal expansion loads, and weld overlay shrinkage-induced loads. The mechanical and internal pressure loads used in the analyses are described in Section 4.1. A discussion of the thermal transient conditions which cause differential thermal expansion loads is presented in Section 4.2. The loads induced by weld overlay shrinkage are discussed in Section 4.3.

4.1 Mechanical and Internal Pressure Loads

The design pressures of 1325 psi (discharge side) and 1050 psi (suction side) were obtained from Reference 5. The deadweight and seismic loads were obtained from Reference 6.

4.2 Thermal Loads

The thermal loads for each weld were obtained from Reference 7.

4.3 Weld Overlay Shrinkage-Induced Stresses

Each weld overlay causes a small amount of axial shrinkage underneath the overlay. This shrinkage induces bending stresses in the remainder of the piping system. These shrinkage-induced stresses are calculated using NUTECH computer program PISTAR (Reference 8). The actual as-built shrinkages are used in the analysis. The resulting stresses are included in the crack growth analyses.

5.0 EVALUATION METHODS AND RESULTS

The flawed welds shown in Table 1.1 were identified by UT inspections during the Fall 1984 outage at Plant E. I. Hatch Unit 1. The flawed welds shown in Table 1.2 were identified during the Fall 1982 outage at Unit 1. For each flawed weld, the methods of Section 3 were applied to determine if an overlay was required to meet the requirements of References 1 and 4.

The evaluation of each weld overlay repair consists of a Code stress analysis per Section III (Reference 3) and a fracture mechanics evaluation per Section XI (Reference 1) and Reference 4. The flawed pipe analysis was performed per References 1 and 4.

The application of weld overlays produces a small amount of axial shrinkage which in turn imposes steady state secondary stresses in the affected systems. Analyses to quantify this effect and address its significance are discussed in Section 5.5.

5.1 Description of Geometries Analyzed

Six distinct flaw geometries required weld overlay at E. I. Hatch Unit 1. These were: 12-inch diameter pipe-to-

elbow (14 cases), 28-inch diameter pipe-to-elbow (2 cases), 28-inch diameter elbow-to-pump (2 cases), 24-inch diameter tee-to-valve (1 case), 22-inch diameter pipe-to-end cap (4 cases), and 24-inch diameter pipe-to-pipe (1 case). Code stress and fracture mechanics evaluations for these cases (which envelope the geometries listed in Tables1.1 and 1.2) are summarized in Tables 5.1 to 5.6. Analysis results for the locations with axial flaws only are discussed in Section 5.4.

5.2 Code Stress Analysis

Finite element models of the weld overlaid regions were developed using the ANSYS (Reference 9) computer program. The models (Figure 5.1 is an example) were based on a composite worst case flaw and on design minimum overlay thickness. The as-built thickness is greater than or equal the design thickness. The stresses in the overlaid weld due to design pressure and applied moments as described in Sections 4.1 and 4.2 were calculated using the models.

The results of Code stress analyses per Reference 3 are given in Tables 5.1 through 5.6. The allowable stress

values from Reference 3 are also given. The weld overlay repair satisfies the Reference 3 requirements.

The weld overlay thermal model was taken to be axisymmetric (Figure 5.3). The exterior boundary was assumed to be insulated. The temperature distributions in the weld overlay, subject to the thermal transients defined in Section 4.2, were calculated using Charts 16 and 23 of Reference 10.

The maximum thermal stress for use in the fatigue analysis was calculated using the following equation:

$$\sigma = \frac{E\alpha\Delta T_1}{2(1-\nu)} + \frac{E\alpha\Delta T_2}{1-\nu} \qquad \text{(Reference 3)}$$

where:

E = 28.3×10^6 psi (Young's Modulus)

α = $9.11 \times 10^{-6}\,°F^{-1}$
(Coefficient of Thermal Expansion)

ΔT_1 = Equivalent Linear Temperature Difference

ΔT_2 = Peak Temperature Difference

ν = 0.3 (Poisson's Ratio)

The values of ΔT_1, ΔT_2, and σ are given in Table 5.7 for the thermal transients.

A conservative fatigue analysis per Reference 3 was performed. A fatigue strength reduction factor of 5.0 was applied due to the crack. The fatigue usage factor was then calculated assuming the thermal transients discussed in Section 4.2. These results are also summarized in Tables 5.1 through 5.6.

5.3 Fracture Mechanics Evaluation

The allowable crack depth was calculated based on References 1 and 4. Crack growth due to fatigue was determined based on Reference 11. Calculation of crack growth due to IGSCC was based on References 12 and 13.

From Reference 11, the calculated fatigue crack growth is less than 0.01 inch during the next five years. The weld overlays applied to welds at Plant E. I. Hatch Unit 1 produce a highly compressive residual stress pattern in the inside portion of the pipe wall. For the circumferential flaws identified, this residual stress pattern will effectively arrest further IGSCC crack growth. Thus, no further degradation of the integrity of these welds is anticipated. Crack growth analyses using the calculated residual stress pattern (Figure 5.4) and a conservative crack growth law (see Section

5.6) were performed with NUTECH computer program NUTCRAK (Reference 13).

Growth of a flaw due to IGSCC requires a susceptible material. Since the cracks found at Plant E. I. Hatch Unit 1 are assumed to go through the original wall, any additional postulated IGSCC growth would have to occur into the weld overlay, which is not susceptible due to the controlled ferrite content of its duplex (austenite and delta ferrite) structure. Measurements of delta ferrite for the first overlay layer show a delta ferrite content which is generally greater than 7.5 FN. This is judged to be sufficiently high to prevent IGSCC propagation into the weld overlay.

5.4 Treatment of Axial Flaws

Axial IGSCC crack length is limited on either end by the original weld and the extent of sensitized material in the weld heat affected zone (HAZ). The tabulated allowable axial crack sizes in Reference 1 are truncated at a maximum depth of 75% of the pipe thickness and are therefore very conservative for axial IGSCC.

The ASME Code minimum thickness is based on maintaining a factor of safety of three against pipe failure. Pipe

thickness in excess of the Code minimum thickness provides a reserve margin which can be used to tolerate short, through-wall (or less than through-wall) axial cracks. The length of through-wall axial cracks which results in a factor of safety of 3.0 during normal operation is calculated in Reference 2 as a function of the applied stress.

Whenever the combination of an axial crack and applied stress results in a factor of safety of 3.0 or more, the axial crack, even if it is through-wall, maintains the originally required Code safety factor.

5.5 Effect on Recirculation System

The effects of the radial shrinkage are limited to the region adjacent to and underneath the overlay. Based on Reference 11, the stresses due to the radial shrinkage are less than yield stress at distances greater than 4 inches from the ends of the overlay. Weld residual stresses are steady state secondary stresses and are not limited by the ASME Code (Reference 3).

The effect of the axial weld shrinkage on the repaired systems were evaluated with the NUTECH computer program PISTAR (Reference 8) using the piping model shown in

Figure 5.5. The measured shrinkages of all weld overlay repairs were imposed as boundary conditions on this model. Since the ASME Code does not limit weld residual stress, all stress indices were set equal to 1.0.

Since weld shrinkage-induced stresses are not limited by the ASME Code, the Code acceptability of these welds is not in question. It is judged that stresses of the magnitude calculated will have negligible effect on the integrity or IGSCC susceptibility of these welds.

5.6 Evaluation of Flaws in Unrepaired Welds

The prediction of crack growth for the flaws in unrepaired welds required the following inputs:

1) Steady state applied stress.
2) Weld residual stress.
3) Flaw characterization.
4) Crack growth model.
5) Crack growth law.

The approach was to use conservative input for applied stress, residual stress, crack growth model and crack growth law. Thus, the result of the analysis is a very conservative prediction of crack depth versus time.

nutech ENGINEERS

The steady state moment due to operating pressure, dead weight and thermal expansion was obtained from References 5, 6, and 7. In addition, the moment due to the axial weld shrinkage of the overlays was added to the other steady state moments (Section 5.5). The stress in the unrepaired weld due to weld shrinkage is negligible.

A conservative crack growth correlation for weld sensitized material was used and is given below:

$$\frac{da}{dT} = 1.697 \times 10^{-8} K^{2.53}$$

where:

da = Differential crack size (inch)

dT = Differential time (hour)

K = Applied stress intensity factor (ksi-$\sqrt{in}$)

The crack growth model is a linear interpolation between an inside diameter (I.D.) cracked cylinder and an edge-cracked plate. The crack growth model assumes a 360° crack. The magnification factors for both an I.D. cracked cylinder and an edge-cracked plate were obtained from Reference 13.

The predicted crack growth for the unrepaired flaws was calculated with the NUTECH computer program NUTCRAK (Reference 13). Allowable crack depth was obtained by taking 2/3 of the Reference 1 source equation values, as required by Reference 4. This analysis indicates that the flaw indications will not grow to their allowable sizes.

Table 5.1

12" PIPE-TO-ELBOW CODE STRESS RESULTS

LATER

Table 5.2

28" PIPE-TO-ELBOW CODE STRESS RESULTS

LATER

Table 5.3

28" ELBOW-TO-PUMP CODE STRESS RESULTS

LATER

Table 5.4

24" TEE-TO-VALVE CODE STRESS RESULTS

LATER

Table 5.5

22" PIPE-TO-END CAP CODE STRESS RESULTS

LATER

Table 5.6

24" PIPE-TO-PIPE CODE STRESS RESULTS

LATER

nutech ENGINEERS

Table 5.7

THERMAL GRADIENT RESULTS

LATER

Table 5.8

PLANT E. I. HATCH UNIT 1

WELD OVERLAY INDUCED SHRINKAGE STRESSES*

Weld ID	Stress (psi)
LATER	

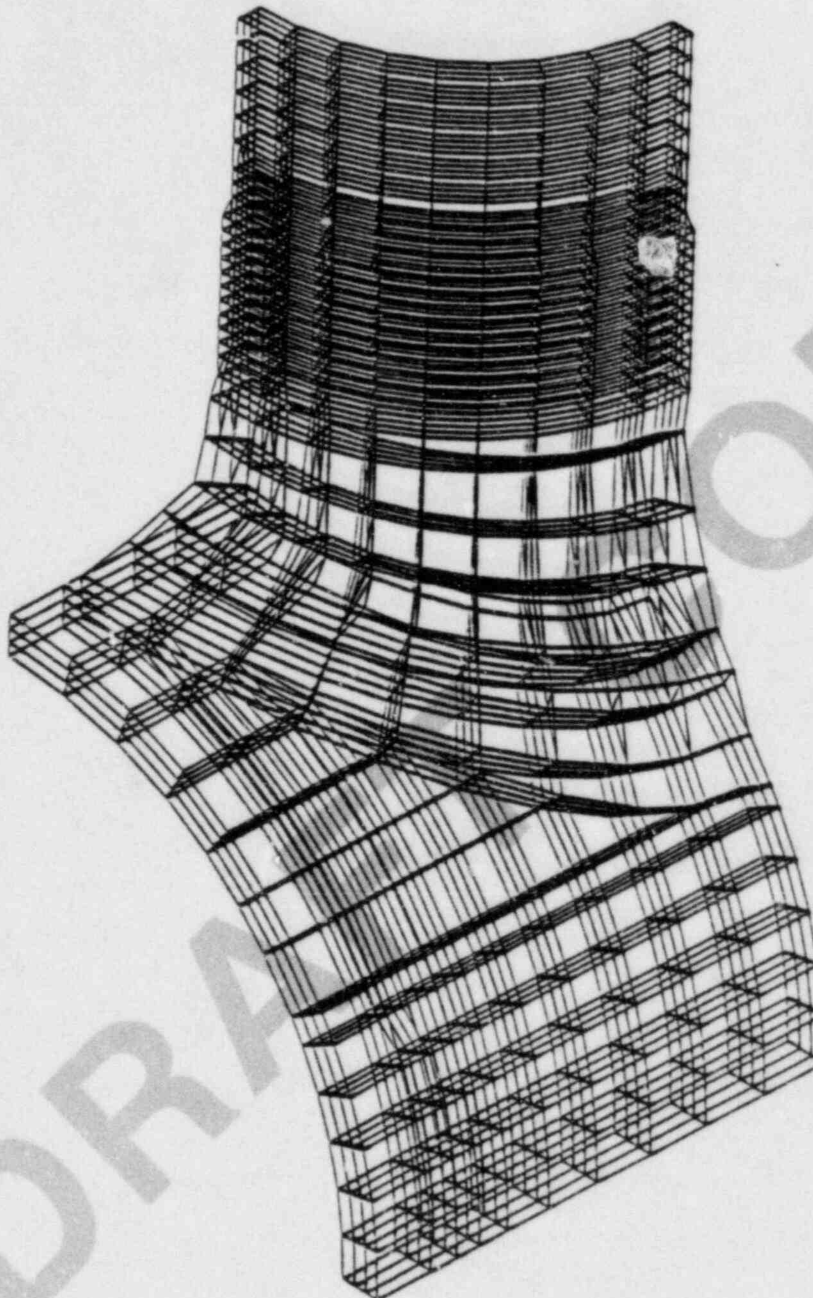


Figure 5.1

Finite Element Model of 12"

Pipe-to-Sweepolet Weld

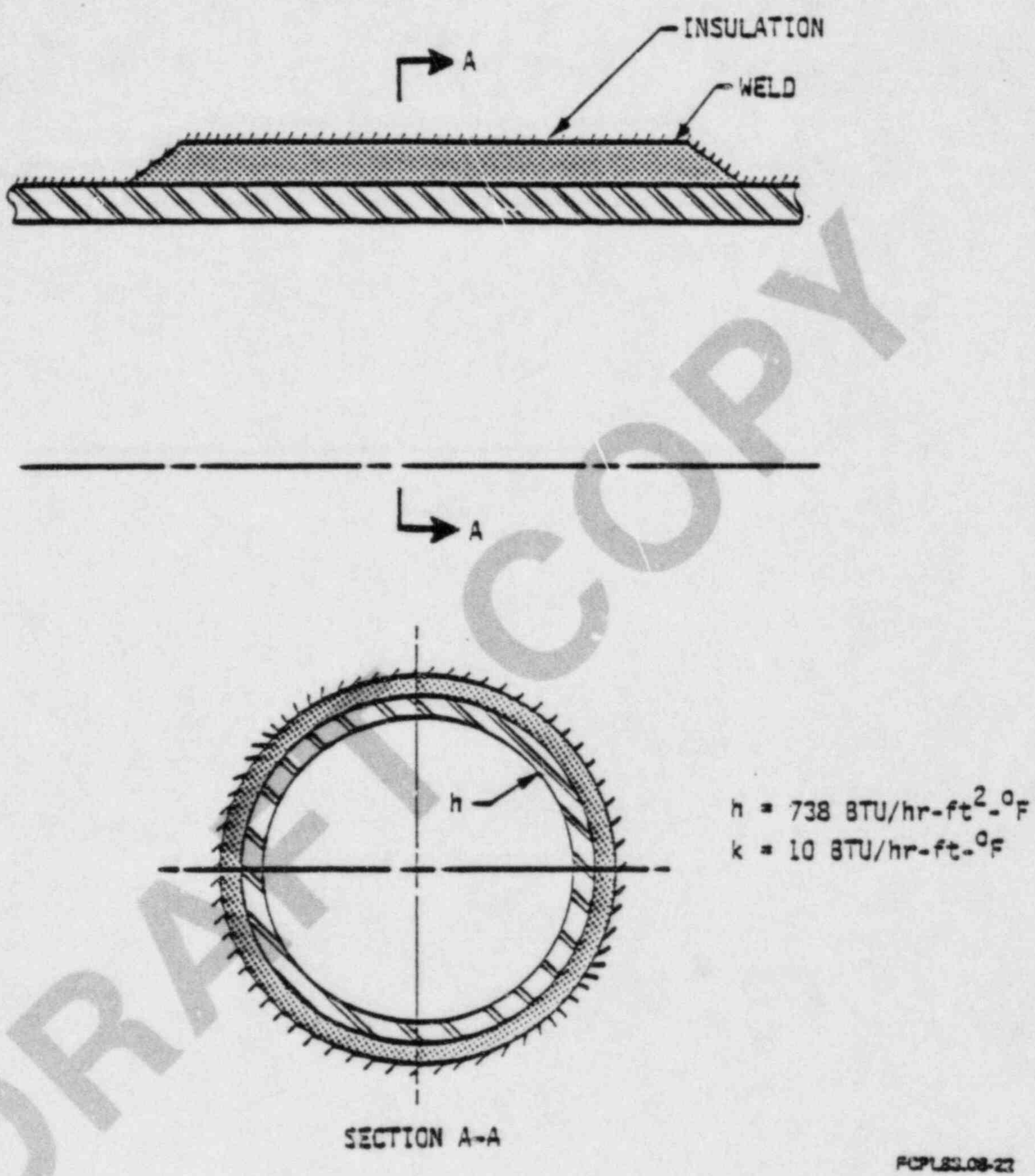


Figure 5.2

Weld Overlay Thermal Model

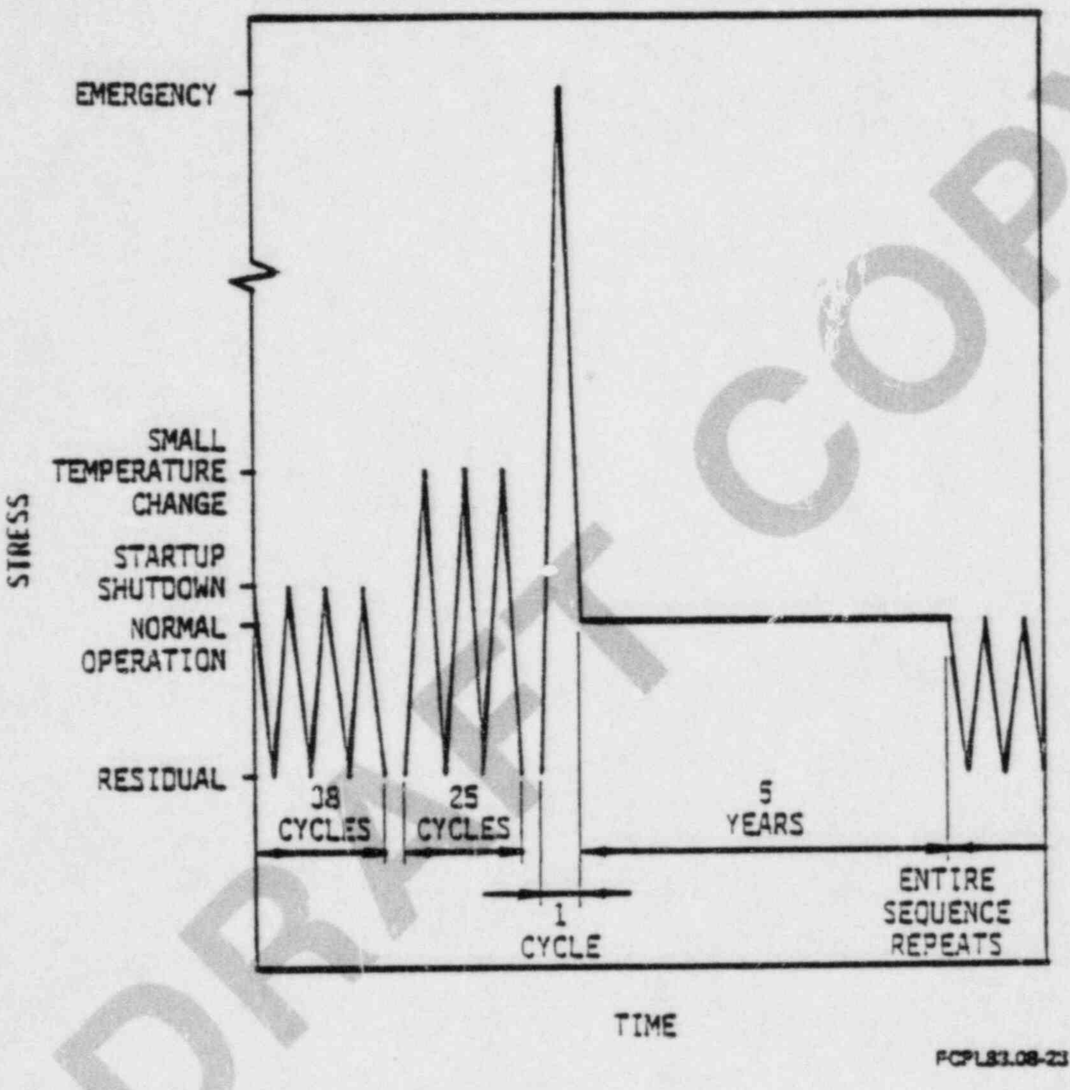


Figure 5.3

Thermal Transients

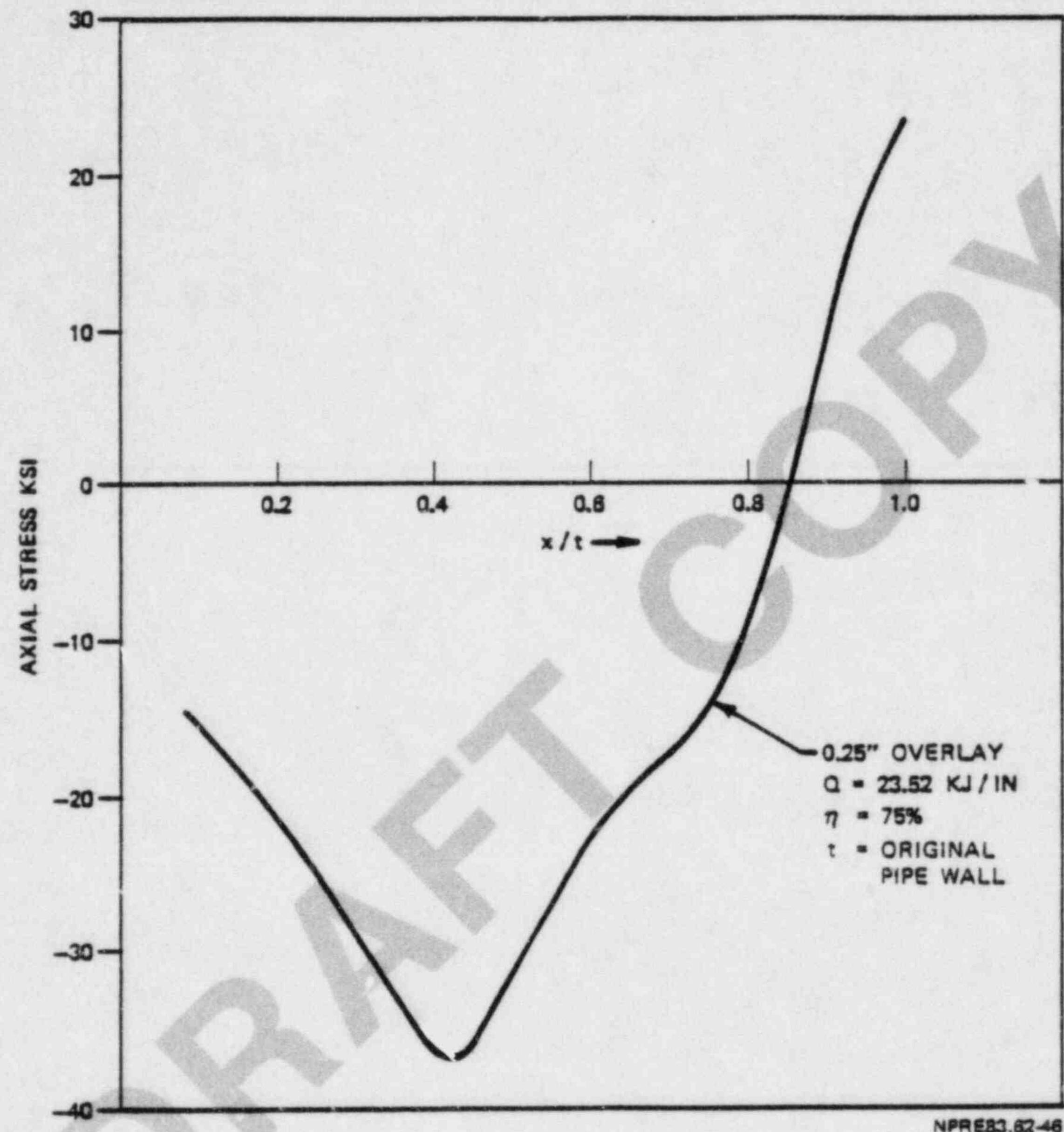


Figure 5.4

Typical Axial Weld Residual Stress Distribution in 12" Pipe After Overlay

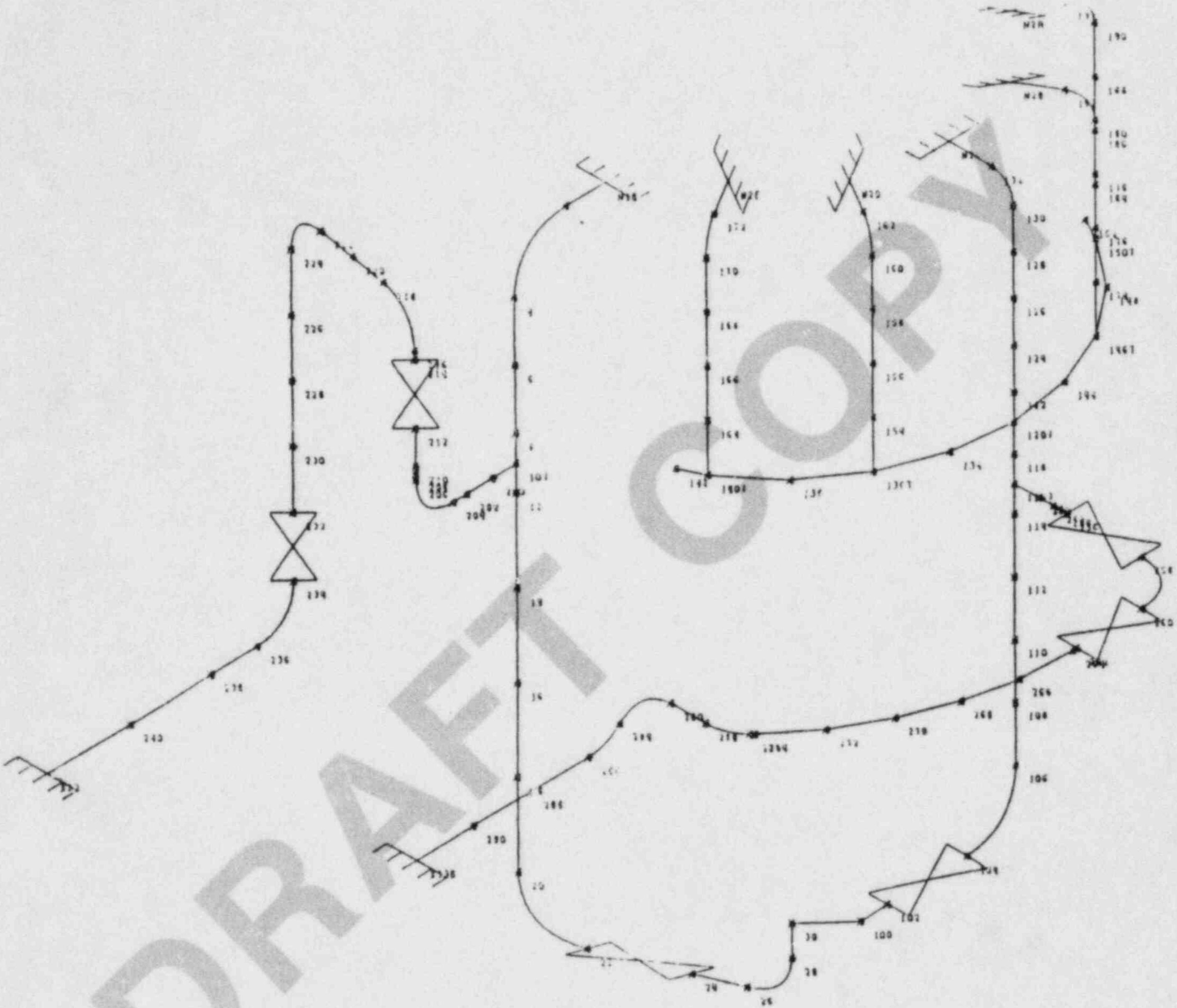


Figure 5.5

E. I. Hatch Unit 1 Recirculation

System Piping Model

6.0 LEAK-BEFORE-BREAK ASSESSMENT

For welds with undetected flaws, or containing IGSCC indications which are judged to be small enough to not require a repair, the following considerations form the basis for continued plant operation for another fuel cycle.

6.1 Net Section Collapse

The effect of IGSCC on the structural integrity of piping is evaluated through the use of a simple "strength of materials" approach to assess the load carrying capacity of a piping section after the cracked portion has been removed. Studies have shown (References 12 and 14) that this approach gives a conservative, lower-bound estimate of the loads which would cause unstable fracture of the cracked section. Typical results of such an analysis are shown in Figure 6.1 (Reference 12). This figure defines the locus of limiting crack depths and lengths for circumferential cracks which are predicted by the net section collapse method to cause failure. Curves are presented for both typical piping system stresses and stress levels equal to ASME Code limits. Note that a very large percentage

of pipe wall can be cracked before reaching these limits (40% to 60% of circumference for through-wall cracks, and 65% to 85% of wall thickness for 360° part-through cracks).

Also shown in Figure 6.1 is a sampling of cracks which have been detected in service, either through UT examination or leakage. In each case there has been a significant margin between the size of crack observed and that predicted to cause failure under service loading conditions. Also, as discussed below, there is still considerable margin between these net section collapse limits and the actual cracks which would cause instability.

6.2 Tearing Modulus Analysis

Elastic-plastic fracture mechanics analyses are presented in Reference 14 which give a more accurate representation of the crack tolerance capacity of stainless steel piping than the net section collapse approach described above. Figures 6.2 and 6.3 graphically depict the results of such an analysis (Reference 14). Through-wall circumferential defects of arc length equal to 60° through 300° were assumed at various cross sections of a typical BWR

Recirculation System. Loads were applied to these sections of sufficient magnitude to produce net section limit load, and the resulting values of tearing modulus were compared to that required to cause unstable fracture (Figure 6.2). Note that in all cases there is substantial margin, indicating that the net section collapse limits of the previous section are not really failure limits. Figure 6.3 summarizes the results of all such analyses performed for 60° through-wall cracks in terms of margin on tearing modulus for stability. The margin in all cases is substantial.

6.3 Leak Versus Break Flaw Configuration

Of perhaps more significance to the leak-before-break argument is the flaw configuration depicted in Figure 6.4. This configuration addresses the concerns raised by the occurrence of part-through flaws growing circumferentially before breaking through the outside surface to cause leakage. Figure 6.4 presents typical size limitations on such flaws based on the conservative net section collapse method of Section 6.1. Note that very large crack sizes are predicted. Also shown on this figure are typical detectability limits for short through-wall flaws

(which are amenable to leak detection) and long part-through flaws (which are amenable to detection by UT). The margins between the detectability limits, and the conservative, net section collapse failure limits are substantial. It is noteworthy that the likelihood of flaws developing which are characterized by the vertical axis shown in Figure 6.4 (constant depth 360° circumferential cracks) is so remote as to be considered impossible. Material and stress asymmetries always tend to propagate one portion of the crack faster than the bulk of the crack front, which will eventually result in "leak-before-break." This observation is borne out by extensive field experience with BWR IGSCC.

6.4 Axial Cracks

Many of the IGSCC occurrences at Plant E. I. Hatch Unit 1 were short, axial cracks. These can grow through the wall but remain short in the axial direction. This behavior is consistent with expectations for axial IGSCC since the presence of a sensitized weld heat-affected zone is necessary, and this heat-affected zone is generally limited to approximately 0.25 inch on either side of the weld. Since the major loadings in the net section collapse

analysis are bending moments on the cross section due to seismic loadings, and since these loads do not exist in the circumferential direction, the above leak-before-break arguments are even more persuasive for axially oriented cracks. There is no known mechanism for axial cracks to lengthen before growing through-wall and leaking, and the potential rupture loading on axial cracks is less than that on circumferential cracks.

6.5 Multiple Cracks

Analyses performed for EPRI (Reference 15) indicate that the occurrence of multiple cracks in a weld, or cracking in multiple welds in a single piping line does not invalidate the leak-before-break arguments discussed above.

6.6 Nondestructive Examination

The primary means of nondestructive examination for IGSCC in BWR piping is ultrasonics. This method has been the subject of considerable research and development in recent years, and significant improvements in its ability to detect IGSCC have been achieved. Figure 6.4 illustrates a significant

aspect of UT detection capability with respect to leak-before-break. The types of cracking most likely to go undetected by UT are relatively short circumferential or axial cracks which are most amenable to detection by leakage monitoring. Conversely, as part-through cracks lengthen, and thus become more of a concern with respect to leak-before-break, they become more readily detectable by UT.

6.7 Leakage Detection

Typically, leakage detection for BWR reactor coolant system piping is through sump level and drywell activity monitoring. These systems have sensitivities on the order of 1.0 gallon per minute (GPM). Plant technical specification and administrative limits typically require investigation/corrective action at 5.0 GPM unidentified leakage, or when there is a 2.0 GPM increase in unidentified leakage in a 24 hour period.

Table 6.1 provides a tabulation of typical flaw sizes which cause 5.0 GPM leakage in various size piping assuming a membrane stress of $S_m/2$ (Reference 10).

Also shown in this table are the critical crack lengths for through-wall cracks based on the net section collapse method of analysis discussed above. For conservatism, the leakage values are based on pressure stress only, while the critical crack lengths are based on the sum of all combined loads, including seismic. Considering other normal operating loads in the leakage analysis would result in higher rates of leakage for a given crack size. Note that there is considerable margin between the crack length which produces 5.0 GPM leakage and the critical crack length, and that this margin increases with increasing pipe size.

6.8 Historical Experience

The above theories regarding crack detectability have been supported by experience (Reference 15). Indeed, of the large number of IGSCC incidents to date in BWR piping, none have come close to violating the structural integrity of the piping.

Table 6.1

EFFECT OF PIPE SIZE ON THE RATIO OF THE CRACK LENGTH FOR 5 GPM LEAK RATE AND THE CRITICAL CRACK LENGTH (ASSUMED STRESS $\sigma = S_m/2$)

NOMINAL PIPE SIZE	CRACK LENGTH FOR 5 GPM LEAK (in.)	CRITICAL CRACK LENGTH ℓ_c (in.)	ℓ/ℓ_c
4" SCH 80	4.50	6.54	0.688
10" SCH 80	4.86	15.95	0.305
24" SCH 80	4.97	35.79	0.139

FCPL83.08-09

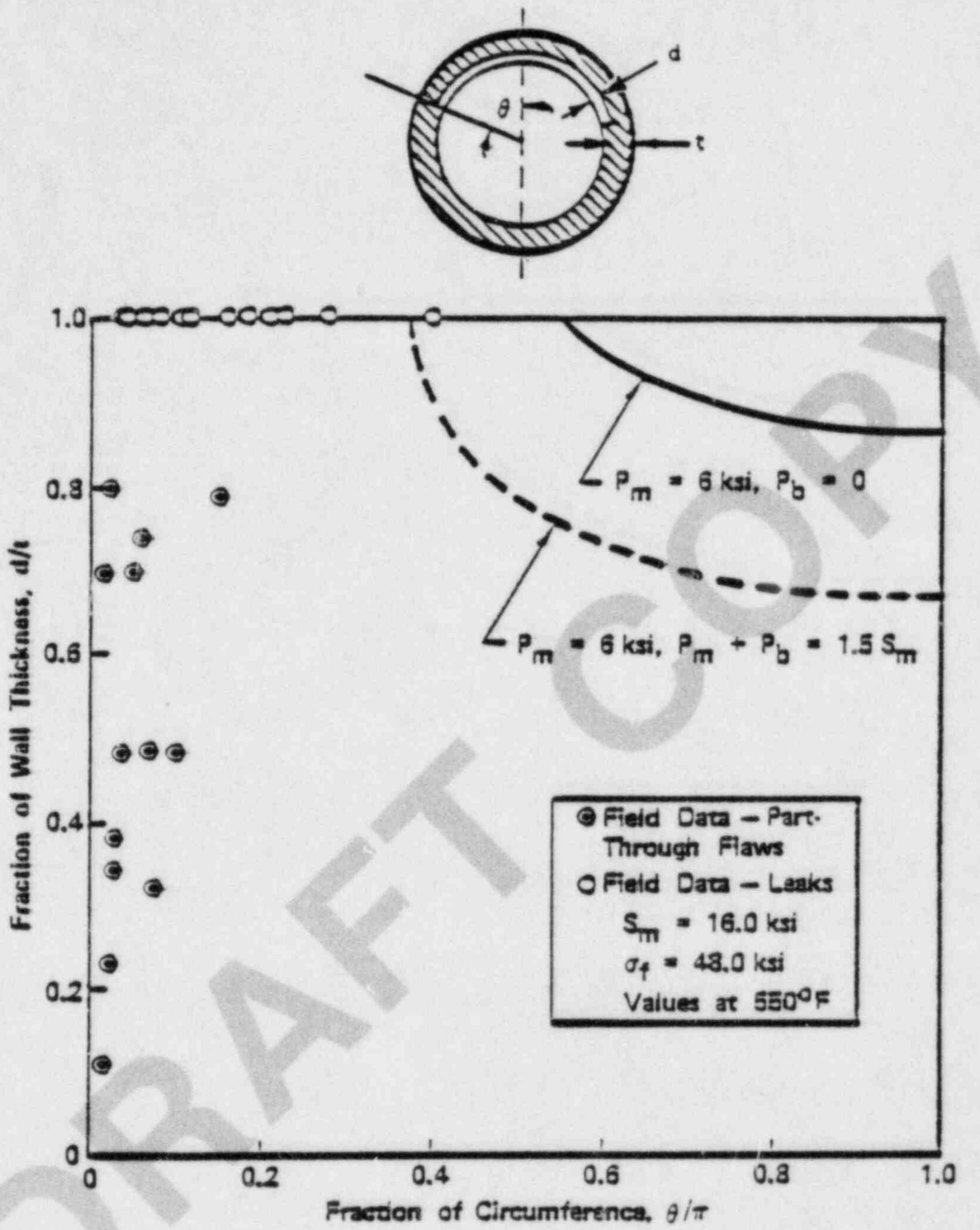


Figure 6.1

Typical Result of Net Section Collapse Analysis of Cracked Stainless Steel Pipe

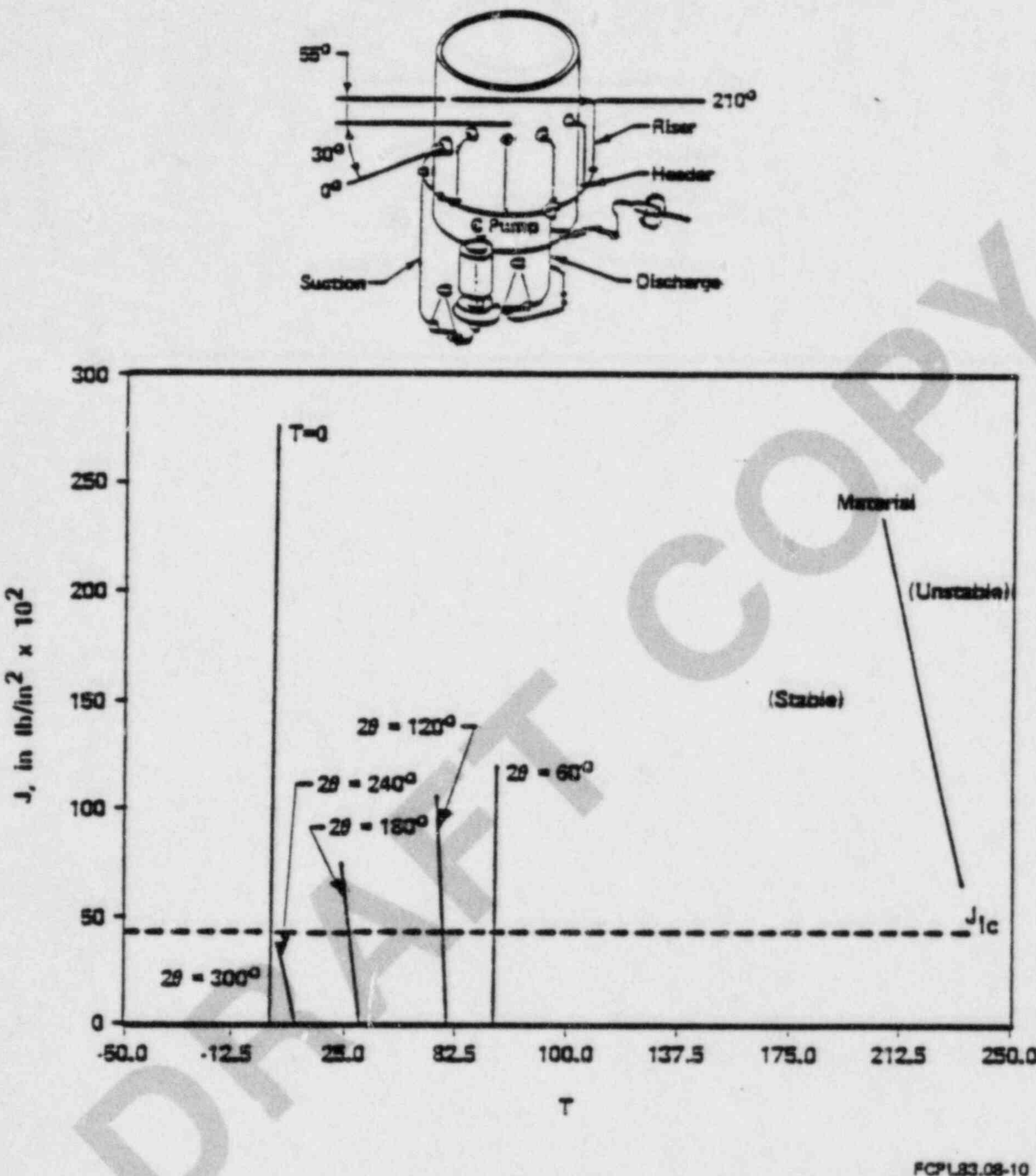


Figure 6.2

<u>Stability Analysis for BWR Recirculation System</u>

<u>(Stainless Steel)</u>

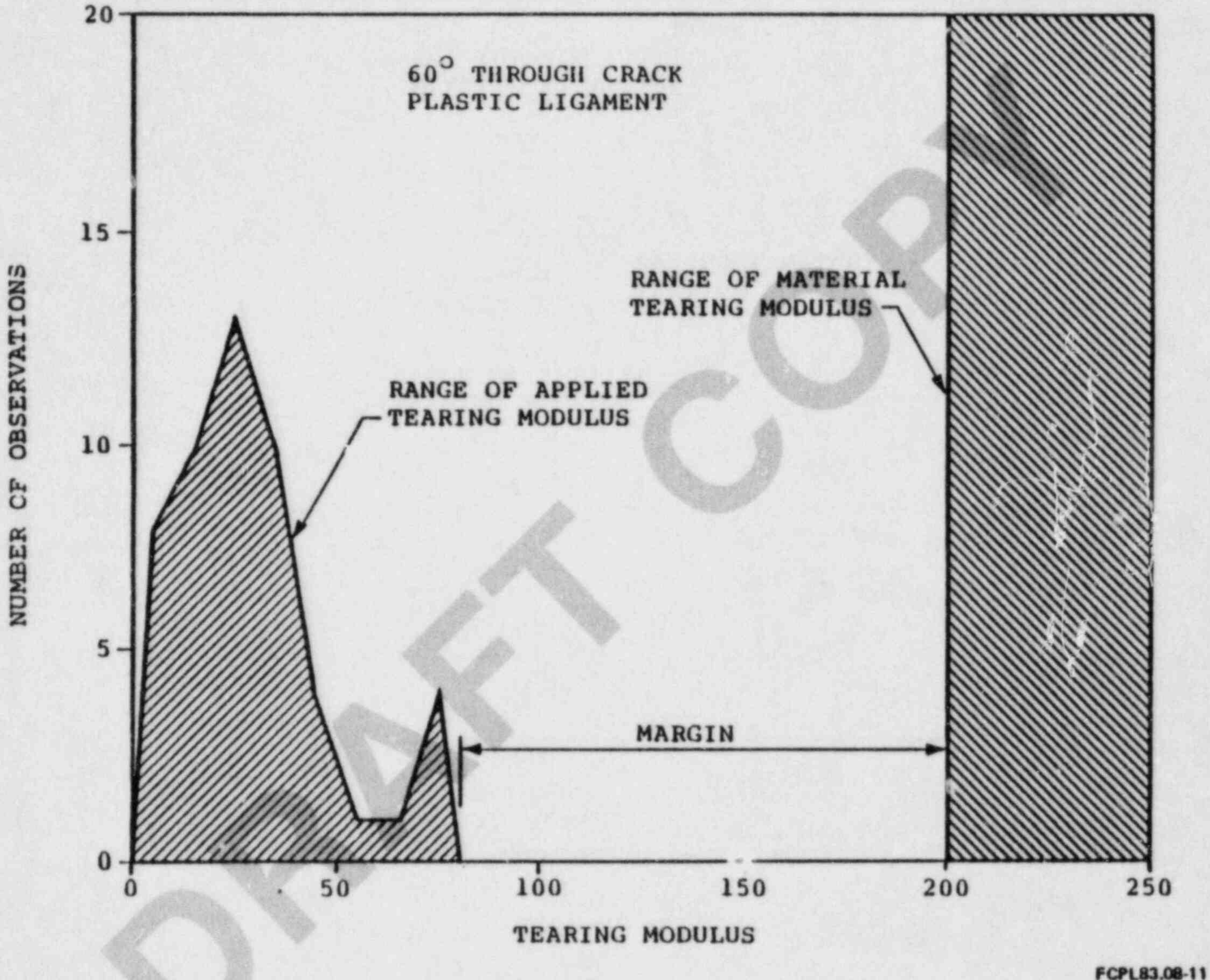


Figure 6.3

Summary of Leak-Before-Break Assessment

of BWR Recirculation System

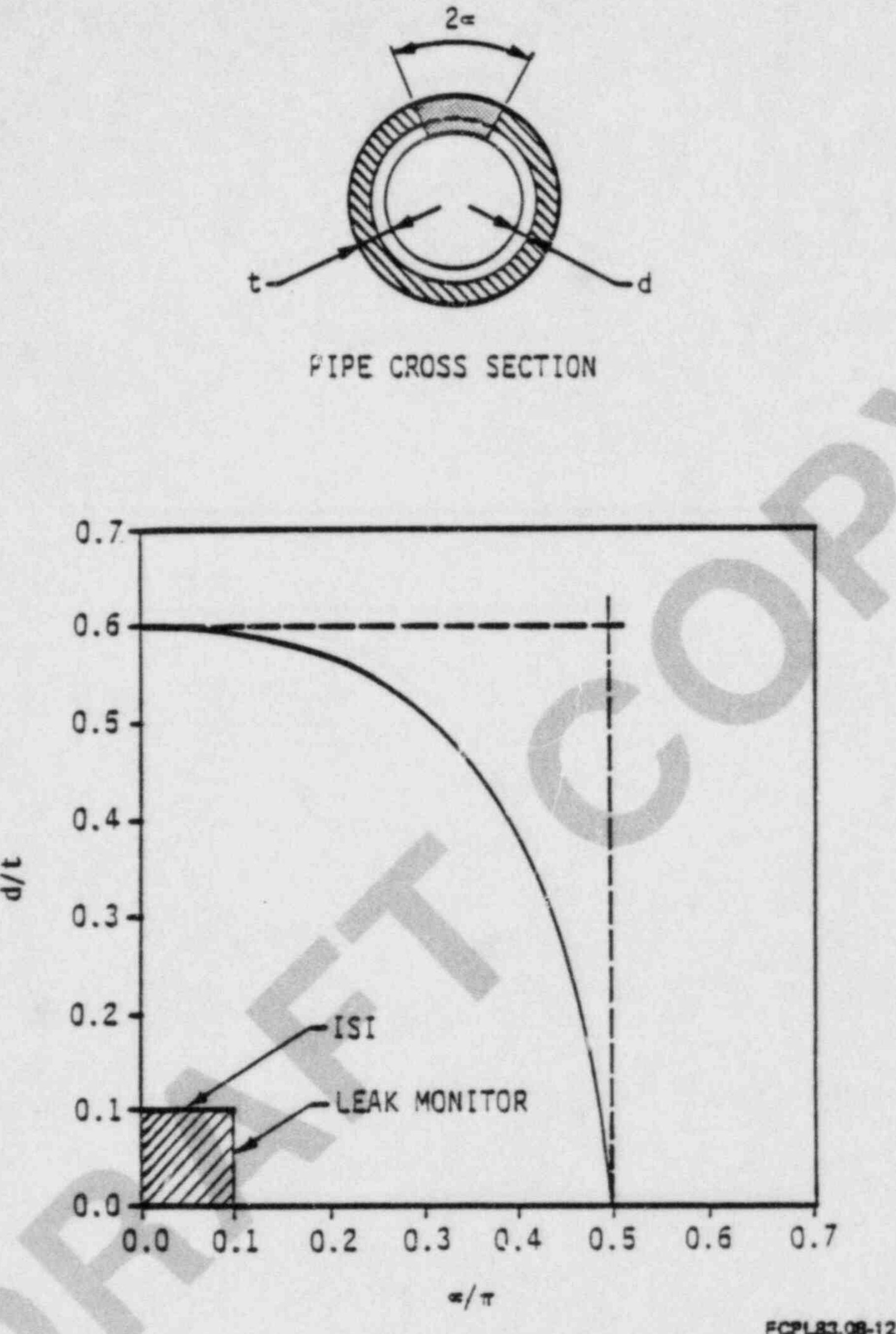


Figure 6.4

Typical Pipe Crack Failure Locus for Combined Through-Wall Plus 360° Part-Through Crack

7.0 SUMMARY AND CONCLUSIONS

Evaluation of the repairs to the Recirculation System reported herein shows that the resulting stress levels are acceptable for all design conditions. The stress levels have been assessed from the standpoint of load capacity of the components, fatigue, and the resistance to crack growth.

Acceptance criteria for the analyses have been established in Section 3.0 of this report which demonstrate that:

1. There is no loss of design safety margin over that provided by the current Code for Class 1 piping and pressure vessels (ASME Section III).

2. During the design evaluation period of 1 cycle for each repair, the observed cracks will not grow to the point where the above safety margins would be reduced.

Analyses have been performed and results are presented which demonstrate that the repaired welds satisfy these criteria by a large margin. Analyses have also been performed which demonstrate that the

unrepaired welds satisfy these criteria. Furthermore, it is concluded that IGSCC experienced in the Reactor Recirculation System at Plant E. I. Hatch Unit 1 does not increase the probability of a design basis pipe rupture at the plant. This conclusion expressly considers the nature of the cracking which has been identified at Plant E. I. Hatch Unit 1, and the likelihood that other similar cracking may have gone undetected. The conclusion is based primarily on the extremely high inherent toughness and ductility of the stainless steel piping material. Cracks in such piping grow through-wall and leak before affecting its structural load carrying capacity.

8.0 REFERENCES

1. ASME Boiler and Pressure Vessel Code Section XI, 1983 Edition, Winter 1983 Addendum.

2. NUTECH Report COM-76-001, "Weld Overlay Design Criteria for Axial Cracks," Revision 0, March 1984, NUTECH File COM076.0208.

3. ASME Boiler and Pressure Vessel Code, Section III, (Subsection NB and Appendix I) 1980 Edition with Addenda through Summer 1980.

4. NRC Generic Letter 84-11, dated April 19, 1984, NUTECH File No. COM096.0010.0001.

5. Later

6. GE Letter No. G-GPC-4-500, "Hatch 1 Seismic Evaluation for Replacement Recirculation Valve Operators", NUTECH File XGP009.0025.

7. NUTECH Calculation Package No. GPC-04-303, "Weld Overlay Thermal Analysis, PISTAR Piping Analysis", NUTECH File XGP009.0025.

8. NUTECH Computer Program PISTAR, Version 2.0, Users Manual, Volume 1, TR-76-002, Revision 4, File No. 08.003.0300.

9. ANSYS Computer Program, Swanson Analysis Systems, Revision 4, NUTECH File No. 08.061.

10. Schneider, P.J., "Temperature Response Charts," John Wiley and Sons, 1963.

11. NUTECH Report NSP-81-105, Revision 2, "Design Report for Recirculation Safe End and Elbow Repairs, Monticello Nuclear Generating Plant," December 1982, File No. 30.1281.0105.

12. EPRI-NP-2472, "The Growth and Stability of Stress Corrosion Cracks in Large-Diameter BWR Piping," July 1982.

13. NUTECH Computer Program NUTCRAK, Version 2.0, Revision 2, December 1983, File No. 08.039.0005.

14. EPRI-NP-2261, "Application of Tearing Modulus Stability Concepts to Nuclear Piping," February 1982.

15. Presentation by EPRI and BWR Owners Group to U. S. Nuclear Regulatory Commission, "Status of BWR IGSCC Development Program," October 15, 1982.