Jersey Central Power & Light Company

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MEMBER OF THE General GPU ELECTRIC POWER COMPANIES SYSTEM Public Utilities Corporation

June 17, 1974

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Mr. A. Giambusso
Deputy Director of Reactor Projects
Directorate of Licensing
Office of Regulation
United States Atomic Energy Commission
Washington, D. C. 20545

Subject: Oyster Creek Station, Docket No. 50-219
Special Report of Investigations and
Repair of In-Core Flux Monitor Penetration

Dear Mr. Giambusso:

This letter is intended to transmit to your office 20 copies of our report entitled, "Report of Investigations and Repair of In-Core Flux Monitor Penetrations." Your timely concurrence with our evaluation and resolution of this matter is requested.

Please advise if you desire any additional information.

Very truly yours,

Donald A. Ross

Donald A. Ross
Manager,
Nuclear Generating Stations

Enclosures

cc: Mr. J. P. O'Reilly, Director
Regulatory Operations, Region 1
(w/enclosure)

Docket 50-219

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June 17, 1974

REPORT OF INVESTIGATIONS AND REPAIR OF IN-CORE FLUX MONITOR PENETRATION

Introduction

During planned leak testing of the Oyster Creek reactor coolant system in May 1974, seepage of water was observed from one of the in-core flux monitor housings which penetrate the lower reactor vessel hemispherical head. The leakage rate at 850 psi was estimated to be less than 2 ml/min and emanated from the annular area between the OD of the housing and the machined penetration in the lower vessel head at location No. 28-05. The configuration of the housing, the materials used, and the location of the observed seepage are shown in Figures 1 and 2. This in-core housing has not been in use, does not contain a flux monitor tube, and is capped with a blind flange.

Visual examination of the lower head area also revealed evidence of a white deposit about 1/2 to 1-inch wide around the periphery of in-core penetration 28-05 on the outer surface of the manganese-molybdenum head and the stainless steel housing. Examination of the other penetrations of the lower head area, including in-core housings and control rod drive penetrations, revealed no evidence of leakage and no other unusual indications with the exception that a small amount of light colored deposit similar in appearance to that found at in-core penetration 28-05 was observed around the periphery of CRD penetration 18-47. The amount of deposit was much less than in the case of in-core penetra-

tion 28-05. A photograph of location 28-05 while at pressure is shown in Figure 3. A second photograph taken later at ambient pressure, which also includes a view of a control rod drive housing, is shown in Figure 4. Control rod drive housing 18-47 is shown in Figure 5. No leakage or weepage was observed during the leak test of the reactor vessel at any of the in-core or CRD housings other than at in-core housing 28-05 mentioned previously.

Investigations Performed

As a result of the observations outlined above, the following examinations and analyses were initiated:

1. Visual Examination of the Lower Head Area - A portion of the insulation was removed to permit better viewing of the lower head area and a more complete visual examination of the in-core penetrations and the control rod drive housings was performed. (Approximately 75% of the in-core penetrations and approximately 80% of the CRD penetrations could be directly observed.) This examination confirmed the initial observations discussed above. There was no leakage from any of the other housings.

2. Chemical and Radiolytic Analysis of the White Deposit from In-Core Penetration 28-05 and from CRD Penetration 18-47 - Scrapings from these locations were taken and both chemical and radioactive isotope analyses have been and are being performed. In this regard, it was noted that the color of the deposit which appeared white on the vessel head was predominately rust colored when scraped off.

The radioactive isotope analysis of the deposit from in-core penetration 28-05 showed the following:

Isotope	Energy (Kev)	Counts/Min.	Specific Activity (μCi/1000 gm)
CO 60	1174	18.4	0.003
CO 60	1332	14.5	0.003
CS 134	1039	27.6	0.042
CS 134	569	748.8	0.40
CS 134	604	4506.3	0.40
CS 134	796	3037.0	0.43
CS 137	662	7760.9	0.92

On the other hand, the analysis of the deposit scraped from the area around CRD penetration 18-47 showed no radioactivity.

Chemical analyses of the deposits have not yet been completed, but will be forwarded as Amendment 1 to this report following receipt and evaluation of the results.

3. Chemical Analysis of Water Sample from In-Core Housing 28-05 - A water sample was taken from in-core housing 28-05 prior to removal of the blind flange. The chemistry analysis of this water sample showed the following:

Chloride ion -	35 ppb
Conductivity -	1.9 μmhos/cm
pH -	6.5

This water chemistry is within the reactor coolant chemistry limits given in the Oyster Creek Technical Specifications and would not be expected to lead to a corrosion problem with the annealed stainless steel tube material.

4. Review of Reactor Vessel Repair Records - As reported in Amendments 29, 35, 37 and 40, the reactor vessel lower head area was repaired in 1968 to eliminate any furnace-sensitized stainless steel which could be exposed to the reactor coolant, and to correct weld defects found in the field welds between the control rod drive housings and the stub tubes, and also between the in-core housings and the lower vessel head. The CRD housing and stub tube configuration is shown in Figure 6. During this repair program, all of the control rod drive housing-to-stub tube field welds were found to contain weld defects and were completely removed and re-welded. In addition, essentially all of the in-core field welds were found to contain minor weld defects. As a result, all in-core field welds were ground as necessary to obtain a white, zero indication liquid penetrant examination and were then repair welded. After repair welding, the welds were contour ground to eliminate any potential for liquid penetrant holdup in a rough as-deposited weld surface, and to provide an optimum ground and contoured surface for final liquid penetrant examination. Final penetrant examination was performed to a zero defect (i. e., white surface) acceptance standard.

Review of the repair records confirmed that the repair and liquid penetrant examination was accomplished for in-core housing penetration 28-05.

5. Ultrasonic Examination of CRD Housing 18-47 - Because of the small amount of white deposit observed adjacent to penetration 18-47, the CRD mechanism from this location was removed on May 31, 1974, for ultrasonic examination of the CRD housing and field weld. This examination was performed using a longitudinal beam, immersion method similar to the procedure used to verify the soundness of the weld after the vessel repair in 1968.

Re-examination of the CRD housing and field weld at location 18-47 during this outage showed no indications of defects in either the housing or field weld.

In a meeting on May 31, 1974, at Oyster Creek among representatives from Jersey Central Power & Light, GPU Service Corp., GE-I&SE, GE-San Jose, Combustion Engineering, Universal Testing Labs, Exxon Nuclear, and MPR Associates, it was decided that in-core housing 28-05 should be opened for further examinations and analyses. The objectives of these examinations and analyses were (1) to determine the location of the leak (i. e., to determine whether the leakage occurred through the in-core housing tube below the field weld or in the field weld itself), (2) to attempt to obtain any evidence of corrosive attack of the tube, and (3) to determine if there is any evidence of vibration or other structural fatigue which could result in cracking of the housing material. The following specific course of action was agreed to:

1. Assembling available procedures and equipment for freeze sealing in-core housing 28-05 at a location below the vessel head. (Approximately 12 feet of tube exists between the reactor vessel head and the blind flange at the bottom of housing 28-05.) The freeze seal procedures and equipment were previously prepared and qualified by physical demonstration in preparation for other work which had been planned for this outage.

2. Design and manufacture of an expandable plug which could be inserted into the housing from the bottom and expanded at a location above the housing-to-lower vessel head field weld to permit access to the ID of the housing from below.

3. Preparation of a procedure for inserting the expandable plug and the actual physical demonstration of this procedure.

4. Assembly of a boroscope for an internal visual examination of the housing.

5. Design and fabrication of a qualification mockup for ultrasonic examination of the in-core housing and the housing-to-lower head field weld.

6. Preparation of leak testing procedures to determine the location of the leak in in-core penetration 28-05.

Subsequent to the meeting on May 31, 1974, it was determined that an eddy current examination might also be feasible and would

provide valuable information regarding the integrity of the housing. Consequently, a procedure was prepared and qualified for eddy current examination of the housing.

Freeze sealing and expandable plug installation were accomplished on June 4, 1974. Subsequently, the following examinations and analyses were performed:

1. Boroscope Examination of the ID of In-Core Housing 28-05

   Visual examinations were made using right angle boroscopes at magnifications of approximately 2-1/2 and 4-1/2. These examinations showed discolorations on the ID of the in-core tube in the areas near the field weld, but no visible cracks of other indications of mechanical damage either above or below the in-core housing field weld. Typical photographs taken through the boroscope are presented in Figure 7.

2. Eddy Current Examination of In-Core Housing 28-05 Tube Material

   Eddy current procedures developed for heat exchanger tube testing were used to examine the material of in-core housing 28-05. The results of this examination revealed no indications of defects in the housing material. The extent of the examination was from an elevation adjacent to the field weld to an elevation approximately 10 feet below the vessel lower head.

3. Ultrasonic Examination of In-Core Housing 28-05 and Field Weld

   Ultrasonic examinations were performed of the housing tube material and the Inconel field weld of in-core penetration 28-05. The procedures

used, their calibration, and the results are described below:

a. Procedures

The ultrasonic examinations consisted of both circumferential shear wave examination of the tube material and longitudinal beam (radially oriented) examination of the field weld. The transducers were installed from the bottom of the in-core housing and were located in the approximate center of the tube in a fixture which permits controlled axial movement and circumferential scanning. The immersion method was used.

The extent of these examinations included 100% of the field weld and a length of tube extending to an elevation approximately 3 inches above the highest point of the field weld. This additional tube length above the field weld was specifically examined to detect any evidence of mechanical damage or vibration which could cause cracking of the tube at or above the weld. (Through-wall defects in this area would not lead to leakage of water from the vessel.)

b. Calibration

Calibration of the procedure was performed using a mockup of the in-core penetration in accordance with Case Interpretation 1456 of Section III of the ASME Code. The mockup consisted of a carbon steel block containing a 2-inch OD Type 304 tube and an Inconel field weld which essentially duplicate the materials and weld joint type used in the vessel. The longitudinal beam

UT procedure for the field weld was calibrated by means of three, 1/8-inch diameter flat-bottomed holes drilled into the field weld at locations in the weld corresponding to (1) the interface between the tube OD and the weld, (2) half-way through the weld, and (3) at the outer periphery of the weld. The circumferential shear wave procedure was calibrated using 0.008-inch deep notches in both the ID and OD of the tube. (The 0.008-inch depth corresponds to 3% of the tube wall thickness.) Distance-amplitude correction (DAC) curves were prepared based on these standards and were utilized for the UT examinations performed in the actual in-core housing and weld.

c. Results

The results of the shear wave examinations showed no defects in the tube material of the housing, either below, adjacent to, or above the field weld. The longitudinal beam examination of the field weld, on the other hand, showed indications in the field weld near the interface of the weld and the OD of the housing. These indications can be interpreted as lack-of-fusion type weld defects. No continuous leak path through the weld could be determined by the UT examination.

Considering that the final weld surface was liquid penetrant examined and found to be free of defects prior to operation of the vessel, it is

possible that relatively tight, under-bead weld defects may have opened sufficiently after several years of vessel operation to permit the small seepage which was observed during the recent hydrostatic leak test.

It should be noted that a similar UT examination is performed of the CRD housing-to-stub tube welds; however, such a UT technique has not been available until recently for examination of the in-core welds. Two distinct differences in these two weld configurations are present:

a. The in-core housing-vessel welds are bi-metallic (Inco 182 to 304 stainless steel), whereas the CRD housing, stub tube and weld are all austenitic stainless steel.

b. The in-core housing welds are not axisymmetric as are the CRD field welds.

These conditions make performance and interpretation of the in-core weld UT difficult.

4. Helium Leak Test of In-Core Housing 28-05

As a further check on the soundness of the tube material in penetration 28-05, a helium leak test of the tube was performed. With the blind flange installed on housing 28-05 and the temporary plug in place above the field weld, the volume inside the housing was pressurized with helium to 20 psig. The area immediately below and around the

annulus between the vessel penetration and the housing OD was checked using helium mass spectrometer leak detection equipment. No leakage was detected.

5. Hydrostatic Leak Test with Temporary Plug Installed

To confirm the preliminary findings discussed above that the source of leakage was through the field weld and not through the tube material below this weld, a hydrostatic leak test was performed with the temporary expandable plug installed in housing 28-05 at a location above the field weld. The test was performed by pressurizing the vessel hydrostatically while the volume within the in-core housing below the temporary plug was pressurized with nitrogen to a pressure approximately equal to the pressure in the vessel. At a hydrostatic pressure of 200 psig in the vessel, seepage of water was observed from the annulus between the vessel lower head and the housing OD, thereby confirming that the leak path is through the field weld on the OD of the in-core housing.

Conclusions Reached as a Result of Examinations and Tests

Based on the observations and results of examinations and tests outlined above, the following conclusions were reached:

1. The seepage from location 28-05 is through a small leak path in the field weld between the in-core housing and the vessel lower head.

2. Stainless steel in-core housing 28-05 is sound and there is no evidence of corrosion attack, cracking or other damage resulting from mechanical loadings or vibration of the tube.

3. There is no evidence of leakage from any other in-core or CRD penetrations in the lower head area.

Accordingly, since (1) in-core housing 28-05 and CRD housing 18-47 have been shown to be sound, (2) no leakage has been observed from any penetration except 28-05, and (3) ultrasonic examination of in-core penetration 28-05 showed indications in the field weld, it is concluded that the small seepage from in-core penetration 28-05 is the result of a defect in the field weld between the housing and the vessel lower head. Such a defect is not considered significant from a safety standpoint. The reasons for this are as follows:

1. The leakage rate is extremely small. Calculations indicate that the leakage rate observed during the hydrostatic leak test corresponds to the flow which would be expected from an orifice having a diameter of less than 1 mil (10^{-3} inches).

2. The leakage rate can be checked periodically to detect any increase which may occur in future operation.

3. Even if the defect were to propagate entirely around the field weld, the likelihood of the housing being ejected from the vessel is very low since even a very small amount of weld attached to the housing would prevent its ejection. (E.g., as little as 0.2 in^2 of weld metal attached to the housing would be sufficient to retain the housing. The nominal weld area available is in excess of 6 in^2, thereby providing a margin of safety of over 30.)

4. A safety analysis has been performed by General Electric and is reported in Amendment 37 to the Oyster Creek Safety Analysis Report. This analysis indicates that even in the unlikely event that an in-core housing failed and was ejected from the vessel, no safety implications are involved.

Nevertheless, in order to minimize the potential for loss in power production and operational/maintenance problems in the event the leakage from in-core housing 28-05 were to increase substantially during continued plant operation, and to positively preclude the possibility of ejection of the housing from penetration 28-05, precautionary repairs and modifications will be undertaken. These repairs and modifications, together with the technical rationale for their selection, are described below.

1. Repair of In-Core Penetration 28-05

During the meeting of May 31, 1974, at the Oyster Creek site, the following repair alternatives were considered:

a. Seal welding of the housing or a plug to the outer surface of the vessel head.

b. Removal of housing 28-05 by parting the housing inside the head penetration just below the field weld and installation of a plug or other mechanical seal. This would be accomplished by remote boring operations followed by either threading or machining to provide a retention method for a mechanical plug or packing.

c. Expansion of the existing housing in the head penetration using conventional boiler tube rolling equipment and techniques.

The third alternative, c., was selected as representing the least risk of damage to the vessel and provides a high probability that it will eliminate or substantially reduce the potential for leakage from penetration 28-05 during subsequent plant operation. This rolling operation can be effectively accomplished in a controlled manner using procedures and equipment for rolling tubes in high pressure boilers, feed heaters, and other applications. This joint would be similar to that used in nuclear steam generators. In addition, GE has reported that this type of repair has been successfully used to repair leakage from a similar in-core housing in the lower reactor vessel head at the Senn plant in Italy. GE has indicated that tube rolling in this plant under similar conditions was successful in eliminating the leakage and the plant has now operated for approximately 8 years since the repair was made without any recurrence of leakage. Accordingly, action has been taken to obtain suitable tube rolling equipment for this application and to develop and qualify procedures for rolling of the housing in penetration 28-05. The criteria and requirements which have been used in developing this repair method are as follows:

a. Rolling of the housing would be performed to accomplish no more than 5% to 6% thinning of the housing wall.

b. The tube would be rolled from a location approximately 1-inch below the field weld for a distance of approximately 6 inches.

c. The rolling procedure and equipment have been qualified by rolling a 304 stainless steel tube in a mockup of penetration 28-05 and subjecting it to hydrostatic leak tests and thermal cycling. Specifically, after rolling of the tube in the mockup, the joint was pressurized to 1425 psi and did not leak. It was then heated to 550° F and cooled to room temperature twice followed by leak testing at 1280 psig. No leakage occurred during this test. An additional eight 550° F thermal cycles have been repeated and leak testing has been satisfactorily conducted at 1280 psig without leakage.

d. This repair procedure has been reviewed and concurred in by the vessel manufacturer, Combustion Engineering, General Electric, and the authorized ASME Code Inspector.

2. Addition of Mechanical Restraint to In-Core Housing 28-05

To positively preclude the possibility of ejection of in-core housing 28-05 from the reactor vessel in the extremely unlikely event of complete failure of the housing or field weld, a mechanical restraint will be installed below the lower flange of the housing. This restraint will be mounted on the existing CRD restraint structure and will limit axial motion of the housing to less than 1 inch even if the field weld and rolled joint were to fail completely.

Repair Testing and Continued Monitoring

In order to assure that the tube rolling operation has been successful, leak testing will be performed prior to returning to power.

Leakage tests will also be performed after each scheduled outage and after conduct of any maintenance operation which requires system leak test. These tests, in combination with available equipment and instrumentation for detection and monitoring of unidentified leakage in the drywell, will provide adequate indication of the continued adequacy of the repair. The periodic leak tests will also provide a continuing check of the integrity of the other in-core housing welds in the vessel since leakage from such a weld would occur long before the structural integrity of the weld was significantly affected. For example, while a relatively insignificant area leak path will result in leakage, as was the case for in-core 28-05, the structural integrity of the weld would still be adequate if over 90% of the weld were defective.

Actions to be Taken Prior to Next Refueling Outage

In parallel with the actions described above which are intended, as a minimum, to limit leakage to a small value during continued plant operation, the following tasks will be performed:

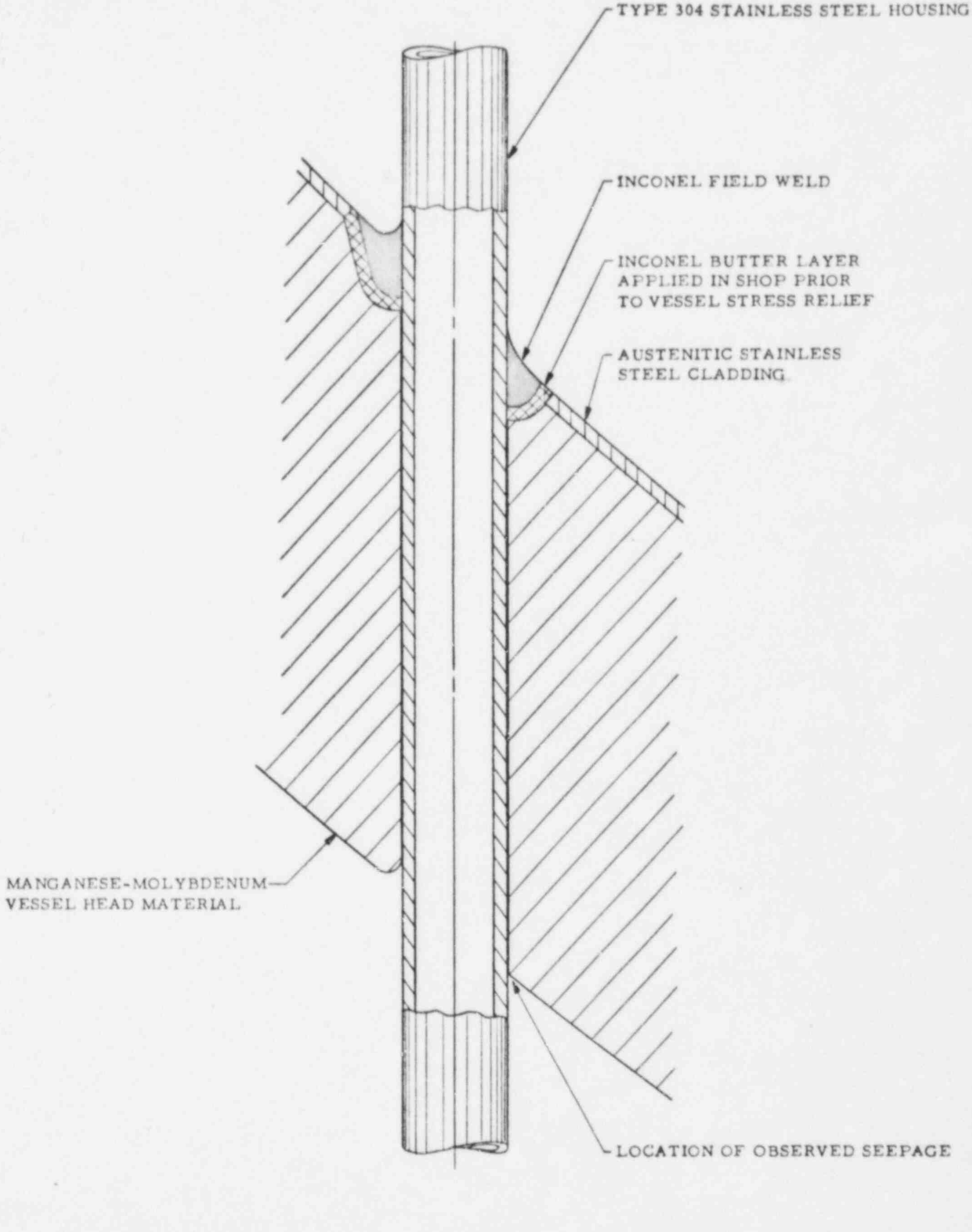
1. Design and evaluation of a mechanical sealing assembly which can be installed from the outside of the vessel if necessary to further limit leakage from in-core housing 28-05 or any other in-core penetration that could conceivably leak in the future.

2. Design and development of special tooling and equipment necessary to install such a mechanical sealing assembly.

3. Performance of mockup tests and qualifications of the mechanical seal design and the required tools and procedures for its installation.

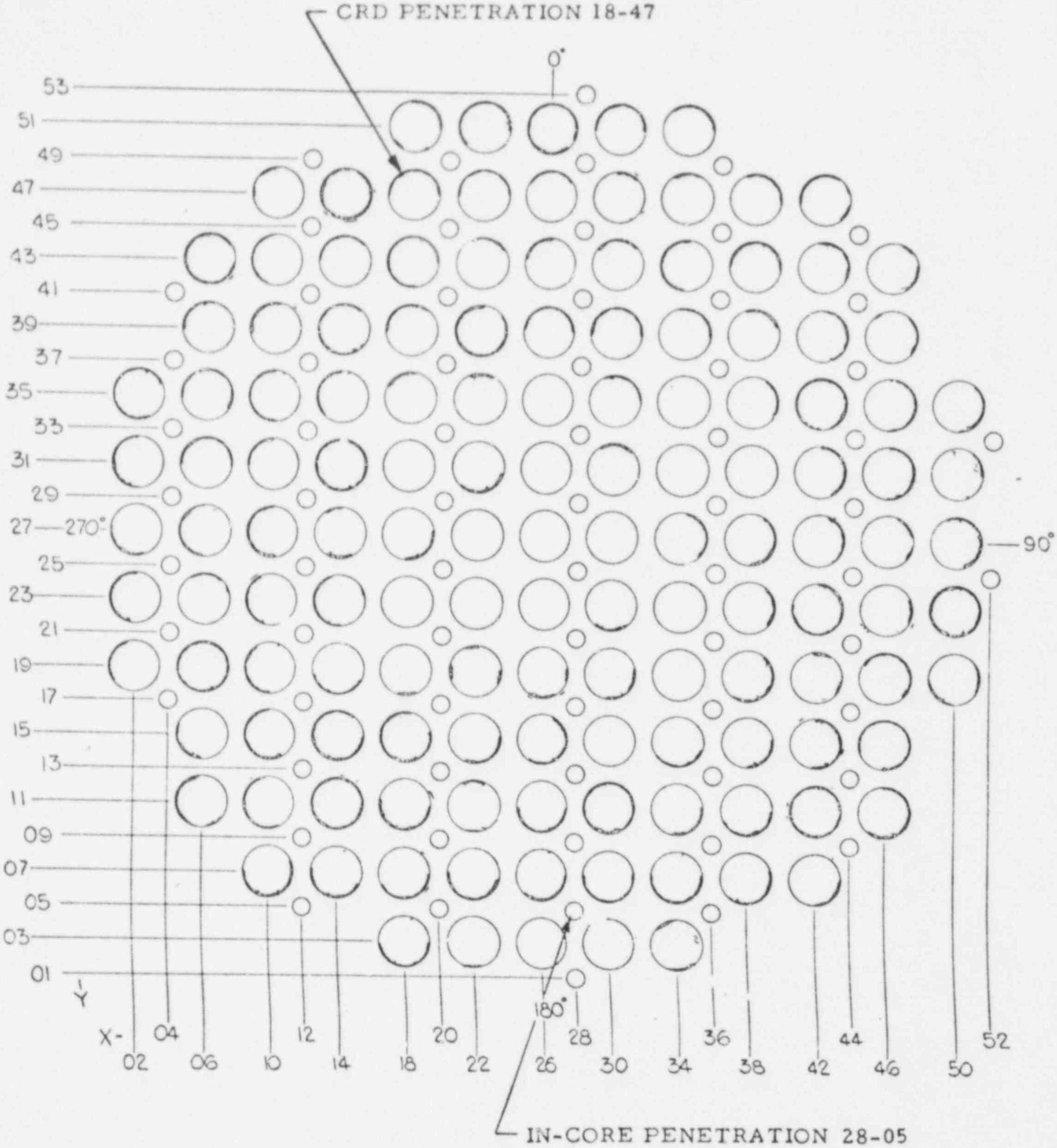
The above effort will be performed on a schedule consistent with having a tested backup mechanical seal design and necessary installation tools and procedures available by the next refueling outage. It should be noted, however, that such a seal would only be installed in the event that the repair of housing 28-05 by rolling proves to be unsatisfactory.

In addition, stress and fatigue analyses have been initiated to determine (1) the stresses in the in-core housing and weld during anticipated transient operations, (2) the cyclic life of the penetration, and (3) the effectiveness of the rolled tube repair after repeated heatup-cooldown cycles.



IN-CORE INSTRUMENT PENETRATION ASSEMBLY

FIGURE 1



PLAN VIEW OF CRD AND IN-CORE INSTRUMENT PENETRATIONS

FIGURE 2

FIGURE 3

PHOTOGRAPH OF IN-CORE PENETRATION 28-05
VIEWED FROM BOTTOM OF VESSEL LOWER HEAD

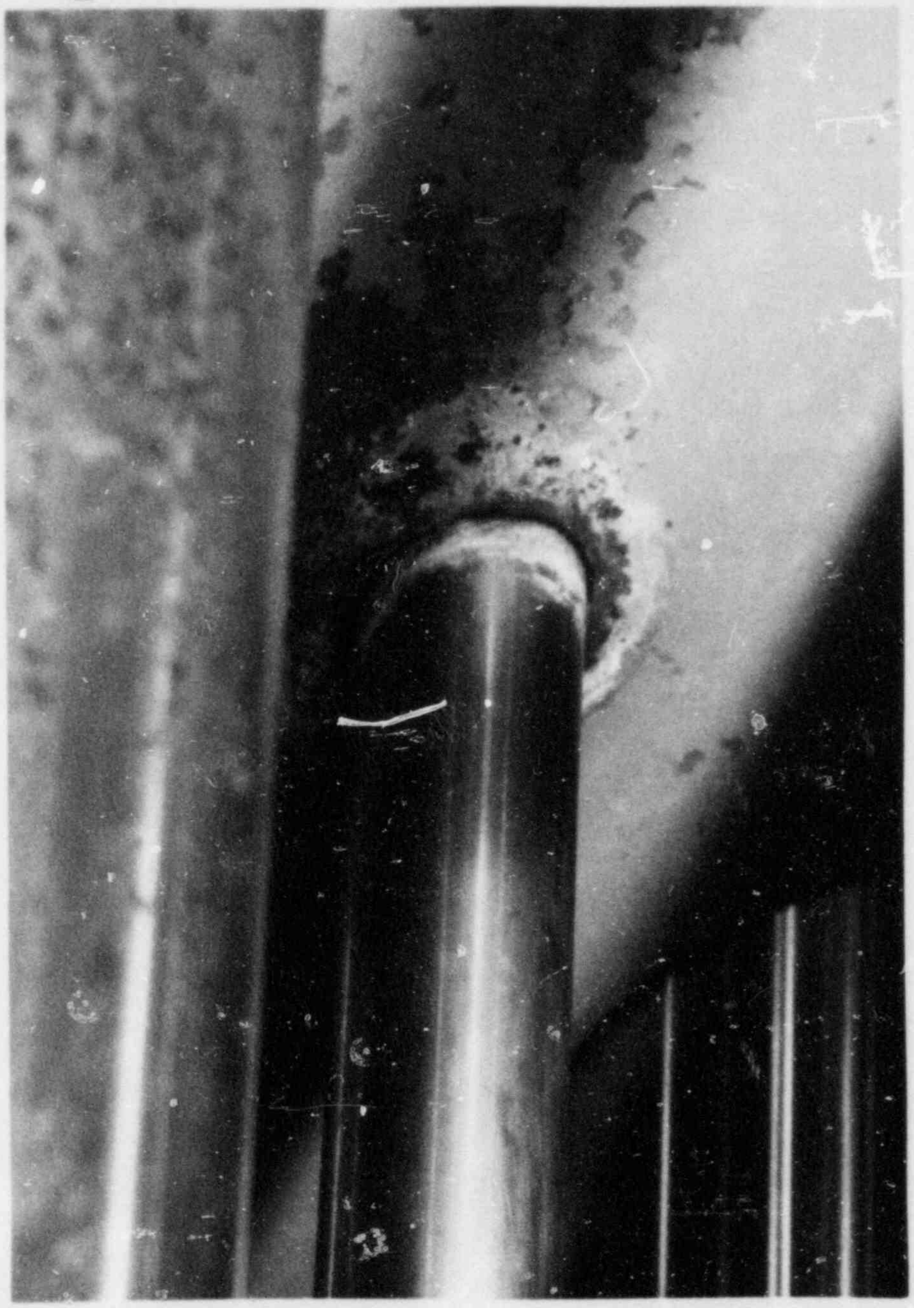
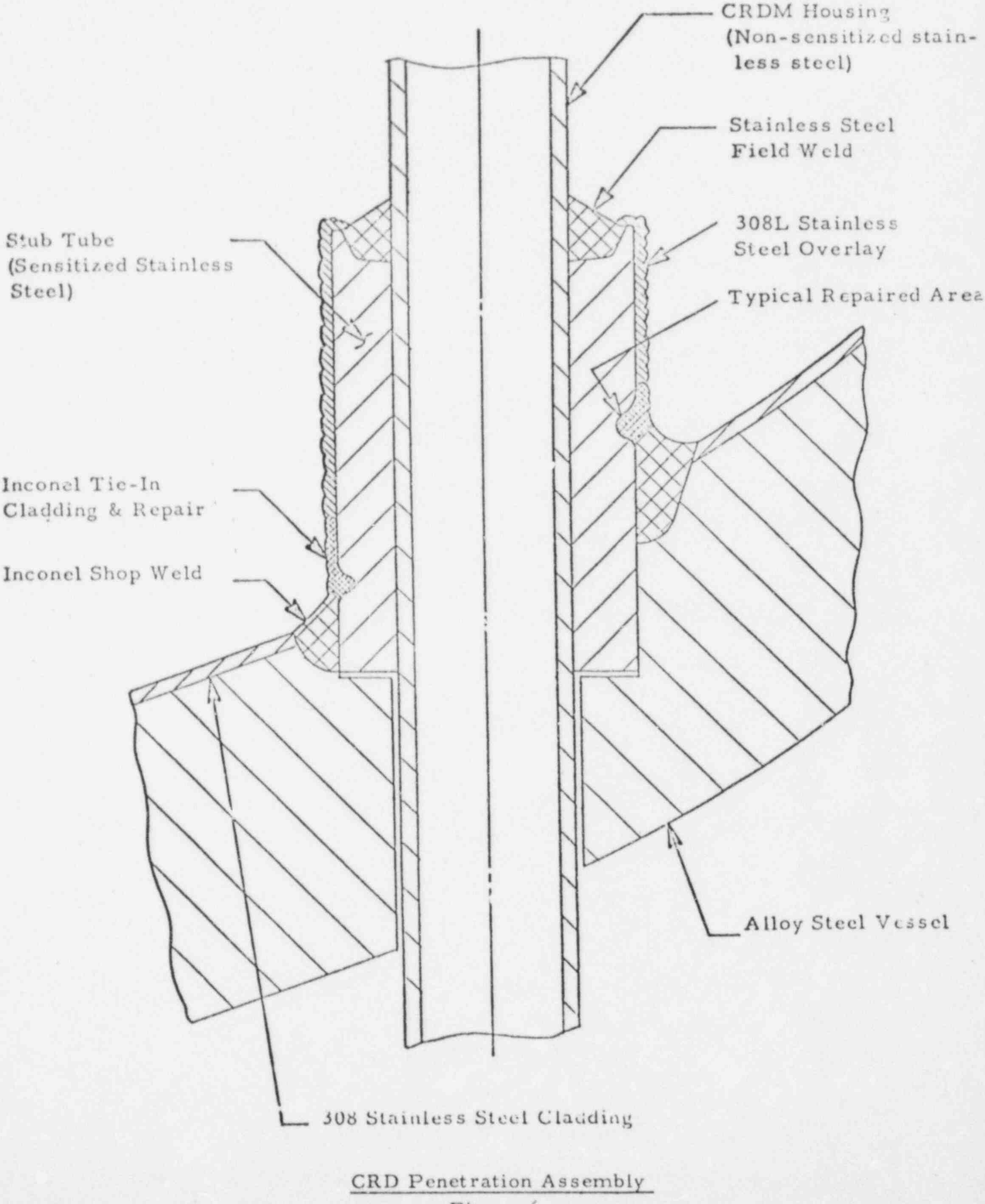


FIGURE 4

PHOTOGRAPH OF IN-CORE HOUSING 28-05
VIEWED FROM BOTTOM OF LOWER VESSEL HEAD.
TYPICAL CRD HOUSING PENETRATIONS ALSO SHOWN

FIGURE 5

PHOTOGRAPH OF CRD PENETRATION 18-47
AS VIEWED FROM BOTTOM OF LOWER VESSEL HEAD



CRD Penetration Assembly

Figure 6

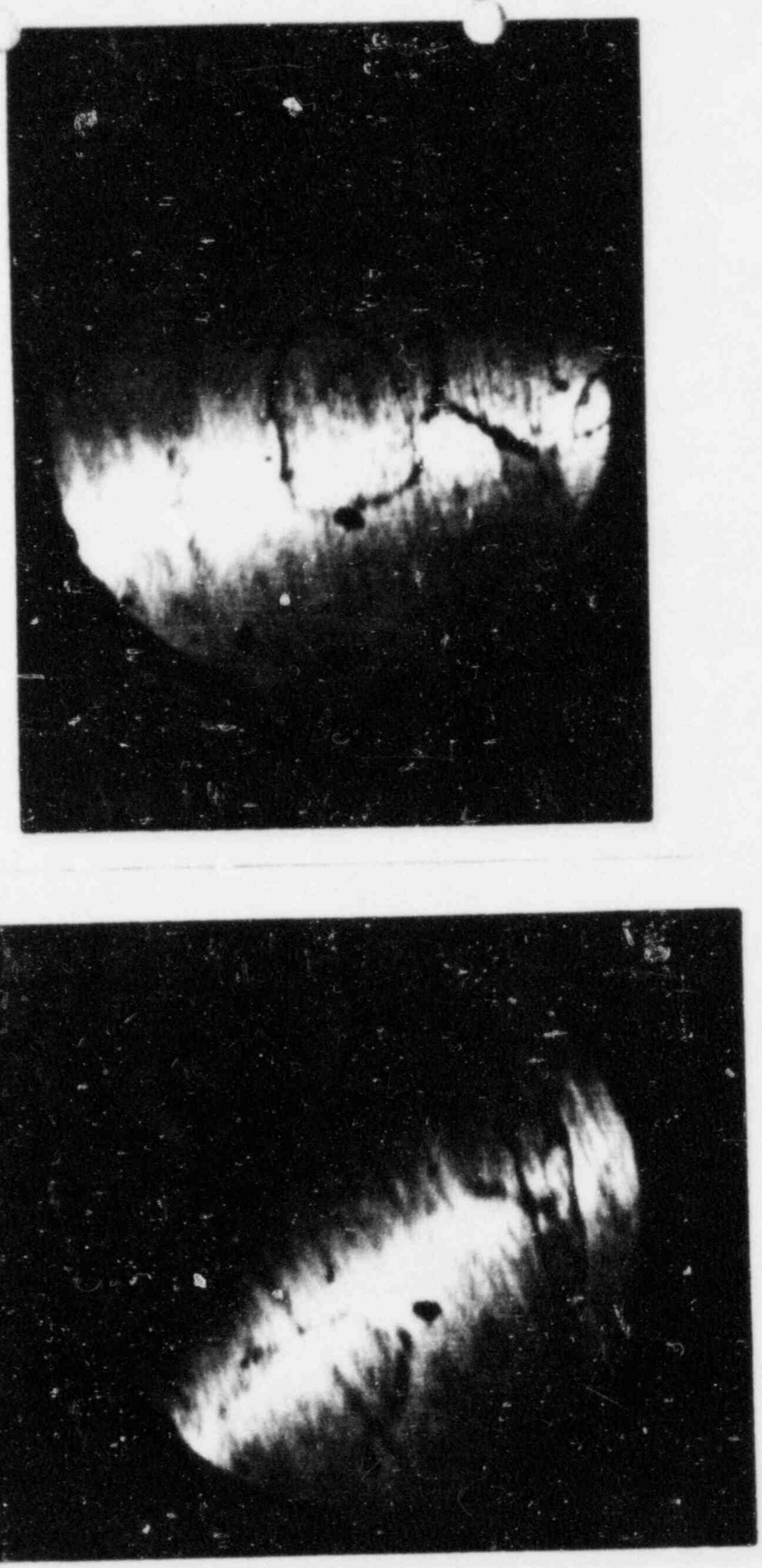


FIGURE 7

TYPICAL PHOTOGRAPHS OF ID SURFACE OF
IN-CORE PENETRATION 28-05 VIEWED THROUGH BOROSCOPE (x4-1/2)