SAXTON NUCLEAR EXPERIMENTAL CORPORATION

DOCKET NO. 50-146
LICENSE DPR-4

Amendment No. 7 to Change Request No. 32

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1. On June 7, 1968, Applicant, in response to Division of Reactor Licensing letter of December 1966, submitted for review and evaluation a report entitled: SAXTON - LOSS OF COOLANT ACCIDENT PREVENTION AND PROTECTION. This report included a description of plans to conduct a thorough nondestructive inspection of the pressure-containing components and piping of the reactor coolant system and a portion of the main steam system. By letter dated July 22, 1969, Division of Reactor Licensing requested SNEC provide a report covering this inspection.

2. Applicant hereby submits a report entitled: SAXTON COOLANT SYSTEM INSPECTION REPORT. This report provides and evaluates the results of the inspections conducted on the reactor coolant system for the period November, 1968 - May, 1969.

SAXTON NUCLEAR EXPERIMENTAL CORPORATION

By /s/ R. E. Neidig
President

(S E A L)

Attest

/s/ R. B. Heist
Secretary

Sworn and subscribed to before me this 27th day of October, 1969.

(S E A L)

/s/ Charles J. Ausel
Notary Public
Muhlenberg Township, Berks County
My Commission Expires October 11, 1970

3301

SAXTON COOLANT SYSTEM

INSPECTION REPORT

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SUMMARY AND INTRODUCTION

1.1 SUMMARY

The inspections outlined in "Saxton-Loss of Coolant Accident Prevention and Protection" have been performed. Minor modifications in scope were made to ensure a more definitive inspection in some areas. The inspection revealed no defects or problems of the type that would cause concern for continued safe operation of the plant.

1.2 INTRODUCTION

Westinghouse Nuclear Energy Systems was requested to institute an inspection program of the Reactor Coolant System of the Saxton Nuclear Experimental Corporation plant located at Saxton, Pennsylvania. The proposed inspection program was outlined in "Saxton - Loss of Coolant Accident Prevention and Protection," Section 2.2, page 2.2-1, titled "Inspection Program." It is planned that this inspection program will be repeated at five-year intervals. Construction and other files on record were reviewed and utilized to make this inspection more relevant. All nondestructive testing was performed to the requirements of ASME Boiler and Pressure Vessel Code, Section III, Appendix IX.

The Magnaflux Corporation, an independent nondestructive testing agency, was employed to perform a portion of these inspections. The results of the Magnaflux Corporation report have been incorporated into this inspection report.

This report will follow the outline established in Table 2.2-1 and Figure 2.2-2 in "Saxton - Loss of Coolant Accident Prevention and Protection." The inspections were not performed in the order presented in the outline, but on a plant availability basis.

SECTION 2

INSPECTIONS

2.1 REACTOR VESSEL CLADDING BETWEEN CLOSURE FLANGE AND THERMAL SHIELD (REMOTE VISUAL)

Initial inspection was made with binoculars and a television camera. Selected accessible areas were then inspected with a 12X glass. No deficiencies were detected in this area by the above visual methods of inspection.

2.2 REACTOR VESSEL FLANGE AND FLANGE-TO-SHELL WELD (VISUAL)

Visual inspection of the reactor vessel flange revealed no unacceptable conditions.

2.3 REACTOR VESSEL OUTLET NOZZLE, ID (VISUAL)

Since the lower core support barrel was not removed, inspection of the outlet nozzle ID was difficult. This inspection was made with the TV camera. No unacceptable conditions were detected. During visual inspection in this area, a surface discoloration was observed on the flange support of the lower core support barrel. A detailed description of the discoloration is given in Appendix D.

2.4 REACTOR VESSEL STUDS (VISUAL AND ULTRASONIC OR PENETRANT)

The 36 vessel studs were ultrasonically inspected and nine studs were fluorescent-magnetic particle inspected on June 21, 1967 by the Magnaflux Corporation. On review of the inspection program, the penetrant or ultrasonic planned test was changed to fluorescent-magnetic particle inspection since experience at other plants has proved it to be a superior method of inspecting reactor vessel studs and nuts.

Visual inspection of the studs and nuts revealed a rusty surface condition. The studs and nuts were cleaned by grit-blasting preparatory to inspection. After cleaning, fluorescent-magnetic particle inspection was performed. All studs and nuts (including spares) were acceptable by fluorescent-magnetic particle inspection.

After magnetic particle inspection, a further inspection was made of the surface condition of the threaded sections of the studs and nuts as it would affect installation and removal. The surface condition of the threads was adjudged unsatisfactory for continued use without corrective action because of the possibility of galling and seizure. Westinghouse Materials Engineering, Westinghouse Research and Development, and Babcock and Wilcox were consulted for recommendations. Babcock and Wilcox recommended a procedure developed by Allen Aircraft Products for conditioning the studs and nuts. The procedure calls for phosphate and electrofilm conditioning of the reactor vessel studs and nuts. This preventative maintenance was performed and will minimize the possibility of thread seizure on subsequent removal and assembly of these studs.

2.5 REACTOR VESSEL TOP HEAD (VISUAL AND PENETRANT)

The reactor vessel head-to-flange weld was cleaned to remove paint and rust prior to inspection. Visual inspections of the entire weld revealed no anomalies. Four six-inch lengths of the weld were selected for liquid penetrant inspection. The three head-lifting lug welds contact the head-to-flange weld, so the areas selected included both welds. The head-to-flange weld was found acceptable.

Linear liquid penetrant indications (intermittently disposed -- totaling approximately one-half inch) were found in the lug weld area. On further surface conditioning and penetrant re-inspection, these indications were found to be 1/8-inch away from the pressure containing head-to-flange weld and were adjudged irrelevant.

The internal clad surface of the head was visually inspected. Particular attention was directed to the head-to-flange weld region.

A manufacturer's repair was found in one area of the cladding. This area and other selected areas were examined with a 12X glass and found acceptable.

2.6 REACTOR VESSEL BOTTOM HEAD (REMOTE VISUAL)

The bottom head was examined with a television camera and binoculars. Illumination was provided by two 1000-watt and two 500-watt immersible lamps. Video tape recordings were made of the entire bottom head. No foreign material or irregularities were observed.

The thermal shield supports, bottom core support casting and tie rods were inspected with binoculars. No irregularities were observed.

2.7 STEAM GENERATOR TUBE PLATE-TO-SHELL, TUBE PLATE-TO-CHANNEL HEAD, NOZZLE-TO-CHANNEL HEAD WELDS (VISUAL AND PENETRANT)

External visual inspections were performed on the steam generator, tube plate-to-head weld, tube plate-to-shell weld, outlet nozzle-to-channel head weld, outlet nozzle-to-main coolant piping weld. The welds were found acceptable.

Four six-inch long areas of the steam generator tube plate-to-head and tube plate-to-shell welds were selected for liquid penetrant inspection. The welds were found acceptable.

2.8 STEAM GENERATOR SECONDARY SIDE (VISUAL)

The manway and the two handhole covers were removed for a visual inspection of the secondary side internals. The surfaces of the shell, tubes, fittings, and the moisture separator were thinly coated with a soft blackish deposit. There was no evidence of pitting of the internal surface of the shell or any of the internal parts. All internal parts, fasteners and locking wires were intact and in good condition. The steam purifier assembly was found to be in good condition. In the lower section, as observed through the handhole openings, there was no visible evidence of erosion or pitting of the tubes. No unusual deposits were observed on the tube plate.

The top head-to-shell weld was visually examined in its entirety. An arc strike was found on each side of the weld on the east side of the steam generator. These were removed by light grinding, less than 0.010 inch of material being removed. These areas plus four selected six-inch segments of the weld were liquid-penetrant inspected and found acceptable.

2.9 STEAM GENERATOR CHANNEL HEAD ID (VISUAL)

The entire internal area of the channel head was visually examined. The tube-to-tube plate welds, the divider plate, and the cladding (particularly the cladding over the tube plate-to-channel head weld) were visually examined. No foreign material was found in the channel head. The steam generator channel head internals are acceptable.

2.10 PRESSURIZER OD, SHELL-TO-HEAD, SURGE LINE NOZZLE-TO-SHELL, AND SURGE - LINE-TO-PIPE WELDS (VISUAL AND PENETRANT)

Both shell-to-head welds (top and bottom), surge line nozzle-to-shell weld, and surge line nozzle-to-pipe weld were visually inspected. In both of the shell-to-head welds, four selected six-inch lengths were liquid-penetrant inspected. All welds were found acceptable.

2.11 PRESSURIZER ID (VISUAL AND PHOTOGRAPHIC)

The heater bundle and spray line were removed to make the internal inspection of the pressurizer. Due to the high radiation levels associated with the pressurizer, a remotely operated camera was used to obtain color photographs of the pressurizer internals. Because of interference with numerous thermocouple probes, only a few representative photographs were obtained in each of the three areas of the pressurizer (water area, water-steam interface area and steam area). These photographs are shown in Appendix B.

Limited visual inspection was made through the heater bundle opening and the top flange opening (which is slightly less than four inches in diameter). The internal cladding was found to be in excellent condition. The heater bundle was visually inspected and found to be in acceptable condition.

During the visual inspection, it was ascertained that a spray nozzle was not attached to the spray line. Since a nozzle could not be found inside the pressurizer and since it is physically impossible for a nozzle to exit the pressurizer, it was concluded that a nozzle had never been installed. Furthermore, examination of the spray line showed no evidence of thread engagement or tack welds. A spray nozzle was obtained and installed.

2.12 REACTOR COOLANT PUMP AND CASING FLANGE (VISUAL)

On March 11, 1968, as part of the reactor coolant pump inspection, inspections were made of the socket welds, the head-to-bend welds for the cooling coils, and the stator cap-to-vent pipe welds. These welds were found acceptable.

A visual inspection of the pump volute and casing flange revealed no anomalies.

2.13 REACTOR COOLANT PUMP FLANGE BOLTS (VISUAL AND DIMENSIONAL)

On March 11, 1968, the flange bolts and bolt holes were visually inspected and found acceptable. The flange bolts were measured for elongation and found acceptable.

2.14 REACTOR COOLANT PIPE (VISUAL, PENETRANT, AND RADIOGRAPHIC)

In 1963 and 1965, the 30-degree bend on the 12-inch reactor coolant pipe at the coolant pump outlet was inspected by liquid-penetrant and radiographic techniques. The results of these inspections were satisfactory.

A strain gage (one of several used during original plant checkout) welded to the 12-inch pipe, was removed and the weld area surface-conditioned prior to liquid-penetrant inspection. Fusion line indications were found by the inspection. The area was further surface-conditioned (less than 0.030 inch of metal being removed) and reinspected. This area was found acceptable.

The 30-degree bend area and the entire pump-to-pipe weld was visually liquid-penetrant, and radiographically inspected. All conditions were found acceptable.

2.15 REACTOR COOLANT PIPE FITTINGS (VISUAL AND PENETRANT)

The pipe-to-fitting welds, and fitting-to-reactor coolant pipe welds (Figure 1) on the pressurizer surge line, the auxiliary system return and the pressurizer spray line were visually and liquid-penetrant inspected.

Liquid penetrant indications were found in both welds on the auxiliary system return line. The fitting-to-reactor coolant pipe weld had numerous small indications aligned, with what appeared to be grinding marks,

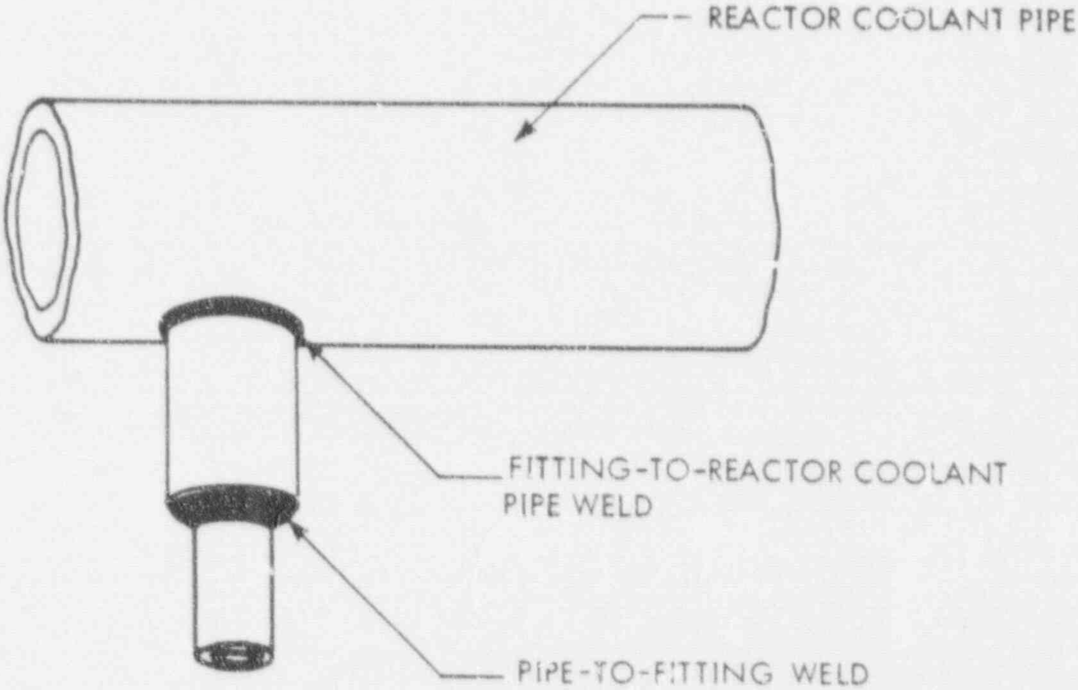


Figure 1. Typical Reactor Coolant Pipe Fitting

perpendicular to the reactor coolant pipe. Surface conditioning of this area (less than 0.005 inch of metal was removed) was followed by a satisfactory liquid penetrant inspection.

The pipe-to-fitting weld had indications on the weld and numerous linear indications at both fusion lines intermittently around the weld. Surface conditioning (less than 0.032 inch of metal was removed) was followed by a satisfactory liquid-penetrant inspection.

2.16 REACTOR COOLANT PIPE WELDMENTS (VISUAL, PENETRANT, AND RADIOGRAPHIC)

The steam generator outlet nozzle weld, outlet nozzle-to-pipe welds, reactor coolant pump-to-pipe and pipe-to-elbow welds were visually and liquid-penetrant inspected (Figure 2). All welds were found acceptable.

2.17 COMPONENT STRUCTURAL SUPPORTS (VISUAL)

Support brackets welded to the steam generator, pressurizer and reactor coolant pump and their attachments overhead were visually inspected. In addition, the turnbuckles on the steam generator support rods were visually examined and two turnbuckles were liquid-penetrant inspected. All inspection results were acceptable.

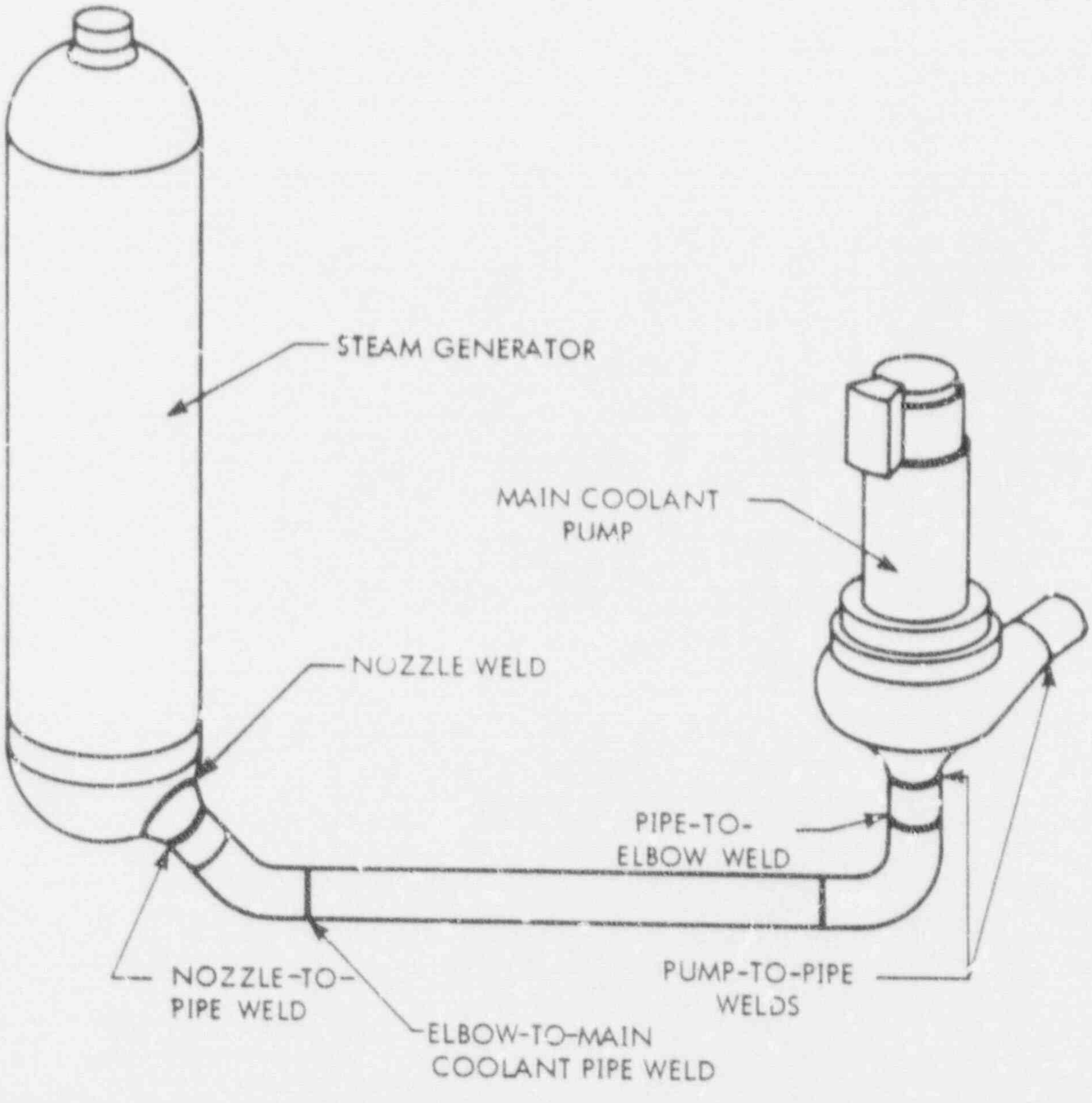


Figure 2. Schematic Diagram of Reactor Coolant Pipe Weldments

APPENDIX A

PHOTOGRAPHS OF PRESSURIZER INTERNAL SURFACES

Representative areas of the steam, steam-water, and water surfaces of the pressurizer cladding were photographed and are included in this appendix. The whitish deposits noted on the instrument probes and on the wall of the pressurizer are boric acid cyrstals.

Photographs taken of the various areas are as follows:

Area	Photograph Number
water	- 1, 2, 3, 4, 5, 6, 7, 8, 9,
steam-water interface	- 10, 11, 12
steam	- 13, 14

The stained rag shown in Photograph 13 was used during fit-up of piping to the pressurizer and has been subsequently removed.

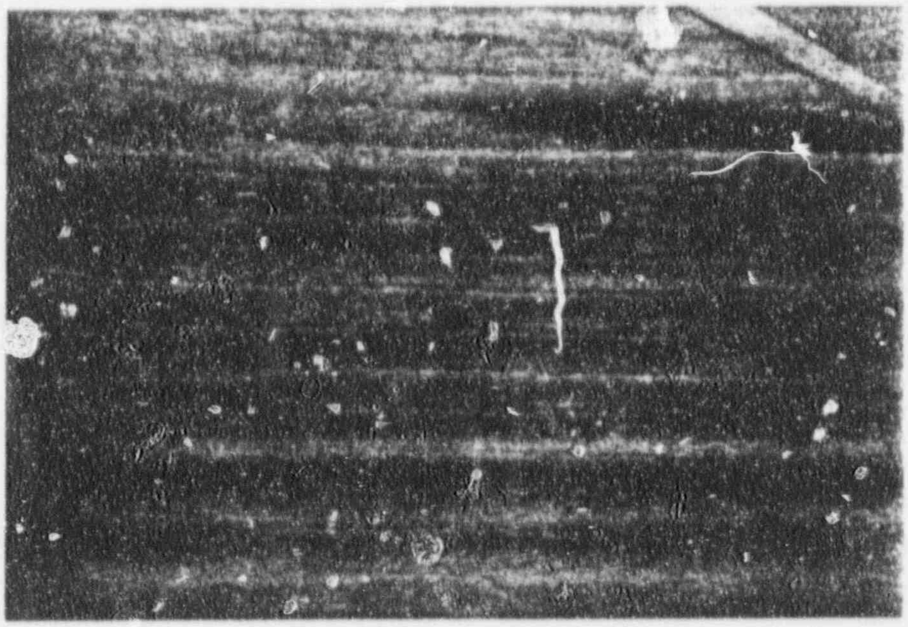


Figure A-1. Saxton Pressurizer Interior -- Water Area

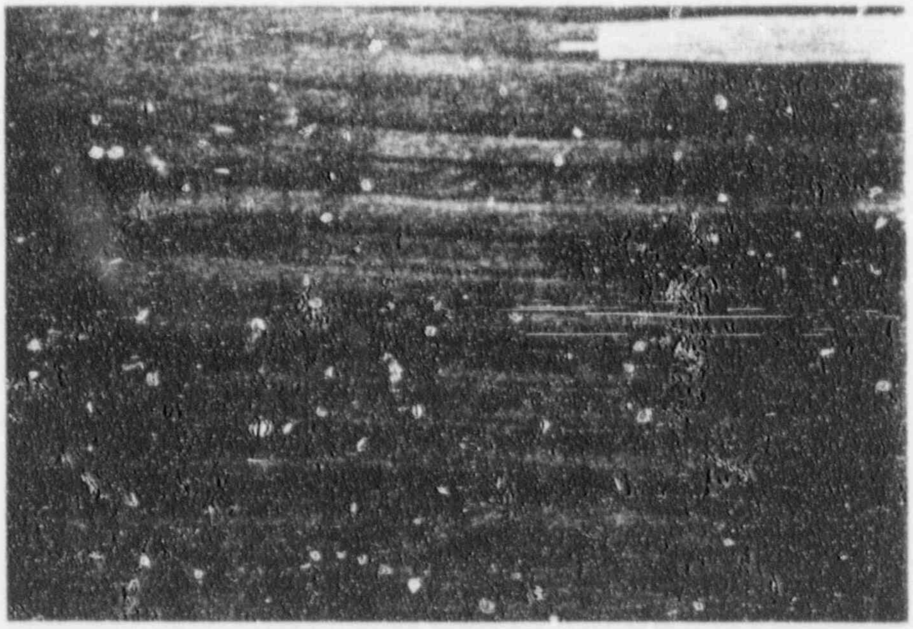


Figure A-2. Saxton Pressurizer Interior -- Water Area

Figure A-3. Saxton Pressurizer Interior -- Water Area

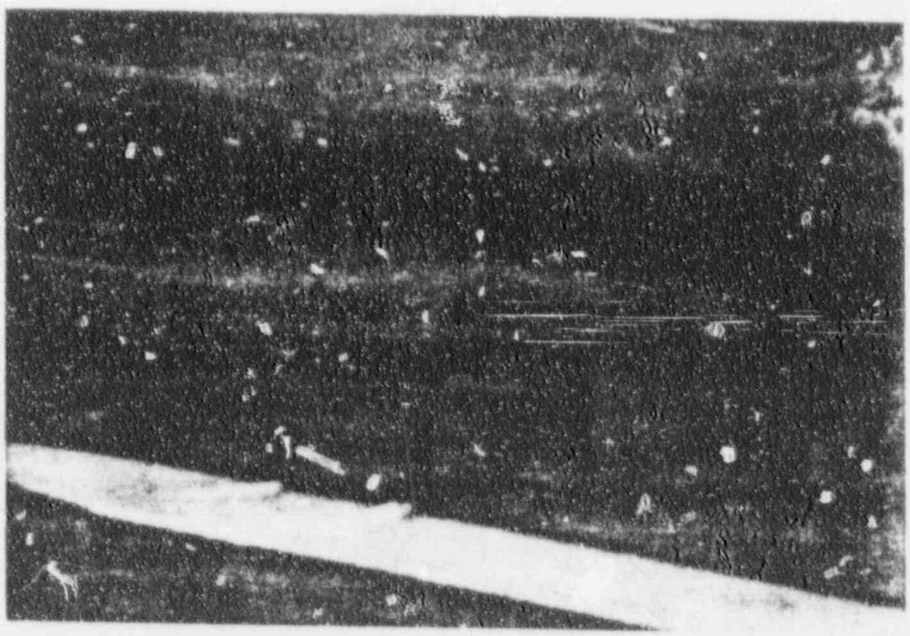


Figure A-4. Saxton Pressurizer Interior -- Water Area

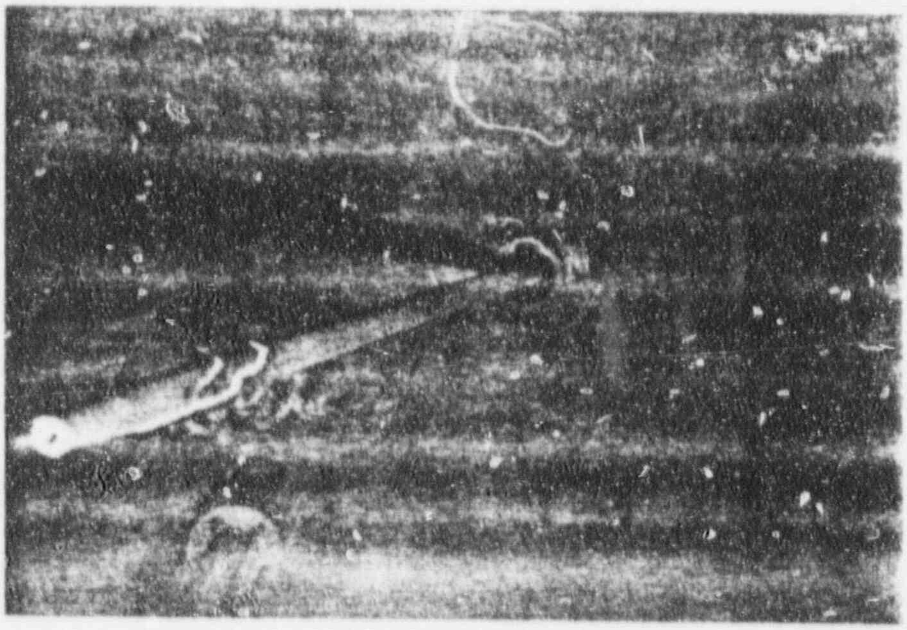


Figure A-5. Saxton Pressurizer Interior -- Water Area

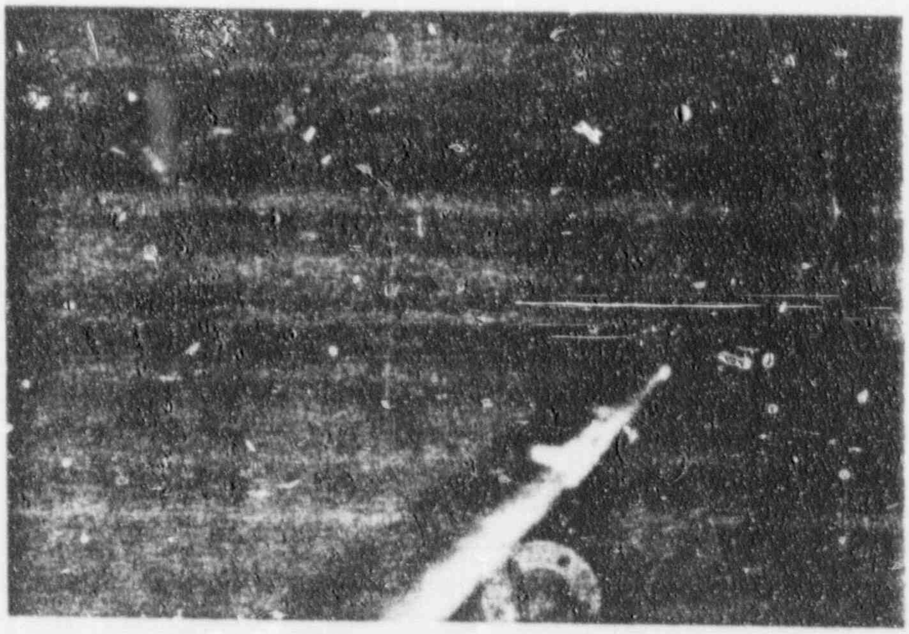


Figure A-6. Saxton Pressurizer Interior -- Water Area

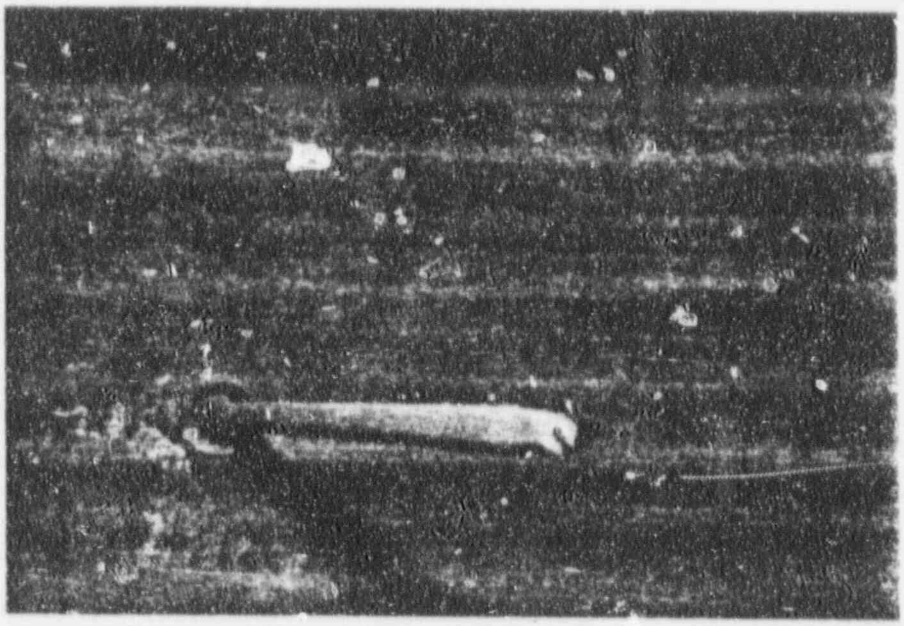


Figure A-7. Saxton Pressurizer Ieterior -- Water Area

Figure A-8. Saxton Pressurizer Interior -- Water Area

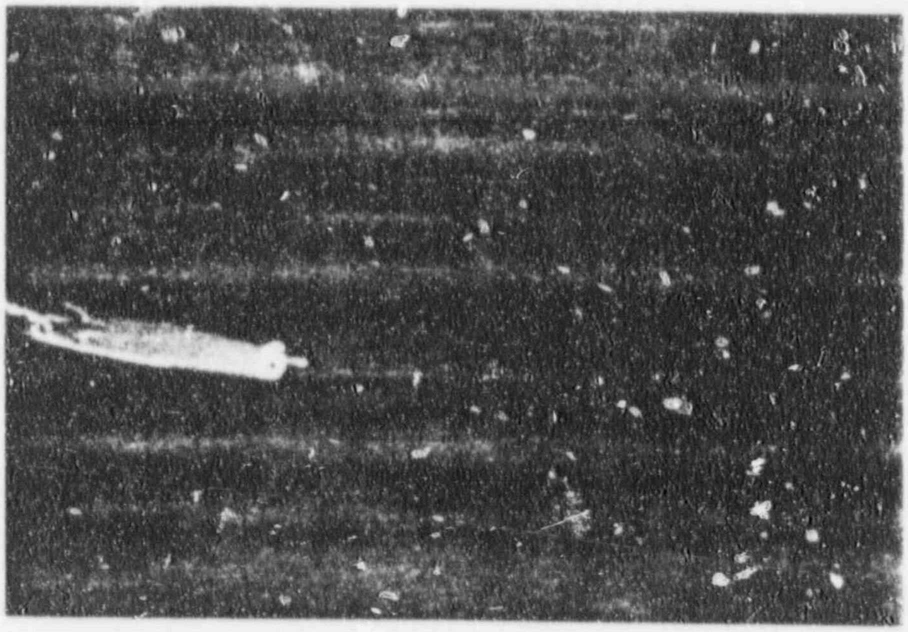


Figure A-9. Saxton Pressurizer Interior — Water Area

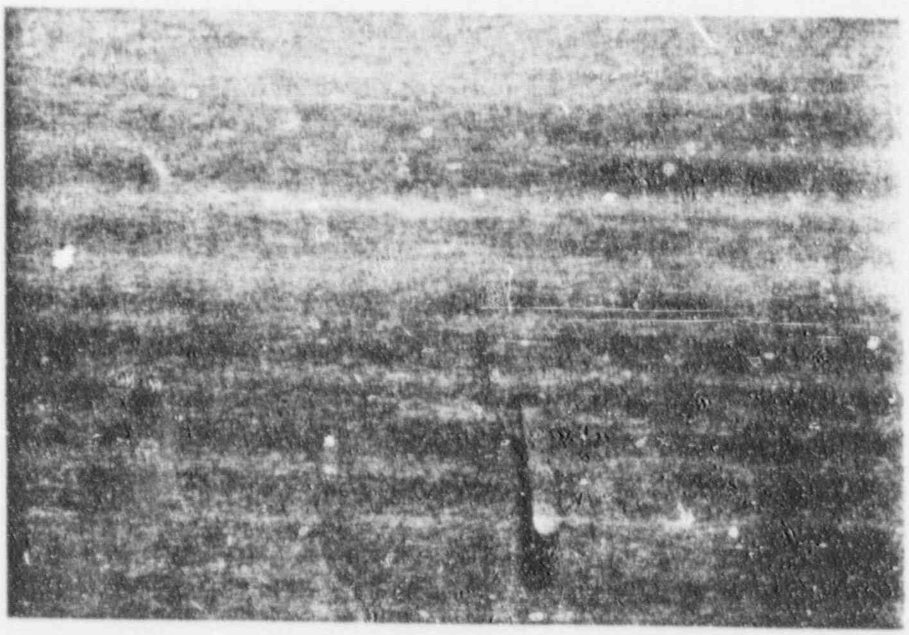


Figure A-10. Saxton Pressurizer Steam - Water Interface Area

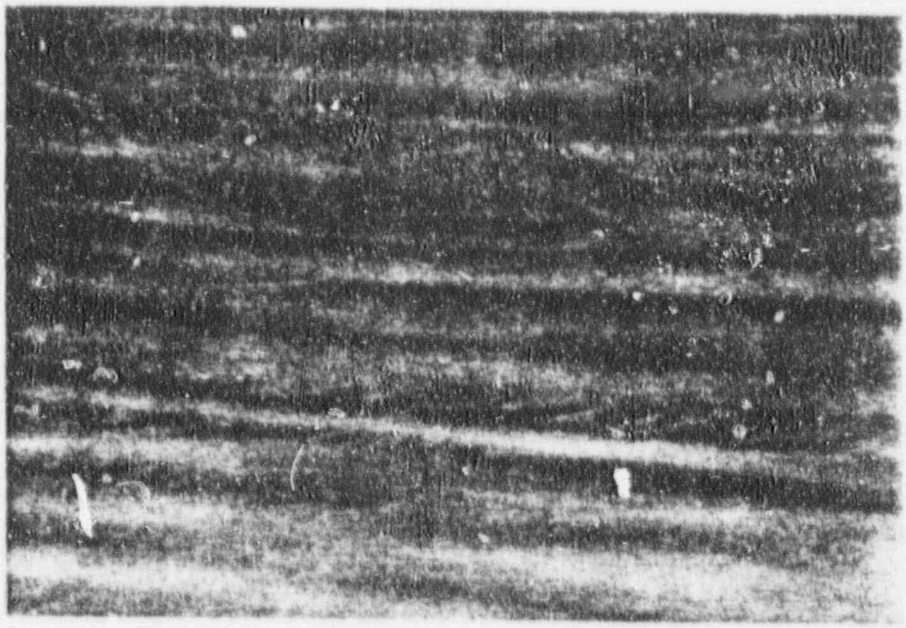


Figure A-11. Saxton Pressurizer Steam - Water Interface Area

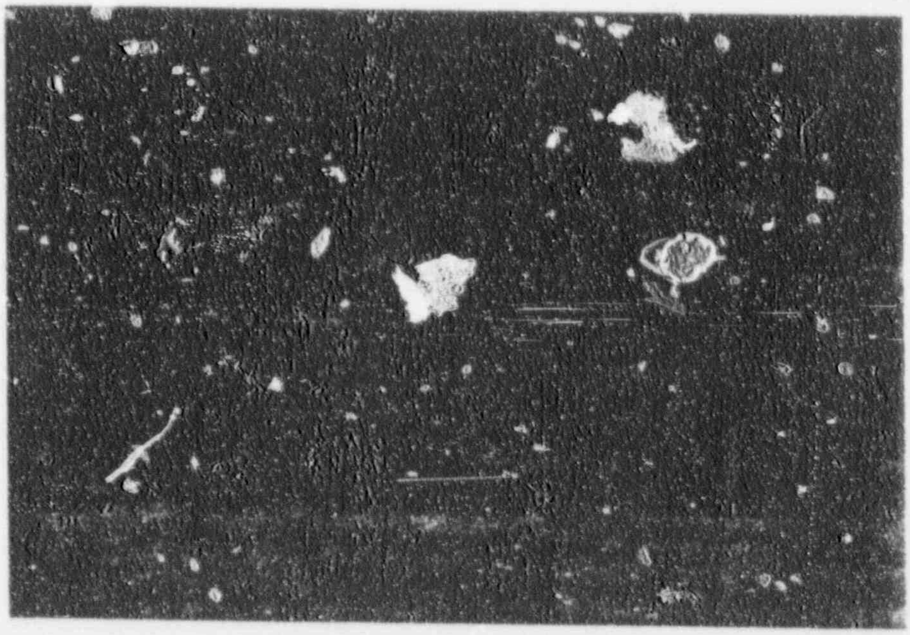


Figure A-12. Saxton Pressurizer Steam - Water Interface Area

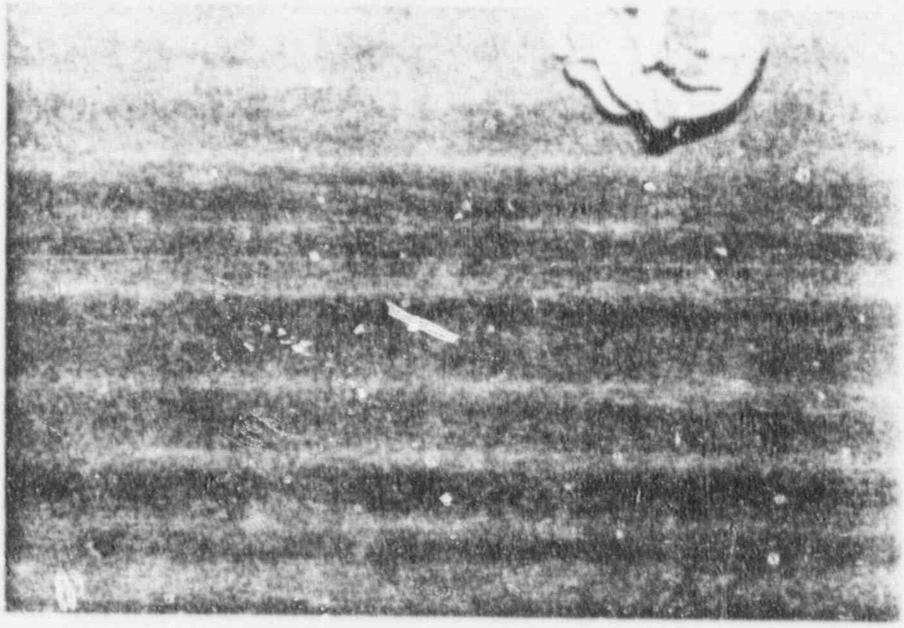


Figure A-13. Saxton Pressurizer Interior -- Steam Area

Figure A-14. Saxton Pressu-izer Interior -- Steam Area

APPENDIX B

INSPECTION PROGRAM CODE REFERENCES

1. All inspections were performed by or under the direction of personnel qualified to the ASME Boiler and Pressure Vessel Code, Appendix IX, Section III.

2. Detailed records of all inspections were prepared and retained in accordance with ASME Boiler and Pressure Vessel Code, Appendix IX, Section III, paragraph 225. This includes written procedures for each type of inspection and for the data developed in each and all inspections. Records are in sufficient detail that a reinspection can be made independently at any future date on the basis of the recorded information. Also, the recorded information is satisfactory for direct submittal to regulatory agencies or other responsible authorities.

APPENDIX C

VISUAL INSPECTION PROGRAM

1. VISUAL INSPECTION PROCEDURE - Saxton Plant 1968-69

A visual inspection is employed to gain detailed information as to the general condition of the part, materials, welds, components or surface, etc., on such conditions as corrosion, erosion, wear cracks, distortion, alignment, movement or any other type of damage or injury.

Personnel performing visual inspections are subjected to a physical examination to assure natural or corrected near-distance acuity such that the inspector is capable of reading J-1 letters on a standard Jaeger's test type chart for near vision or equivalent test type. Color vision and/or additional medical requirements as applicable are also considered. The examination is conducted within one year of the time the inspection is made. This examination is equivalent to the requirements of "Recommended Practice No. SNT-TC-1A" issued by the American Society for Nondestructive Testing, Evanston, Illinois.

a. Direct Visual Examination

Direct visual examination may be performed when access is sufficient to place the eye within 24 inches of the surface to be examined and at an angle no less than 30 degrees with the surface to be examined. Mirrors may be used to improve the angle of vision. Lighting, in addition to the general area lighting, shall be provided to illuminate the area to be examined at right angles and at oblique angles to expose cracks or evidence of corrosion or erosion. Mirrors and lighting must be designed to avoid breakage.

b. Remote Visual Examination

Remote visual examination may be substituted for direct visual examination when, for any reason, it is desirable. Remote visual examination may include visual aids such as telescopes, periscopes, borescopes, fiber optics or TV cameras and monitoring systems, with or without attachments for permanent recording.

Such systems shall demonstrate the ability to provide a resolution at least equivalent to that obtainable by direct visual observation. Mirrors, movable lights or rotating optics, or any combination thereof, may be employed to display cracks, surface scratches, or evidence of corrosion, erosion, alignment, or movement.

c. Replication

Surface replication methods shall be considered acceptable provided the surface resolution is at least equivalent to that obtainable by the visual observation.

d. Photography

Photography shall be employed to document observed conditions to the maximum extent possible. This can serve as a vivid description of the actual condition as well as a record for future reference, as may be required.

e. Special or Questionable Areas

When questionable areas are ascertained, additional detailed inspection shall be applied. This may consist of using a 10X glass or other visual aid. If adjudged necessary, applicable nondestructive testing may be applied. Some areas may require surface conditioning to reveal relevancy of indications. Appropriate engineering review will be made in all questionable areas found in the visual inspections.

2. VISUAL INSPECTION SCOPE

a. Components and Piping Welds - All welds to be visually inspected shall be:

1) Free from oxide, scale, paint, craters, slag, porosity, cracks, incomplete penetration and lack of fusion.

2) Free from surface markings resulting from mishandling, punchings, etc., and any permanent marking not in accordance with the ASME Code.

3) Examined for surface irregularities. The weld surface shall merge smoothly and gradually into the base material. Butt welded joints may be flush with the base material or may have a reasonably uniform crown not to exceed the following thicknesses:

Base Material Thickness, inches	Thickness of Reinforcement, inches
Up to 1/2 inch	1/16
Over 1/2 inch to 1	3/32
Over 1 to 2	1/8
Over 2	5/32

4) Free from abrupt ridges to valleys.

5) Aligned to meet requirements of ASME Boiler and Pressure Vessel Code, Appendix IX, Section III, paragraph N-525.

6) Examined to ensure that when different base metal thicknesses are joined, the finished joint shall have a taper of 1.4 between the thick and thin section.

7) In suitable condition to perform any and all required nondestructive testing.

NOTE: a) Other optical aids such as 10X magnification may be employed to verify condition of questionable areas.

b) Areas for other or additionally required nondestructive testing shall be identified by this visual inspection.

b. Reactor Vessel - Other areas shall be inspected by TV cameras, binoculars, mirrors or other optical aids. Areas will include:

1) Cladding on the ID of the closure head

2) Cladding from the vessel flange down to the top of the thermal shield.

3) Bottom head through the holes in the lower core support plate.

c. Steam Generator

1) Secondary Side Inspection - Handhole and Manway Cover Removal

a) Examine for corrosion and/or erosion and note unusual conditions in sufficient detail for review and appropriate action now and in the future.

b) All internal members shall be checked for secure attachment.

c) Check separator drain lines to make certain that braces are intact.

d) Check centrifix separator for signs of excessive corrosion and erosion.

e) Check to make certain that all fastener locking wires are intact.

f) From handhole inspect back side of the tube plate for mud accumulation and tube surface deposits.

2) Primary Side

a) Examine for corrosion and/or erosion and note unusual conditions in sufficient detail for review and appropriate action for now and in the future.

b) Visual examination of tube welds.

c) Visual examination of divider plate welds.

d. Pressurizer

Visually examine internals, cladding, penetrations, weld areas and heater bundle. Note condition of cladding in steam phase, water phase and water-to-steam phase interface to determine if there has been significant corrosion or cracking of cladding. Photographs will be taken of representative and significant areas. These observations and photographs are to serve as a reference for future examinations.

APPENDIX D

LOWER CORE SUPPORT BARREL INSPECTION
REPORT ON DISCOLORATION AND DISCONTINUITY OBSERVED ON THE OUTLET NOZZLE

1. OBSERVATION

During visual inspection of the lower core support barrel some surface discoloration was observed on the flange support (Figure D-1, Item 7) of of the lower core support barrel in the downstream direction from the weld that joins the flange support (Item 7) to the lower barrel (Item 4). The discoloration was parallel to the water flow tapering off at the downstream end. It initiated at the weld which joins the flange support to the lower barrel.

Subsequent inspection by television camera and binoculars confirmed there was a surface discontinuity at the origin of the discoloration. The area was television tape recorded (Figure D-4). The size of the discontinuity was estimated to be 1/4-inch wide, 4-1/4 inches long, and on the order of 1/16-inch deep. It was oriented in the direction of the weld, i.e., perpendicular to the direction of flow. The surface within the discontinuity was not abrupt or indicative of any stress-related structural defect.

2. OBJECTIVES OF EVALUATION

Since there was no immediate explanation of these observations, an investigation was carried out with the following objectives:

1. An engineering evaluation and analysis of the condition as to its nature and possible causes.
2. An evaluation of the possiblility of further degradation.
3. Assuming the nozzle wall could become penetrated, would the additional by-pass flow create a potential hazard?

3. SCOPE OF EVALUATION

It is clear that the observed discontinuity was either present when the reactor was first commissioned, or that some removal of metal occurred subsequently.

The investigation was therefore directed at the following areas.

a. A check on original records to determine if there was evidence of the existence of the discontinuity prior to original commissioning.

b. A list of possible mechanisms which could account for the appearance of the discontinuity during service.

c. An evaluation of each mechanism to see if it would account for the observations, and if so, what prediction could be made as to the future growth of the discontinuity.

d. An evaluation of the stresses existing in the vicinity of the discontinuity.

e. An evaluation of the additional by-pass flow resulting from a possible penetration of the nozzle wall at the discontinuity.

4. CHECK OF ORIGINAL RECORDS

This check disclosed the existence of a photograph (Figure D-3) showing the Lower Core Support Barrel during fit up of the internals in the manufacturer's plant. An enlargement of the nozzle area is shown in Figure D-3 and may be compared with Figure D-4. The comparison shows that both the discontinuity and some features of the discolored area (lines parallel to flow) can be observed in both pictures. The discontinuity extends round the circumference of the flange support (Item 7), to the interpenetration with the conical section of the barrel (Item 3), at which point a misalignment can be observed in both Figure D-3 and Figure D-4. The discontinuity appears to have been caused by a misalignment of the parts (Items 3, 4 and 7) during manufacture. It appears that a fillet weld was deposited in this area to smooth out the profile. No immediate explanation

can be given of the lines parallel to flow in the discolored area, but they may be grinding marks which did not clean up during machining of the nozzle.

5. EVALUATION OF MECHANISMS WHICH COULD ACCOUNT FOR THE DISCONTINUITY DURING SERVICE

The mechanisms considered were:

a. Mechanical interaction.

b. Corrosion or erosion.

Mechanical interaction was ruled out because of the absence of any conceivable mechanism whereby any other part could have come in contact with the discontinuity during service.

The possible corrosion-erosion mechanisms are reviewed below:

5.1 Uniform Corrosion

(Assuming that the materials complied with the assembly drawing, i.e., ASTM A240 Type 304 stainless steel was welded with Type 308 stainless steel weld metal.) For Type 304 stainless steel in reactor purity water, Wanklyn and Jones[1] report an average corrosion penetration of 0.06 mils per year and a maximum of 0.12 mils per year. Variations of composition among the austenitic grades of stainless steels had little effect on the penetration depth, therefore the same value is applicable to the Type 308 weld, under the assumption of uniform corrosion (galvanic effects are considered below). Variation in water flow rate from nearly stagnant to 30 feet per second (fps), variations in surface condition, variations of the water pH between 7 and 11, additions of dissolved hydrogen or oxygen, water temperatures of up to 572°F, and additions of up to 1500 ppm of boric acid did not significantly modify the corrosion rate. For comparison, the Saxton conditions at the area of interest are: temperature is about 510°F, flow rate is estimated as 20 fps, pH (cold) is 6.0, boron is 0-1600 ppm -- boric acid equivalent is 0-9120 ppm.[2,3] On the basis of the experimental results for 1500 ppm of boric acid,[1] it is estimated

on a conservative basis that the actual boric acid concentration in the Saxton coolant would result in a rate of corrosion not exceeding 0.24 mils per year.

Neutron irradiation (in-pile) has been found to enhance the corrosion of Type 304 stainless steel clad by a factor of about two, in experiments using nitric acid as a corroding medium.[4] Since the outlet nozzle is not subjected to the intense irradiation as experienced by fuel rods, the effect of neutron irradiation is negligible in this case.

In summary, the expected normal uniform corrosion of the specified materials is conservatively estimated as 0.24 mils per year under Saxton conditions and is negligible for time at temperature experienced thus far by the Saxton Reactor. A time of 18,000 EFP* hours plus a very conservative estimate of at least an equivalent time period at temperature for training and physics purposes would yield about 1.1 mils corrosion. This mechanism does not therefore account for the observed discontinuity.

5.2 Weld Metal Contaminants

The only weld metal contaminants that could possibly occur would be slag formed during the welding operation and, less likely, sulfur in the electrode forming metal sulfides.[5]

In the case of slag, experience[5] has shown that for a situation where sufficient water flow exists (as in Saxton), corrosion occurs in the area of original slag deposition and the corroded material is eroded away. Corrosion continues until the slag is removed. Such a situation could occur as the result of poor welding practice, but the corrosion rate would be expected to remain relatively constant. Any future corrosion penetration, assuming slag contamination throughout the weld, can be calculated from the present rate of assumed corrosion, as was done in Section 5.1 above.

*Effective Full Power

In the case of sulfides occurring as a result of sulfur impurities in the weld material, the expected course of corrosion is similar to that described for slag, since the sulfide particles would cause preferential corrosion ultimately leading to removal of the impurity.

In either case, it is normally expected that such contaminants would occur over the entire weld length and corrosion would not be localized as shown in the photograph (Figure D-4).

In summary, weld contaminants could cause the supposed corrosion if it is very conservatively assumed that the corrosion conditions, particularly water flow rates, are greater in the area shown, resulting in preferential removal of corrosion products and localized, faster corrosion rates than in the rest of the weld. In this case, it is expected that the rate of corrosion would be constant.

5.3 Galvanic Corrosion

Two aspects of galvanic corrosion are possible in this case. In the first, it is assumed that the specified weld metal (Type 308) is different in composition from the joined material (Type 304) and therefore is theoretically subject to galvanic corrosion due to a difference in electrochemical potential. However, noted above, this actual case has been studied and the galvanic corrosion effects are negligible upon an already negligible overall corrosion rate. It is expected that the same results would be obtained for any other grade of stainless steel which might have been mistakenly used for the weld metal.

The second aspect considers weld metal other than stainless steel. The worst possible case is considered to be that where a carbon steel weld metal was mistakenly used. An examination of the galvanic series of metals and alloys[6] shows that carbon steel is decidedly anodic and hence corrodable when coupled to stainless steel. Therefore, one can theoretically expect preferential corrosion of the carbon steel, especially since the area of stainless steel is large by comparison. In practice, however, Wanklyn[1] reports that galvanic couples of mild steel to stainless steel have little effect on accelerating corrosion of the mild steel.

Assuming, first of all, that the above experimental finding is correct, one can therefore consider the hypothesized mild steel as corroding alone. According to Wanklyn,[1] corrosion rates for mild steel are roughly ten times greater than for stainless steels under the conditions described in Section 5.1., Uniform Corrosion. This amounts to about 2.4 mils corrosion per year. Conservatively assuming the time at operating temperatures as twice the EFP hours, the expected corrosion is about 11 mils compared with the stated observation of 1/6" or 62 mils. No information is availabe to justify a future corrosion rate in excess of that already hypothetically established.

Secondly, if the experimental report of galvanic efects of stainless-to-mild steel couples is assumed to be incorrect, a corrosion depth greater than that for uniform corrosion of mild steel can be assumed. There are no data to expect a rate greater than is already assumed from the depth of the discontinuity. For this situation, it should be kept in mind that two "ifs" are necessary: "if" a carbon steel electrode was mistakenly used and "if" Wanklyn's reported experimental findings are not correct.

In summary, galvanic corrosion is a possible cause of the observed discontinuity only if one assumes two separate errors, and the expectation of continued corrosion in excess of the established rate is not justifiable from the literature. In addition, it would be expected that this type of corrosion would occur over the entire length of weld exposed to the water, rather than in the localized manner shown in the photographs. This is contrary to the observed condition.

5.4 Stress Corrosion

Stress corrosion must be considered in any evaluation of corrosion of stainless steels. In reactor waters contaminated with chlorides, oxygen must be present for stress-corrosion cracking to occur.[7]

A check of the Saxton water chemistry[3] shows that the hot water chloride and oxygen contents are less than 0.005 ppm, which represents the limits of detectability for each species. Conservatively assuming that at least 0.005 ppm of each species actually exists in the Saxton coolant

water, and comparing with a curve of reactor water oxygen and chloride content as related to stress corrosion cracking under intermittent wetting[7] (a condition whereby chlorides can be concentrated), it is seen that the chloride content is one to two orders of magnitude and the oxygen content is at least two orders of magnitude too low for chloride stress corrosion cracking to occur.

Another possible source of intergranular stress corrosion is from caustic solution such as the LiOH used for pH control in Saxton. Berry[7] reviews work which shows that several thousands ppm of caustic solution are required for corrosion of stainless steel. Pement[8] found a threshold of 0.1 M lithium hydroxide, or less, at 450-615°F for failures of stainless steel. This amounts to about 1470 ppm of LiOH. The Li content in Saxton coolant is 0.1-0.2 ppm[3], and therefore LiOH is highly unlikely to be a source of corrosion.

In summary, stress corrosion is highly unlikely on the basis of the excellent Saxton water chemistry. Recourse to the assumed existing corrosion rate is necessary if one speculates that the chemistry or literature data are incorrect, but in this case there is no reason to believe that the rate of corrosion would increase with time.

5.5 Corrosion - Summary

No corrosion-erosion mechanism examined will account for the observed discontinuity unless some other unfavorable assumption is made. However, if it is assumed that the discontinuity was in fact caused by some corrosion-erosion mechanism, there is no reason to suppose that the rate will increase over that implied by the known size of the discontinuity. The thickness of the nozzle is 1/2 inch. If the assumption is made that corrosion could occur from both sides, then a further 3/16" of corrosion (measured from one side) would have to occur before the nozzle wall is penetrated. At the assumed rate of corrosion, this would not occur in the expected lifetime of the plant.

6. STRESS ANALYSIS

The structure has been treated as a continuous, constant thickness shell. The shell is a cylinder with a conic reduction to a smaller cylinder and a reinforcing ring at each end of the shell.

The computer program "Seal Shell 2" has been used to determine the basic shell stresses.[19] In the region of penetration the basic stress is essentially a uniaxial hoop stress of 300 psi. A resolution of all the component stresses on a Von Mises criteria or on an octahedral stress basis gives a resolved stress of 350 psi.

Because of the complex nature of the nozzle construction, no accurate stress concentration factor is available. A factor of 5 has, therefore, been used.

The basic stress is of the order of 2% of the material yield stress and is compressive. Allowing a stress concentration of 5, the stress in the nozzle area is still less than 10% of the material yield strength at temperature.

On the basis of such low steady state stresses, it has been concluded that there is adequate margin for safe operation of the reactor.

6.1 Input for Seal Shell 2 Calculation

Loading Conditions

Temperature	510°F
Vessel Differential Pressure	11.3 psi
Core Differential Pressure	4.1 psi

Self Weights

Lower Core Barrel	=	2750
Baffle Assembly	=	1230
Core Support Assembly	=	1750
21 Fuel Assembly	=	2310
21 Dummy Assembly	=	1210
TOTAL		9,250 lbs.

Pressure Drop over Core	=	4.1 psi
41" I/D core area	=	1320 in^2
Lift force	=	5,420 lbs.
Load on Core Barrel	=	3,830 lbs. axial

Materials

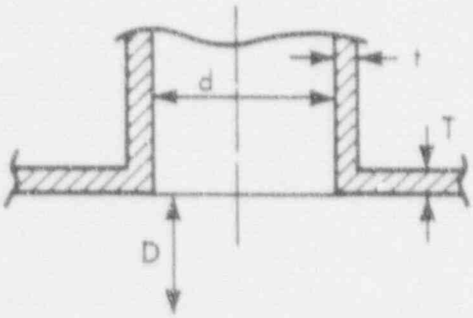
Barrel	ASTM 240 T 304 Grade 5
Electrode	ASTM 298 E 308

Specified minimum yield 30,000 psi
Specified ultimate strength 75,000 psi
Yield strength at temperature 18,200 psi

6.2 Basis for Estimation of Stress Concentration Factor

From "Seal Shell 2" Printout by inspection, the stress field across the penetration at mid-plane is effectively uniaxial and constant at 350 psi (Figure D-5).

Points of interest are at 90° and 135° as noted (discontinuity lies in this region) i.e., a nozzle type reinforcement in uniaxial stress. (Figure D-6)



$d/D = .259 \quad \frac{t}{T} = .67$

$\frac{t}{d} = .045 \quad \frac{T}{D} = .017$

Reinforcement Factor = .203

Penetration Angle = 42.4° Lateral

1. From the reference by R. T. Rose[17] the stress concentration factor for a completely unreinforced nozzle ($\frac{t}{d} = \frac{T}{D}$) for $\frac{T}{D}$ = 0.017 and and d/D = 0.259 is given as 5.0.

The nozzle actually has 20% reinforcement therefore the factor 5.0 is high.

2. From the ASME Code 68 the recommended factor is 2.6.

For the lateral connection of a cylinder at an angle the stress concentration index = K (1 + (tan ϕ) 4/3) where K = inside stress index.

In this case K = 1.0 tan ϕ ~ 1.0 and therefore stress index = 2.0.

The stress concentration factor is difficult to estimate for this case since there are no directly applicable references.

A minimum value of 2.5 and a maximum value of 5.0 for stress concentration appears to be a valid range. This range is based on judgement from the list of references given.

The resultant maximum stresses in this region of the nozzle are in the range 825 psi to 1750 psi.

7. EVALUATION OF BY-PASS FLOW

The only potentially serious consequence of a penetration of the nozzle wall is the increase in flow of primary coolant bypassing the core. Calculations have been made which show that a bypass hole in the nozzle would leak flow at the rate of 1 percent of the total system flow per square inch of leakage area. The Saxton Core III design values of 7880 GPM total system flow and 15% core bypass flow contain at least 5% conservatism, i.e., the design value of heat transfer flow in the core at 0.85 x 7880 GPM has at least 5% design margin. Therefore, the core design is not jeopardized by a 5 in^2 hole in the outlet nozzle.

8. CONCLUSIONS

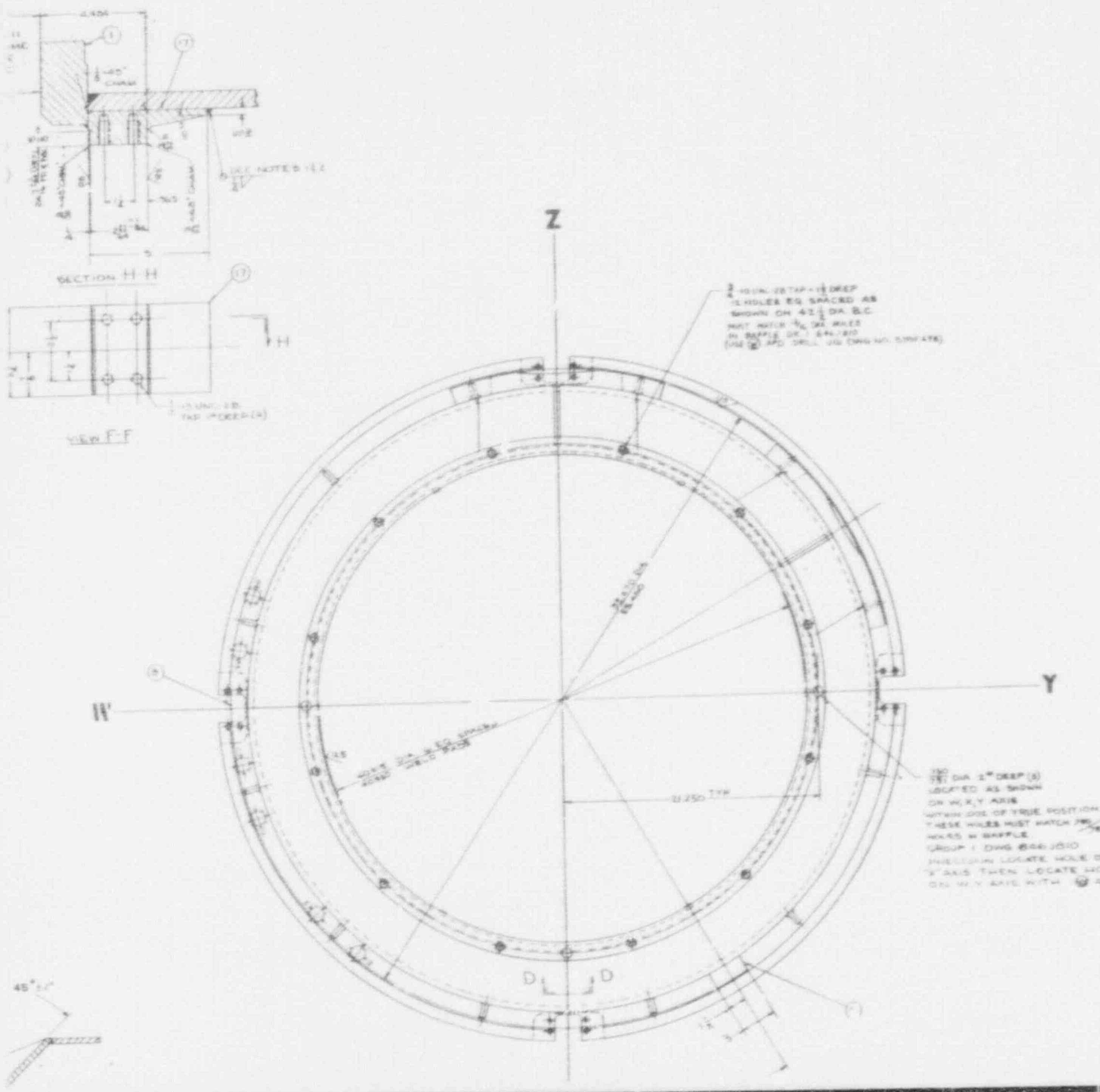
This evaluation indicates that the discontinuity occurred in manufacture. No mechanism has been identified to account for the appearance of the

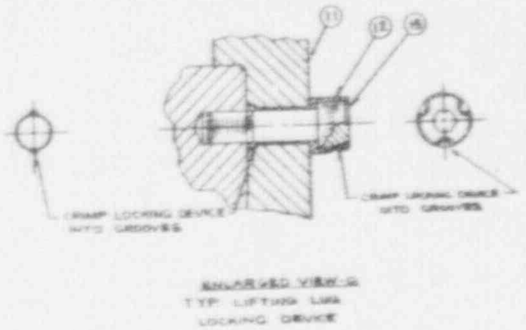
discontinuity in service. However, even if these conclusions are incorrect, the evaluation demonstrates that no hazardous condition could develop during the plant lifetime.

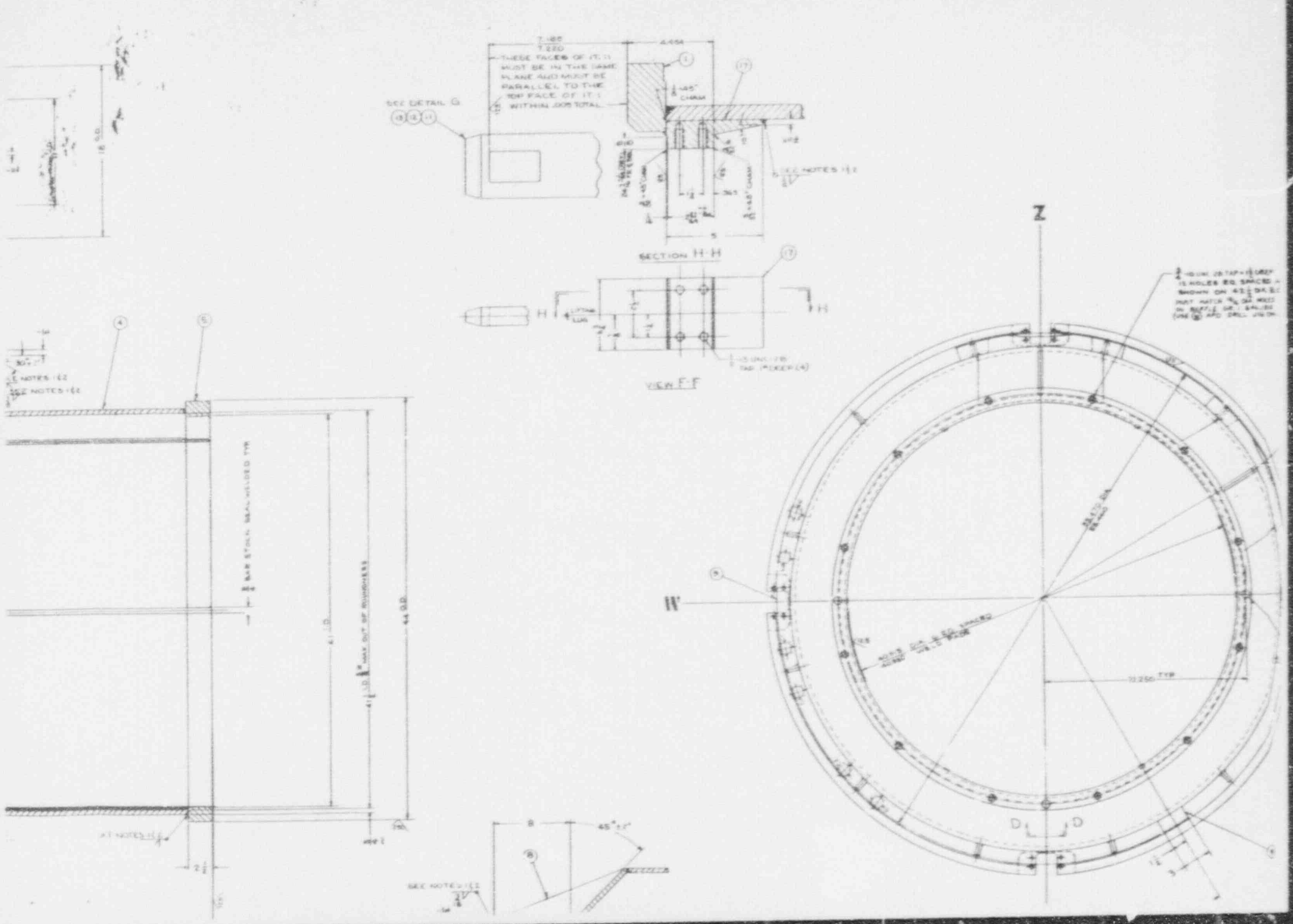
NO. REQ	PC NO.	TITLE
	1	TOP RING
	2	UPPER BARREL
	3	BARREL CONNECTOR
	4	LOWER BARREL
	5	BOTTOM RING
	6	OUTLET FLANGE
	7	FLANGE SUPPORT
	8	GUSSET
	9	SPACER BLOCK
	10	GUSSET
2	11	LIFTING LUG
	12	LOCKING DEVICE
	13	LOCKING SCREW
3	14	GUIDE PIN
4	15	½-13 × 1 SOCKET HD. CAP SCR F-10
3	16	⅜ DIA × 1½ LG. STD SST DOWEL PIN
	17	PAD
	18	GUSSET

BILL OF MATERIAL

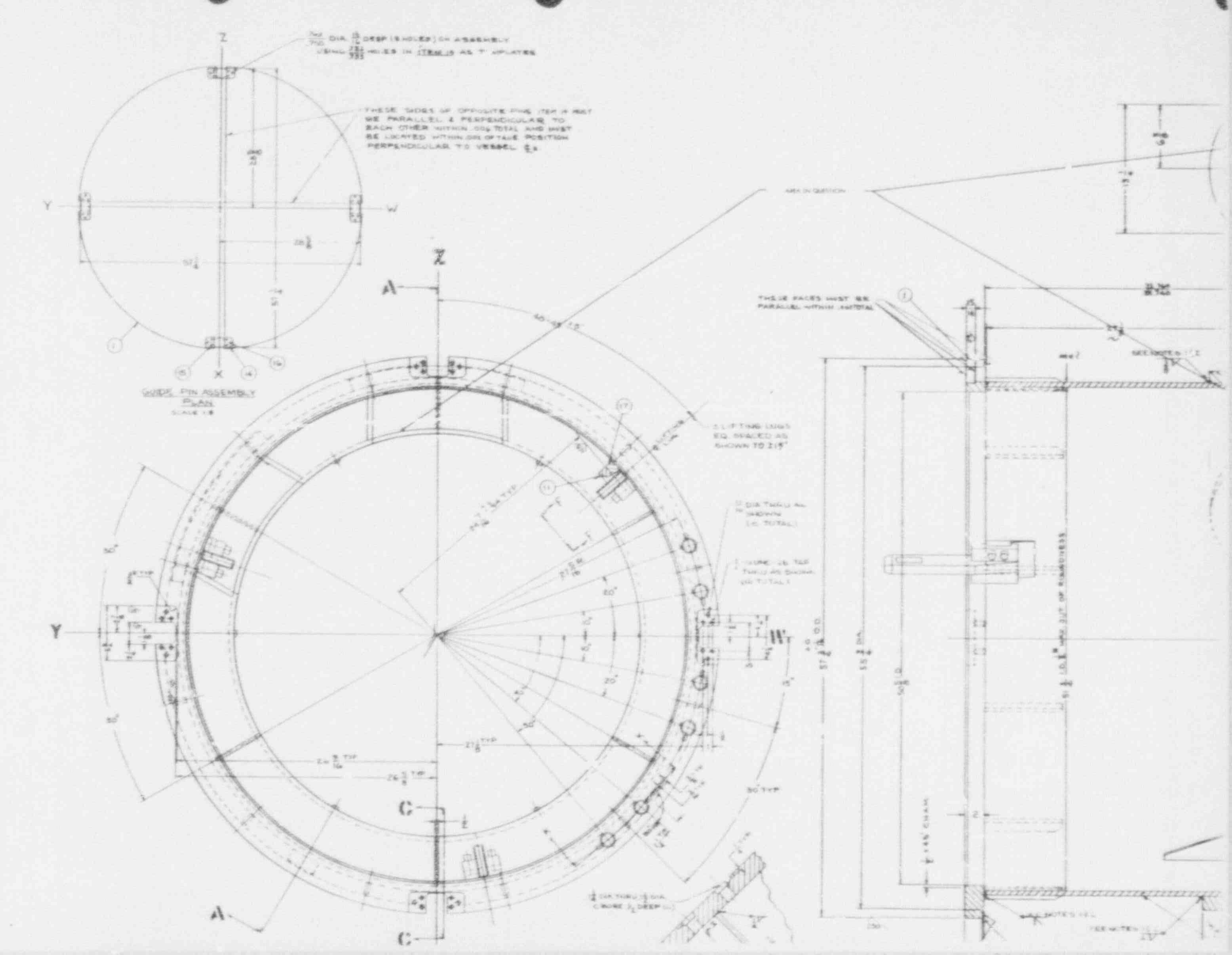
NOTES:
1. WELD PER [illegible] PROC. SPEC. [illegible]
2. DYE PENETRANT PER [illegible] PROC. SPEC. [illegible] (APPENDIX III) NOTE A2
3. REMOVE BEFORE SHIPPING
4. CLEAN ASSY PER [illegible]
5. B.O. FROM ALLEN MFG CO. HARTFORD 2, CONN.







THESE FACES OF IT. 11 MUST BE IN THE SAME PLANE AND MUST BE PARALLEL TO THE TOP FACE OF IT. 1 WITHIN .005 TOTAL
SEE DETAIL G
SECTION H-H
VIEW F-F
SEE NOTES 1&2
Z
W
D
D



THESE SIDES OF OPPOSITE PINS ITEM 14 MUST BE PARALLEL & PERPENDICULAR TO EACH OTHER WITHIN .005 TOTAL AND MUST BE LOCATED WITHIN .010 OF TRUE POSITION PERPENDICULAR TO VESSEL ℄
GUIDE PIN ASSEMBLY
PLAN
AREA IN QUESTION
THESE FACES MUST BE PARALLEL WITHIN .001 TOTAL
3 LIFTING LUGS EQ. SPACED AS SHOWN TO 21.5°
Z
Y
W
X
A
C

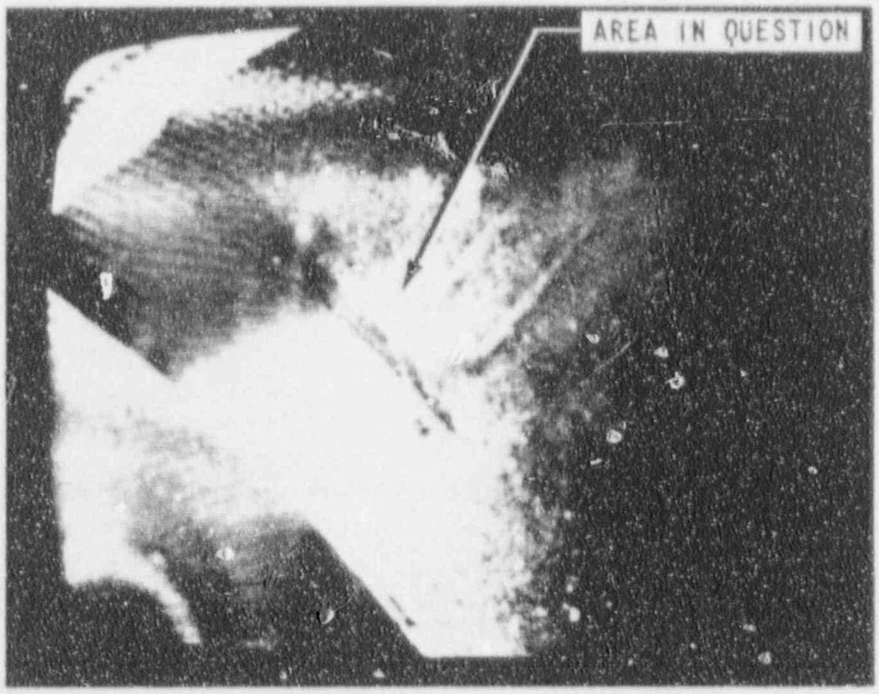


Figure D-2. Photograph of Area from TV Tape

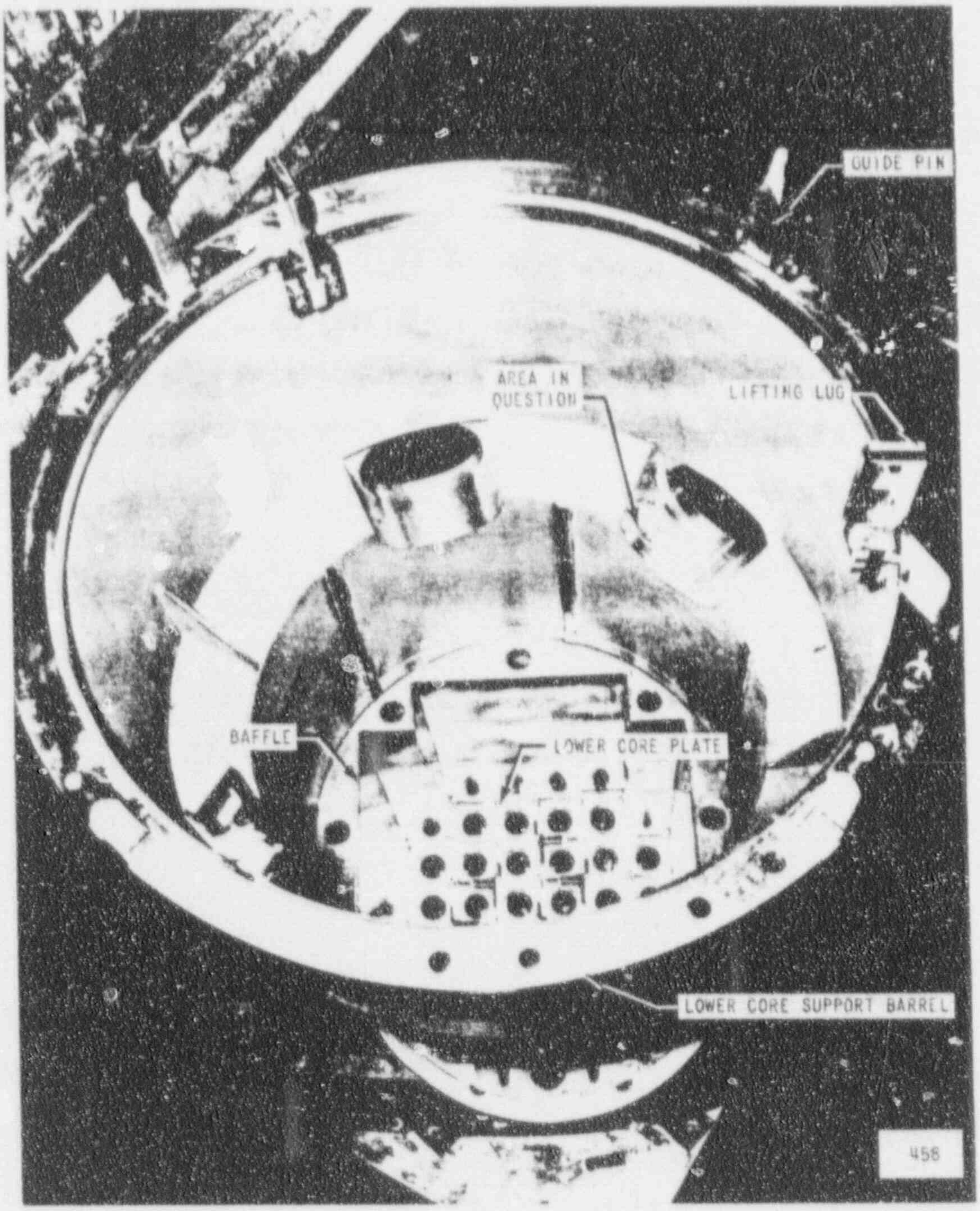


Figure D-3. Saxton Internals Assembly

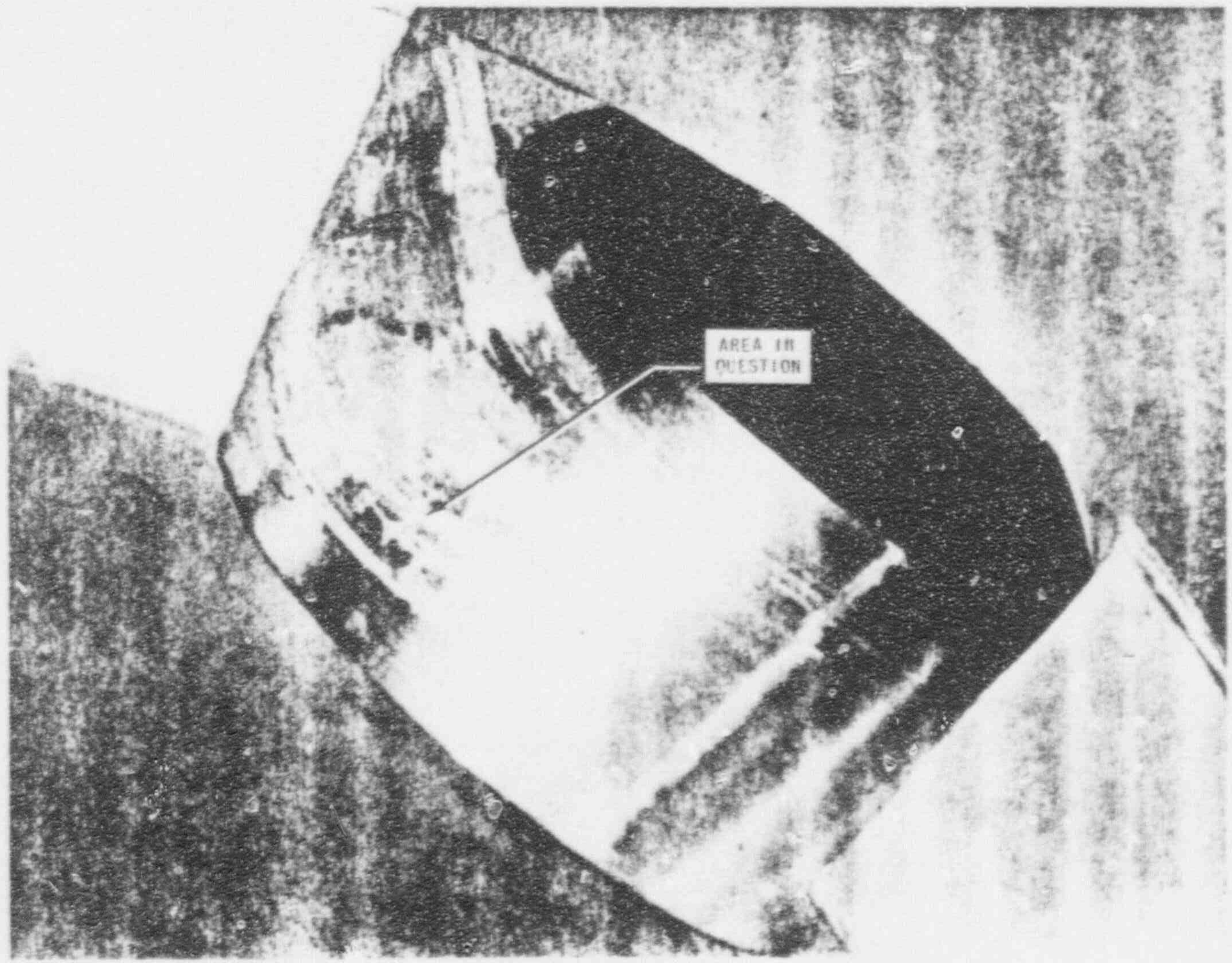


Figure D-4. Enlargement of Vendor's Original Photograph

VON MISES MID-PLANE STRESS	COMPUTER GEOMETRY POINT
384 PSI	14
347 PSI	17
315 PSI	20
340 PSI	24
334 PSI	29
356 PSI	32
364 PSI	35
364 PSI	38
364 PSI	39

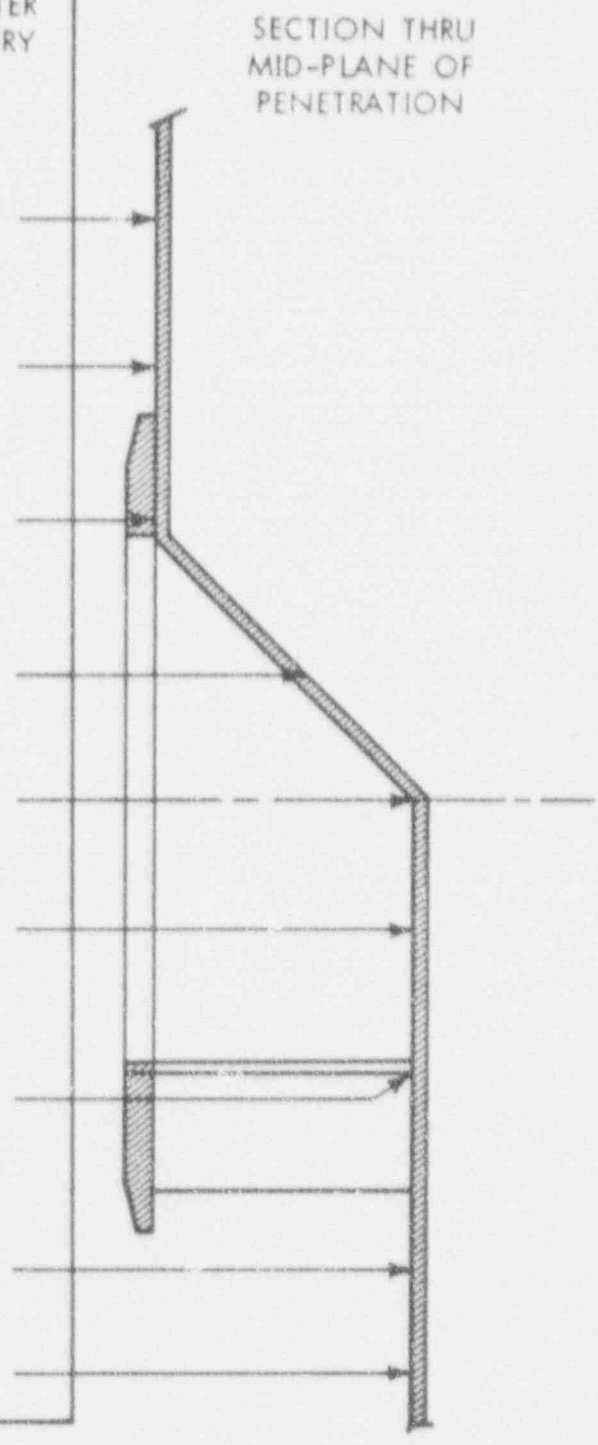


Figure D-5. Saxton Lower Core Barrel Stress Distribution

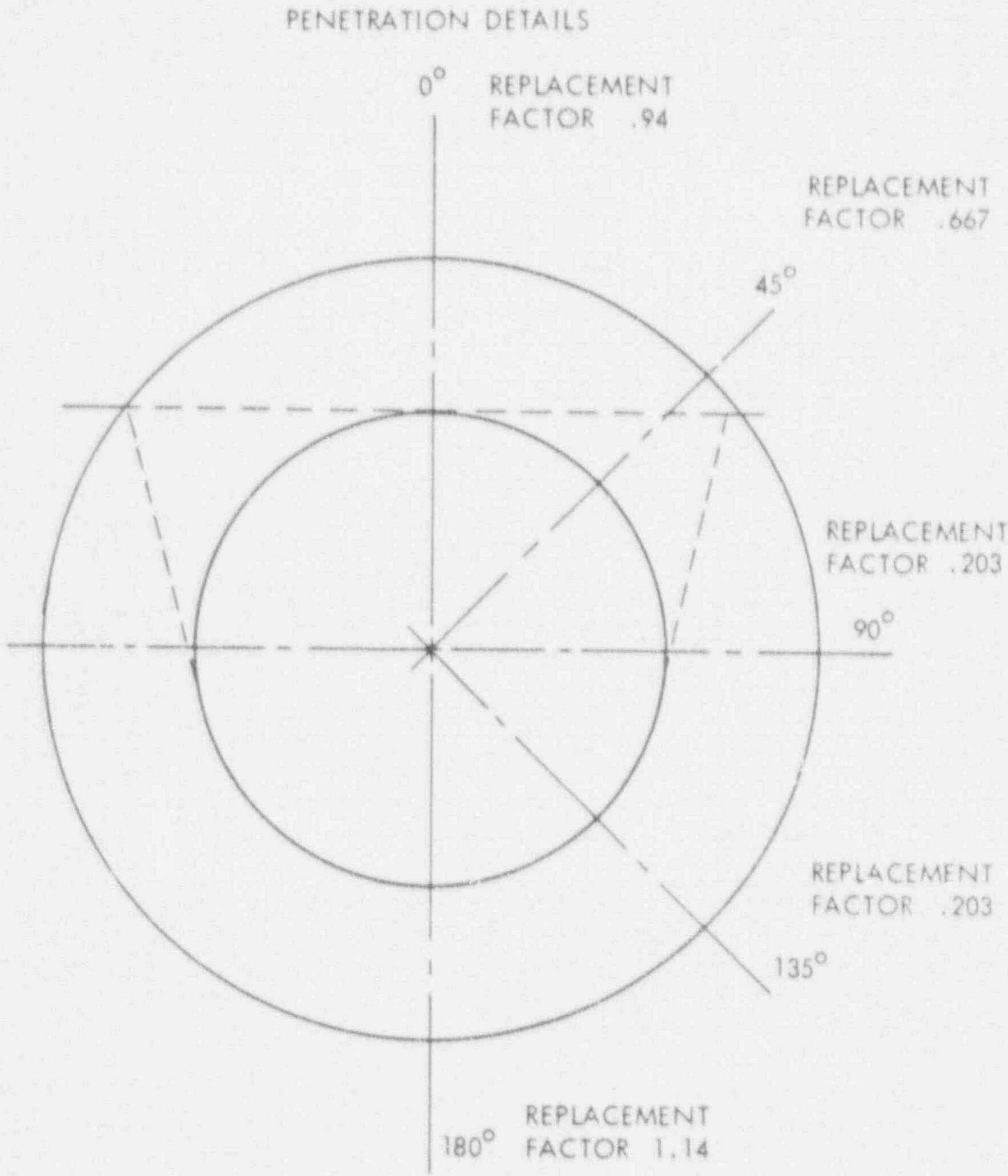


Figure D-6. Saxton Lower Core Barrel

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