BAW-1732
July 1, 1982

EVALUATION, REPAIR AND REPLACEMENT
OF
DAMAGED INTERNAL AUXILIARY FEEDWATER HEADER
AT
DAVIS BESSE 1, OCONEE 3 AND RANCHO SECO

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50-312
50-287

Babcock & Wilcox
a McDermott company

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1.0 Introduction

There are two configurations of auxiliary feedwater (AFW) header assemblies which are used on the steam generators for Babcock & Wilcox's 177 Fuel Assembly Plants. The first type uses an external distribution header mounted outside the once through steam generator (OTSG) with nozzles penetrating the shell and shroud. The second type uses an internal distribution header mounted inside the OTSG. Recent inspections showed damage in the internal AFW headers at three plants: Duke Power Co., Oconee 3, Sacramento Municipal Utility District, Rancho Seco, and Toledo Edison Co., Davis Besse 1. Internal AFW header designs also exist at General Public Utilities, Three Mile Island (TMI-2), and Consumers Power Co. Midland 1 and 2 Units. TMI-2 has not been inspected, and Midland 1 and 2 are still under construction and have not begun commercial operation. The external AFW headers have operated for more than 22 reactor years with no evidence of damage. They are used at: Duke Power Co., Oconee 1 & 2, Arkansas Power & Light Co., ANO-1, Florida Power Corp. Crystal River 3 and General Public Utilities, Three Mile Island-1.

The purpose of this report is to describe the inspection, evaluation and repair activities related to resolving the damaged internal header problems which have occurred at the plants using that header configuration. It will also be used as a failure analysis report under the requirements of ASME Boiler and Pressure Vessel Code, Section XI, Article IWA 7000.

In the following sections of this report, facts will be presented to show that a logical cause has been established and that the intended repair prevents recurrence of that problem in both the non-functional internal header and the new external header. In addition, the report will show that the modified design provides all functional requirements previously provided by the internal header design. Based on these facts, the report will demonstrate that start-up and continued operation of the affected plants is justified.

1.1 Internal AFW Header Design

The internal AFW header is a rectangularly shaped torus fabricated of welded plate segments. The header is positioned on the upper end of the upper vertical cylindrical baffle (upper shroud) (see Fig. 1-1). The header also serves as a continuation of the upper shroud to separate the tube bundle from the steam annulus. The header is positioned and retained by eight sets of inner and outer brackets welded to the bottom of the header and match drilled through the shroud. A dowel passes through each set of brackets and is welded to the inner bracket (See Fig. 1-2).

A single 3 1/2 inch diameter AFW nozzle delivers water to the header via a thermal sleeve which slip fits into the header (see Fig. 1-3). Water leaves the header through 60 - 1 1/2 inch diameter flow holes near the top of the inner header wall. The flow holes are equally spaced around the circumference. There are 8 - 1/4 inch diameter drain holes near the bottom of the inner vertical wall (See Figures 1-4 and 1-5).

The auxiliary feedwater system piping connects to the AFW nozzle outside each steam generator. During power operation the internal AFW header, thermal sleeve, and a portion of the horizontal piping are filled with dry superheated steam.

The bracket and dowel arrangement permits differential thermal movement of the internal AFW header in a radial direction during operation.

1.2 Internal AFW Header Functional Requirements

The internal auxiliary feedwater header provides three functions. The header distributes auxiliary feedwater whenever required over the steam generator tube bundle at a point just below the upper tubesheet. It also acts as an extension of the upper shroud which separates the tube bundle from the steam outlet annulus.

The third function is served while the plant is shutdown. When a plant is in wet lay up the header distributes water and chemicals, during fill and recirculation, to the top of the steam generator secondary side to insure a well mixed solution.

1.3 History of the Problem

In April, 1981 tube leakage was experienced at the Davis-Besse 1 station. An eddy current (EC) inspection determined that two adjacent peripheral tubes were leaking. The elevation and circumferential location of the tube leaks were aligned with the location of a header bracket pin. An expanded eddy current inspection carried out in this generator in the areas near the other dowel pins identified one additional tube indication (ding) which could be correlated to a dowel pin location.

In May, 1981 tube leakage at Rancho Seco was identified. Although the leaking tube was adjacent to the inspection lane and not related to the header, an eddy current inspection was performed at all dowel pin locations. The inspection recorded dings in tubes at five of the eight dowel pin locations.

In February, 1982 a leaking tube at the bundle periphery was identified at Oconee 3. An eddy current inspection performed at four of the eight dowel pin locations recorded no tube indications.

As a result of these indications more EC inspections of the perhipheral tubes in the OTSG at Davis Besse 1 were planned for their 1982 refueling outage. As a result of these inspections visual examinations of the internal headers were made to check for loose dowel pins in the brackets attaching the internal header to the steam generator shroud. It was during this inspection that the header and bracket damage was first detected. The results of this inspection led to the inspections at Rancho Seco and at Oconee 3 which also employ the internal header design.

Following the preliminary inspections during April of this year at Davis-Besse and Rancho-Seco a meeting was held April 23, 1982, to provide the NRC staff with information then available on this problem. Since that time, there have been several plant specific meetings with the staff to review additional inspection information and the repair plan. The three operating plants with the internal header design have also filed Licensee Event Reports with their regional NRC Inspection and Enforcement Offices and Consumer Power Company has filed a 10CFR50.55e Report with their NRC I&E regional office.

Figure 1-1

ONCE-THROUGH STEAM GENERATOR
WITH INTERNAL AUX. FEEDWATER HEADER

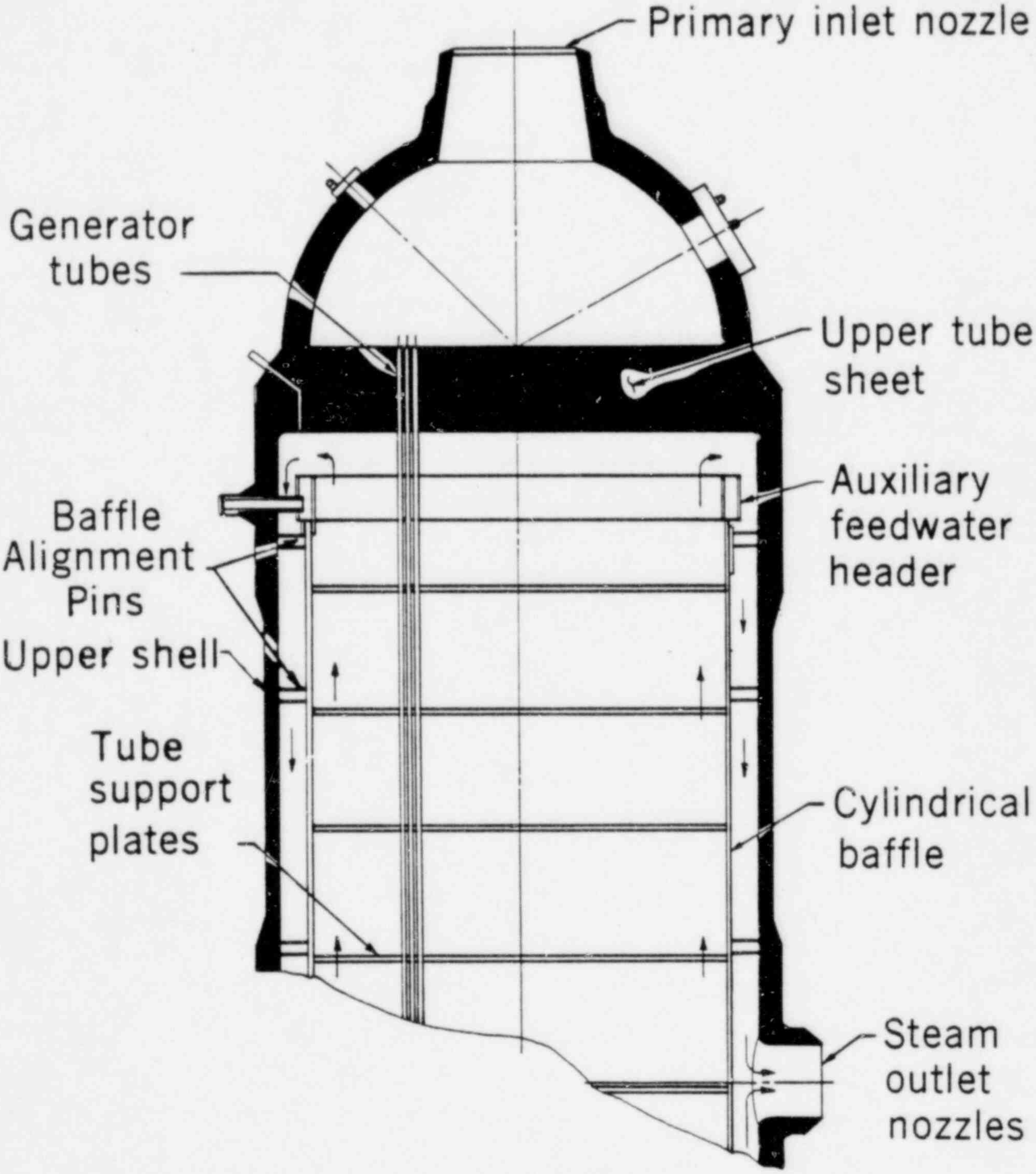
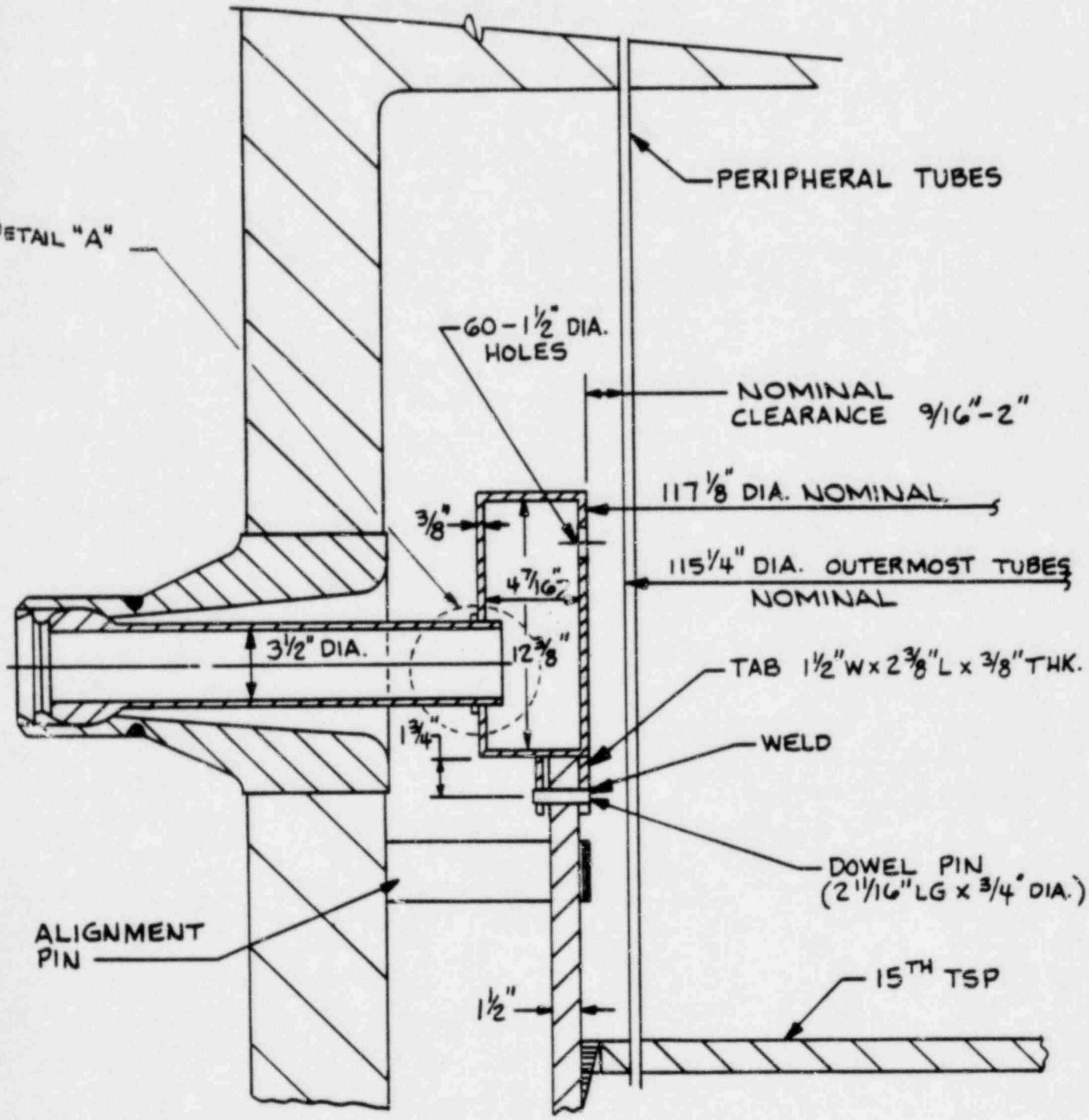


Figure 1-2

LONGITUDINAL SECTION OF INTERNAL

AFW HEADER AT DOWEL PIN



DETAIL A

AUXILIARY FEEDWATER SLEEVE AT INTERNAL HEADER INTERFACE

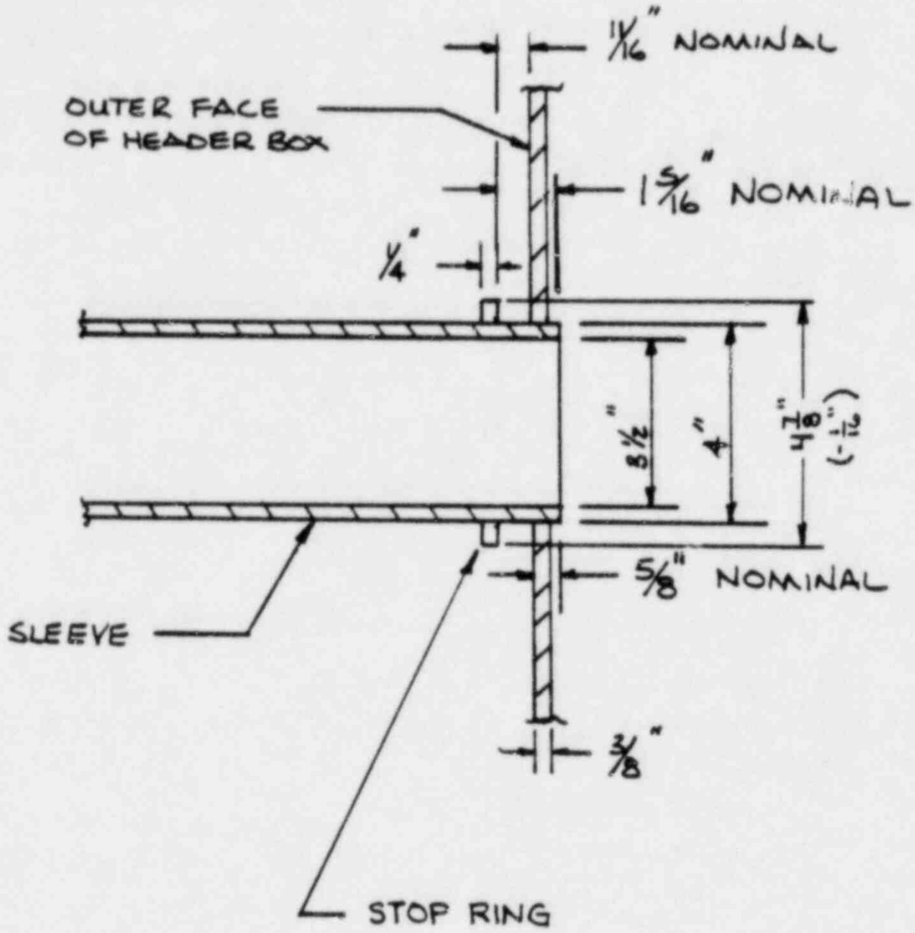


Fig. 1-3

PLAN VIEW OF INTERNAL AUXILIARY
FEEDWATER HEADER

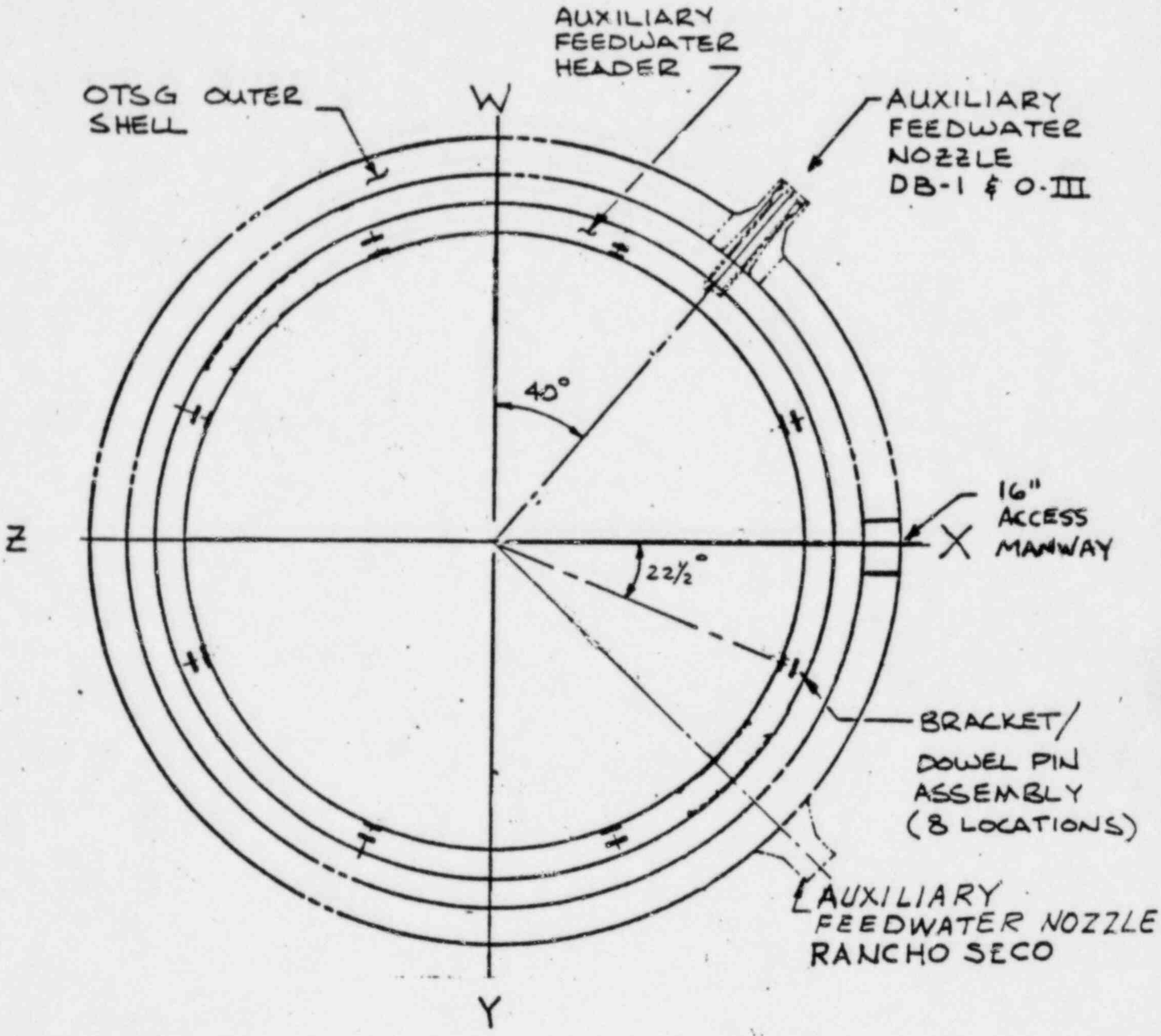


Fig. 1-4

LOCATION OF INTERNAL AUXILIARY FEEDWATER
HEADER FLOW HOLES

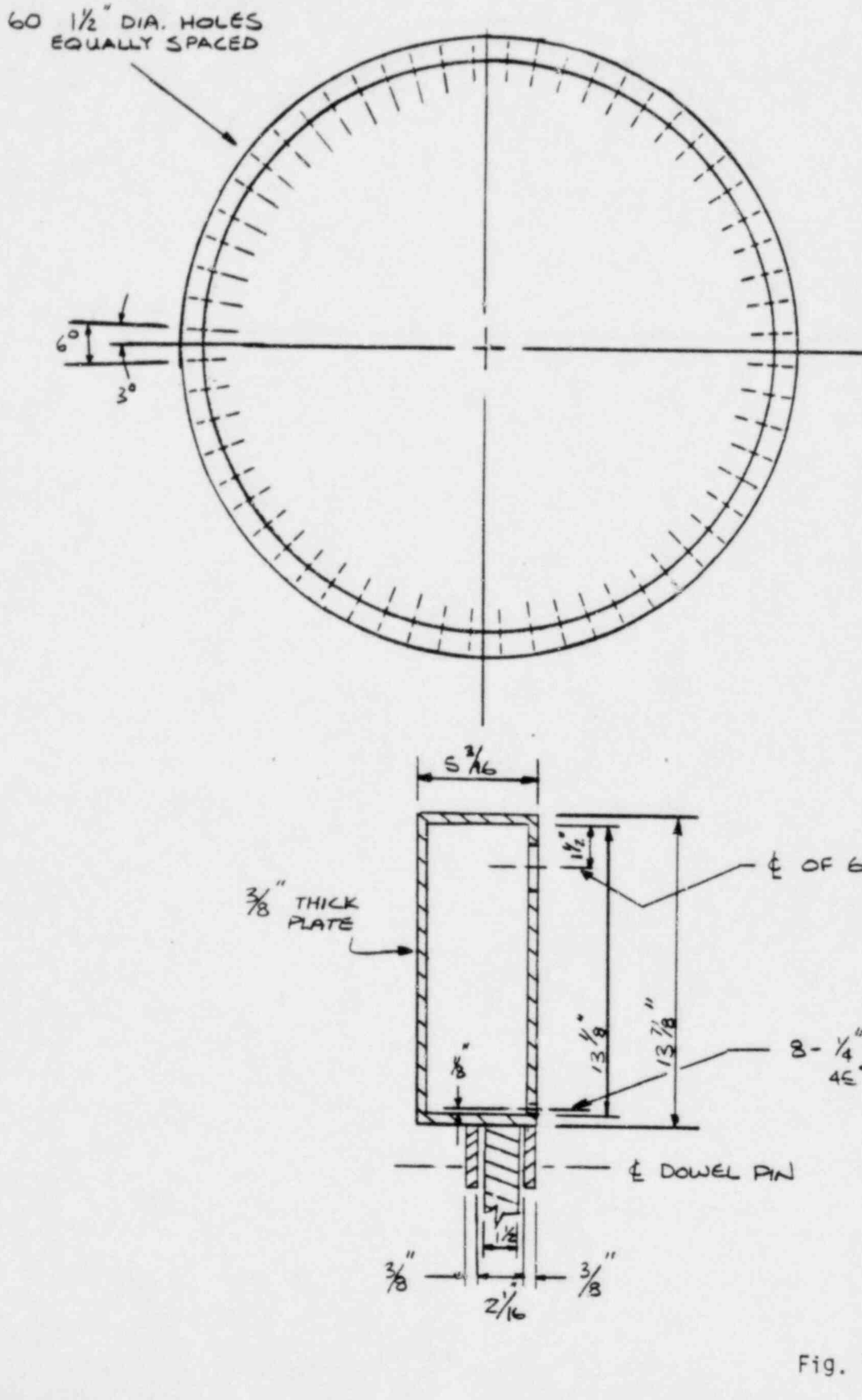


Fig. 1-5

2.0 Site Inspections and Results

As a result of the 1981 eddy current inspections additional inspections were initiated at Davis-Besse 1 in March of this year during their planned refueling outage. The damage noted during that inspection and the absence of any plant specific cause suggested the need for inspection of Rancho Seco and Oconee 3 internal headers.

The site inspection techniques used for these inspections include direct visual inspection, dimensional measurement, fiber optics and remote TV camera viewing. In addition eddy current testing (ECT) is being used to determine tube wall thinning. Debris analysis of the ECT data is used to indicate clearances between peripheral tubes and the inner most parts of the internal headers. Visual examinations along with ultrasonic (UT) and penetrant tests (PT) are also being performed to establish the mechanical integrity of the feedwater header plates and welds and the steam generator shell in the vicinity of the new AFW nozzle penetrations. These results and the status of inspections at the three plants are described in Sections 2.1 through 2.3.

With one exception, the inspection results from all three plants were generally similar. The outer vertical wall of the header was distorted inward toward the center of the generator, the support brackets were bent or damaged and the dowel pins were either out of position or missing. The exception was the presence of holes in the parent metal at the top and bottom plates of the headers at Oconee 3. Investigation of the holes in the Oconee 3 headers is continuing.

Clearances between the inner wall and inner brackets and peripheral tubes have been inferred at Davis Besse and Rancho Seco to be minimal. It is postulated that the distortion of the outer vertical wall of the header has led to some inward bowing of the inner vertical wall and movement of the top and bottom corners of the inside of the header closer to the pheripheral tubes. This bowing was checked by feeling the inner wall at Davis Besse 1 and SMUD after machining the access holes. This movement along with distortion of the inner brackets could also account for the apparent reduction of inner bracket to perhipheral tube clearance. The distortion of the header inner wall is indicated in Figure 2-1, 4-1, and 4-2.

UT of the shell and internal header nozzle region was performed prior to machining. These examinations showed those areas to be free of unusual or unacceptable indications.

At all three plants, some gaps were noted between the top of the shroud and the bottom of the header. These gaps varied from 0 to about 1/4".

2.1 Davis Besse 1 Inspection

During the 1982 refueling outage at DB-1 eddy current inspection identified a number of new indications in tubes corresponding to the dowel pin locations. In addition, a significant number of indications were recorded on peripheral tubes between the dowel pin locations. The indications correlated with the top and bottom edge of the internal AFW header.

An expanded inspection program was initiated on both of the DB-1 OTSGs to characterize further the initial findings. This included:

- o 100% peripheral tube eddy current inspection.
- o Selected profilometry inspection of peripheral tubes with eddy current indications in the header region.
- o Secondary side visual inspection of the internal AFW header.

Eddy current inspection showed 24 peripheral tubes in the two generators had indications which were interpreted to show contact with the internal header assembly at some point in time. Of these 24 tubes, seven tubes had outside diameter (OD) indications, and 17 tubes had tube diameter reduction (ding) indications. Three of the OD indications exceeded the technical specification plugging limits of 40% through wall.

Eddy current debris analysis of the peripheral tubes indicated that the header was very near tubes around one axis and showed that there is only slightly more clearance at all other locations.

Profilometry indicated that the direction of the tube diameter reduction for tubes apparently in contact with the header was oriented toward the AFW header. The amount of tube diameter reduction is less than 20 mils.

A visual inspection of the internal headers, followed by a 360° remote video inspection, showed that the outer wall (shellside) of the header is distorted inward (concave) as much as 4 1/2". In addition, the inner vertical wall was noted to be bent inward in some locations. It was also noted that certain header support brackets were bent, the bottom ligament torn out, or were broken off and that there was evidence of wear and/or distress on dowel pins and brackets. Dowel pins were found to be not in place at the majority of the eight bracket locations in each of the steam generators (See Fig. 2-1). All brackets and all but one dowel pin have been located and retrieved. The missing dowl pin is not in the tube bundle or on the 15th tube.

In one generator the thermal sleeve was disengaged from the inlet hole of the header and was offset from the center of that opening. Further visual inspection of the internal headers by remote TV camera indicated the accessible header plates and welds were sound. In addition, a penetrant test (PT) of the lower corner weld accessible from the manway and a UT of the most concave area of the outer wall of the header were performed. Following those tests about 40% of the bottom plates of the header were ultrasonic tested (UT) after machining holes for the new external header AFW injection connections (See Section 4.0 Description of Repair). These inspections also indicated the header plates to be of full thickness and sound.

Eddy current inspection will be performed after securing the header to the shroud to locate any wall thinned tubes that need to be stabilized and plugged and to verify that 1/8" clearance still exists between the header and brackets and the peripheral tubes.

2.2 Rancho Seco Inspections

Examination of the internal headers at Rancho Seco showed similar results. A 360° visual and video inspection of the two headers indicates that there is inward distortion of the outer vertical plate of the header. The

The concavity approached what was noted at Davis Besse 1. No misalignment of inlet thermal sleeves with the header inlet holes was noted altnough one sleeve was disengaged from the inlet hole in the header.

Visual inspection of the A steam generator indicated the inner wall of the header at top and bottom to have greater than 1/8" clearance between the header and perhipheral tubes. However, four inner brackets appear to be less than 1/8" away from at least one tube. One dowel pin is not in place and the other seven are loose. The missing dowel pin has been located and retrieved. One inner bracket has a crack in the weld attaching it to the header bottom but all the other 15 brackets are in place and appear to have sound welds.

In the B generator, clearance between the header and peripheral tubes is greater than 1/8". Five inner brackets are in contact with at least one tube, while three have at least 1/8" clearance. The outer brackets are in place with sound welds. Four dowel pins are not in place and four are loose. All missing dowel pins have been located and retrieved.

UT indicated no flaws or plate thinning in the lower plate of either header.

Eddy current inspection will be performed after securing the header to the shroud to locate any wall thinned tubes that need to be stabilized and plugged and to verify that 1/8" clearance still exists between the header and brackets and the peripheral tubes.

2.3 Oconee 3 Inspections

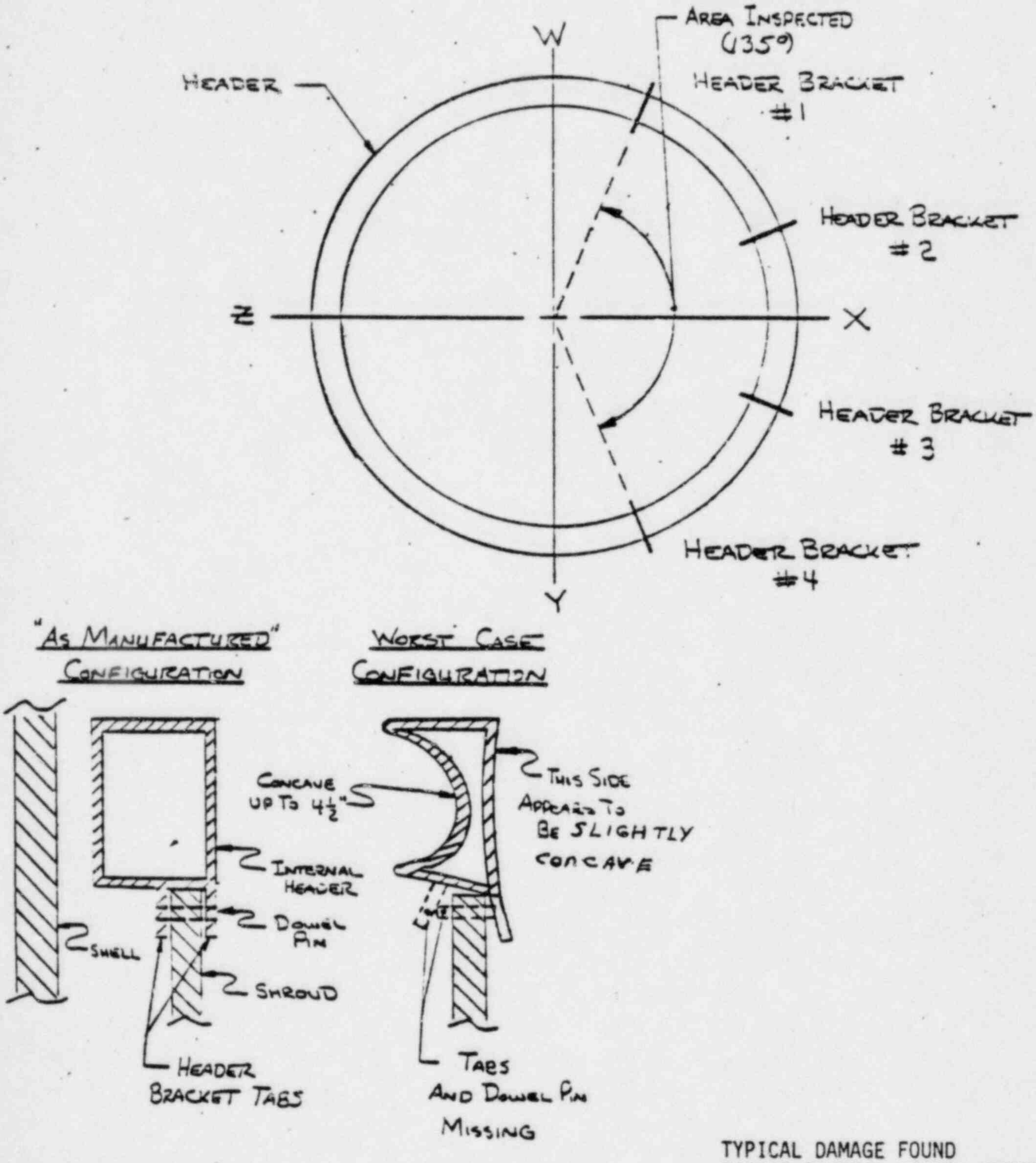
Visual and video inspection of the header is complete at Oconee 3. Machining of the new header inlet holes is also complete. Visual inspection indicates distortion of the outer vertical wall of the header and distortion of most of the fastener brackets on both headers. All brackets are in place and only one dowel pin is not in place in the A generator. A hole approximately 4" long and 1/4" wide oriented circumferentially, was noted in the bottom of the header of the A generator and one hole 2" - 3" long and 1/8" to 1/4" wide was found in the top of that header. This hole was oriented radially. UT examination of the wrappers in the A SG showed them to be sound with no loss of thickness. One crack about 1/16" wide by about 18" long was noted visually in the bottom inside corner weld Fiber optic inspection through the feed water inlet showed the inside of the header to be free from corrosion or chemical attack.

In the B generator none of the dowel pins were in place. All brackets are in place but show some distortion or damage. There is one 1/4" hole in the top of this header.

Location and retrieval of missing dowel pins is in progress. Visual examinations of both generators have shown that none of the missing pins are located inside the shroud on the 15th tube support plate.

Inspection of the header in the B generator will be completed after machining of the holes in the shells. Ultrasonic inspections of the bottom plates through the new holes will be performed after machining to assure the soundness of the points for tie-down. E.C. inspection to determine wall thinning and verify header clearances will be performed in both generators after the header is welded to the shroud as described in Section 4.2.

Fig. 2-1



TYPICAL DAMAGE FOUND
DURING INITIAL VISUAL INSPECTIONS

3.0 Most Logical Cause

3.1 Mechanisms Examined

A number of mechanisms were evaluated as possible causes of the internal header deformations. Both stress and thermal hydraulic calculations were performed to analyze these mechanisms. Early in the evaluation, phenomena from normal operating conditions were ruled out as candidate mechanisms.

Mechanisms examined were:

- o Impingement velocity and turbulent flow conditions due to high AFW flows
- o High pressure drop due to high steam flow through header holes at the beginning of AFW flow
- o Thermal stresses due to cold AFW flow into a header preheated by steam to about 550-590°F

It was concluded from these evaluations that some other deformation mechanism must be present to cause partial collapse of the internal AFW header. Stress calculations indicated that a pressure differential above about 200 PSI would be required for this to occur.

3.2 Most Logical Cause

Condensation-induced high differential pressure has been postulated to be the deformation mechanism which could create large enough pressure differentials to partially collapse the internal AFW header. Vertical walls have less rigidity and tend to buckle inward. This inward distortion could bow the lower plate upward binding the bracket and dowel pins. This could defeat the dowel pin slip mechanism and ratcheting of the brackets and pins could occur. Forces may be sufficient to break bracket ligaments, bend pins, break bracket or dowel pin welds and deform inner brackets. Repeated application of such forces could increase the severity of the damage.

According to the Creare Report, NUREG 0291(1) condensation-induced high difference pressure can be anticipated under the following conditions:

1. Trapped steam
2. Sufficient flow of subcooled water
3. Sufficient subcooling

   Resulting in:
   - Rapid condensation of steam
   - Sudden depressurization of steam void

NUREG 0291 describes condensation-induced pressure surge phenomena which can occur in a flowing system. These phenomena can be separated into three distinct stages. Stage #1 is the process of void formation, assumed to occur mainly by fluid mechanical interaction, possibly aided by countercurrent steam flow. Stage #2 is the condensation and heat transfer driven void collapse, resulting in potentially very large localized pressure decreases in the header. Stage #3 is the water slug impact with the upstream water, creating the large amplitude shock waves.

The AFW header internal damage mainly shows evidence of an inward collapse of the outer (shellside) wall. The "ballooning" effects which are typical of feedwater line water hammer (Stage 3) were not evident.

The observed damage to the AFW headers points to a conclusion that the most logical deformation mechanism is condensation-induced high differential pressure. The first phase of the pressure transient appeared to create a condensation induced high pressure difference across the AFW header wall when trapped steam pockets collapsed, resulting in header deformation. The effects of a resulting shock wave were not evident due to the attentuation by both the wall deformation and by the flow holes in the header which provided a fluid "escape route".

4.0 Description of Repair

The repair of the units involved meeting three objectives in an optimum combined manner:

- Retain all AFW functional requirements
- Complete the inspections of the damaged header
- Perform the required repairs

The most logical choice from a functional standpoint was to use a configuration as similar as possible to that used on other operating OTSGs, i.e., the external AFW header. Because it was considered desirable to retain the internal header as an extension of the shroud to serve as a steam flow baffle, it was necessary to have sufficient access to inspect fully the damaged header. It was also necessary to locate the inspection holes so that they could serve both as repair access openings and subsequently as AFW injection points.

The following general considerations will be applied to the inspection and repair program:

- All work will be conducted to minimize radiation exposure of personnel.
- Secondary side lay-up conditions will be monitored and kept within established water chemistry limits.
- Machining techniques used and materials control exercised will be designed to maintain systems' and components' cleanliness, protect the steam generator tubes and prevent the creation of loose parts.

4.1 Internal Header Design Requirements(2)

The evaluation of these considerations led to the establishment of a set of design requirements for securing the internal header. These requirements met by the repair described in Section 4.2 include the following:

- The header must be maintained in a fixed position relative to the tube bundle. The minimum clearance between unplugged (functional) steam generator tubes and the header/restraint is 1/8". This clearance was based on twice the sum of the maximum differrential thermal motion, the maximum movement due to flow induced vibration, and the maximum thermal induced movement during heatup and cooldown.

  It should be noted that although Figure 1-2 indicates a possible nominal clearance of 9/16" to 2" in the original header design, there was no minimum clearance criteria defined. No minimum dimension was specified.

- The secured header must serve as an extension of the shroud to channel steam flow through a similar flow area as it did in the original design.

- Based on analysis performed, the AFW inlet opening in the internal header will not be closed.

- The secured header must withstand the expected static and dynamic loads resulting from:

  1) normal and upset operating transients

  2) seismic conditions (OBE)

  3) flow-induced vibration

- Restrained header must not cause leakage of steam generator tubes when subjected to faulted conditions from the most severe accident (steam line break) and seismic (SSE) conditions.

- The header restraint design must meet ASME, Section III Class 1 allowables.

- The design must minimize the risk of creating loose parts in the steam generator. Any existing brackets and pins which could potentially become loose parts shall either be removed or fastened in such a manner to prevent them from becoming loose during operation.

- The design must be compatible with the carbon steel materials of the header, upper cylindrical baffle, and steam generator shell, and it must be compatible with the feedwater chemistry requirements.

- The process of securing the header must be accomplished via the existing secondary manway and/or the auxiliary feedwater nozzle openings, old and new.

- The process of securing the header must not damage the tubes, create loose parts inside the steam generator, or introduce contaminants which cannot be removed from the steam generator.

- The process of securing the header may use but should not necessarily be limited to existing brackets and dowel pins at locations that are verified by inspection to be sound. Appropriate capture of the dowel pins and brackets must be achieved.

- The design must be licensable without violating any of the plant's design bases.

- A volumetric examination of the lower plate in the areas of attachment of the header is required.

4.2 Internal Header Repair

The bottom of the internal header will be secured to the shroud in eight locations around the circumference. These will be oriented above and adjacent to the circumferential location of the shell to shroud alignment pins. At each location a 7 inch long continuous fillet weld will be used to attach the outside of the shroud to the bottom of the header. In areas where there is significant separation between the shroud and the header, a shim will be used and will become part of the fillet weld. In the same locations 1/2 inch thick by 5 inch long by 3 inch wide gusset plates will be fillet welded to the bottom of the header and the outer face of the shroud. The fillet welds and 5" gusset plates acting together or separately are designed to take the forces and moments generated by normal operating or accident conditions. Figure 4-1 illustrates the intended repair. All three affected units will employ this concept. However, there will be minor differences due to utility preference in regard to use of the existing brackets and dowels. At Davis Besse and Oconee 3 the remaining brackets and dowel pins will be removed prior to securing the header. Rancho Seco has decided to exercise the option permitted by the design requirements of leaving the brackets and dowel pins in place with appropriate capture to preclude loose parts.

At all three plants the thermal sleeves used to direct AFW to the internal header will be removed. A flange will be welded to the existing nozzle and a blind flange will be used to seal the opening.

It is presently anticipated that the repair as described will be used at Oconee 3. Additional inspections are being performed to establish the mechanical integrity of the headers. Repairs to the header will be performed, if needed, to meet the established requirements for soundness of the secured header. Analysis to determine the probable cause of the holes noted in the top and bottom plates is in progress.

As mentioned at the beginning of this section a major consideration in the repair approach was to provide access to the damaged internal header with a minimum of machining on the shell. An engineering evaluation indicated that 5" diameter holes would provide sufficient access for securing the header while still complying with the code requirements for the mechanical strength of the steam generator shell. A demonstration of the ability to secure an internal header to the shroud by the described method was performed on a full scale steam generator mock-up May 21, 1982.

It is important to note that the probable cause of deformation to the internal header, identified in Section 3.2, describes a condition that only exists when that header is used for auxiliary feedwater additions. It is, therefore, considered reasonable to leave the internal header in place, once it is properly secured, since it will no longer be exposed to conditions which produced the deformation.

4.3 External Header

4.3.1 Description

The new external header will be connected to the existing plant auxiliary feedwater line by 6" diameter piping. The header will be about a 300° circumferential ring made from 6 inch schedule 80 pipe capped at each end. Each of the plants will employ either six or eight 3 inch schedule 80 pipe risers spaced around the ring to feed auxiliary feedwater through the steam generator shell and shroud to the secondary side of the tubes. Flanges will be located in the vertical riser just above the ring and at the point of entry into the steam generator shell.

The centerline of the riser inlet to the steam generator will be located about 14 inches above the top (15th) tube support plate. A tapered thermal sleeves will direct the flow from the shell opening through the shroud to the steam generator secondary side. The risers will contain variable size orifices at the flange in the vertical run to help equalize distribution of flow. Figures 4-2, 4-3A, and 4-3B show the arrangement of the replacement external AFW header.

4.3.2 Functional Design Requirements

Specifications have been issued to insure the header design meets its two basic functional requirements, i.e. supplying and distributing auxiliary feedwater to the steam generator tube bundle and providing distribution of recirculating water and chemicals during wet lay-up.(3)

The effects of flow-induced vibration have been examined(5)(6) to insure that the retrofit design is at least equal to the existing external header design in this area.

The applicable ASME codes will be those which are consistant with the licensing basis of the individual plants. Design, fabrication and analysis of the B&W supplied components will meet the requirements of Section III of the ASME code, Class 2 for the header ring, risers and shell flanges.(4)

4.3.3 Comparison to Existing Designs

As pointed out in Section 1.0 of this document the retrofit of the auxiliary feedwater external header has the advantage of applying a design proven in more than 22 reactor years of operation at five operating plants No evidence of water hammer or other condensation-induced pressure surges have been noted. The thermal sleeves have been inspected at all operating plants that use the external header design and have been found to be free of damage due to thermal shock or condensate induced pressure surge.

There are two additional features in the external header design which tend to minimize the possibility of any damage by condensation induced pressure surges. These are:

1) Top discharge nozzles to preclude header ring draining and suppress slug formation, and

2) Short horizontal runs to limit void formation and slug acceleration.

These facts have led to the conclusion that no water hammer tests prior to operation are required.

There are a few minor differences between the existing design and the retrofit design. Figure 4-4 shows the existing external AFW header arrangement. The injection point for AFW in the retrofit is about three inches higher than in existing designs to allow access for securing the internal header. This could result in an increase in flow induced vibration loads. This increase however is more than offset by a reduction in these flow loads due to a more gradual taper in the thermal sleeve resulting in a lower discharge velocity.

Two features of the retrofit design should provide more equal distribution of AFW flow. These are:

1) the use of variable size orifice plates in the flanges of the vertical riser

2) feed to the risers at circumferential locations nearer the midpoint of the header ring rather than from one end as is the case for existing designs

Lastly the thermal sleeve was redesigned and will be constructed partially of inconel, rather than carbon steel providing improved fatigue properties.

4.4 Loose Parts

It is the intent, as part of this repair, to locate and remove all loose parts. Should it be impossible to account for all parts, the location of such parts would be either at the 15th tube support plate or in the steam annulus. All missing brackets have been located and retrieved. Missing dowel pins have not been found on the 15th support at any of the three plants and are judged not to be within the tube bundle. This judgment is reached on the basis that the diameter of the dowel pin, 3/4", is greater than the 1/4" space between tubes; and, since no gross damage or spreading of tubes in the areas concerned have been noted, the pins could not have entered the tube bundle. It is concluded that they are outside the shroud and tube bundle; therefore, there should be no concern that they would endanger steam generator tube integrity.

Blankets to catch particles from the boring operations on the shell and shroud followed by a vacuuming to remove residual chips and dust will be used to prelude the machining operations producing contamination or loose parts. A careful inventory of all tools and parts that enter and leave the steam generator will also be kept.

4.5 Eddy Current Inspection and Tube Plugging

After the repair and external header installation are complete an eddy current inspection and debris analysis will be performed on peripheral tubes. Any tubes with greater than 40% wall thinning or in a location where the secured internal header and bracket clearance is less than 1/8" will be stabilized and removed from service by plugging.

Tube stabilization is done by inserting into the tube to be plugged 1/2" diameter inconel rods of whatever length is necessary. Varying lengths are obtained by coupling standard rod lengths. Each rod has a male and female thread at opposite ends to permit coupling. After coupling, the female thread is crimped to prevent decoupling. The rods are screwed into the plug prior to welding.

This stabilization technique is used as a capture mechanism to prevent instabilities due to potential flow-induced vibration and is not intended as a structural device.

The stabilizers are only used in conjunction with plugs in the upper tube sheet. More than 100 of these have been installed in OTSGs since inception of their use in 1976.

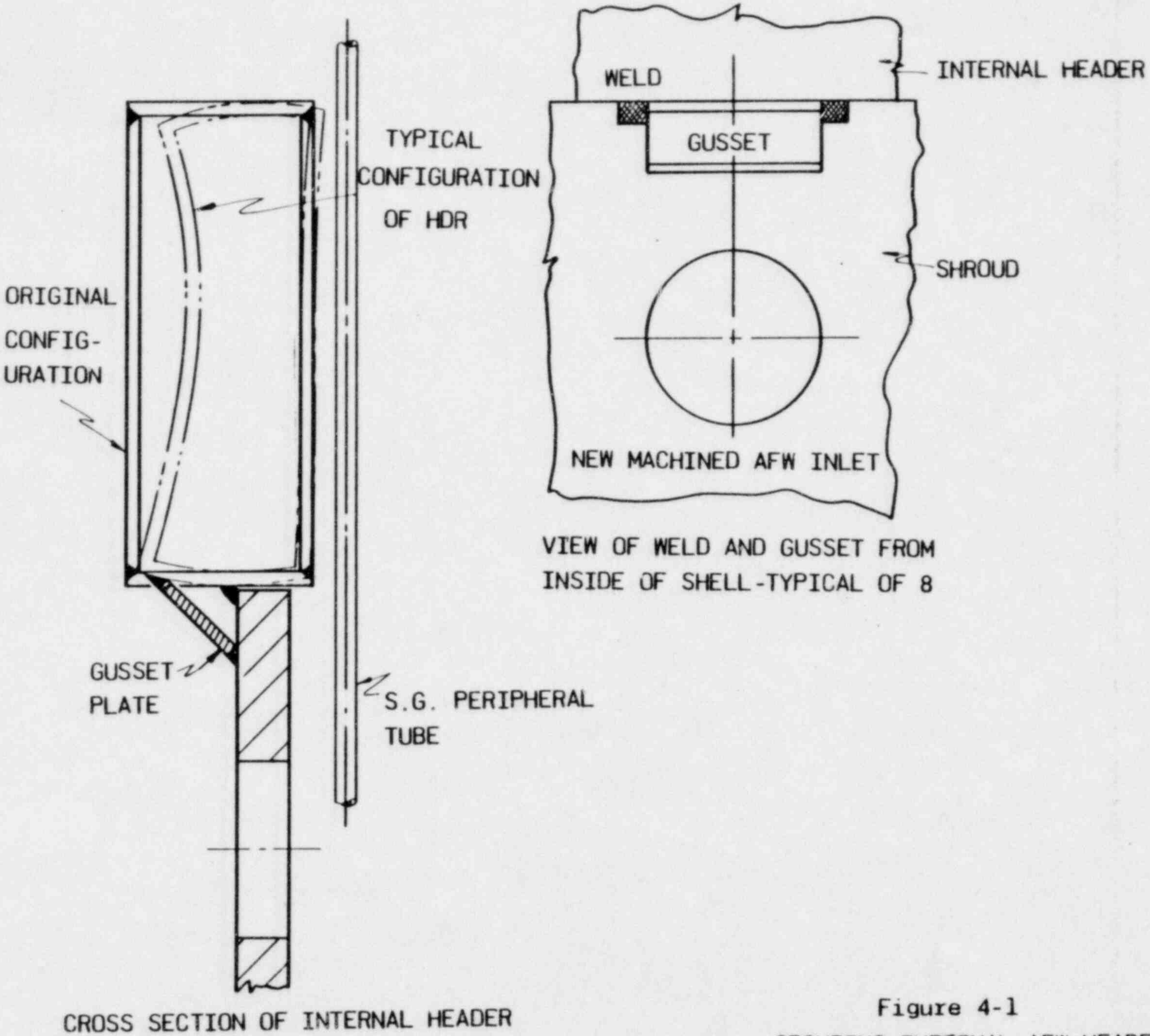


Figure 4-1
SECURING INTERNAL AFW HEADER

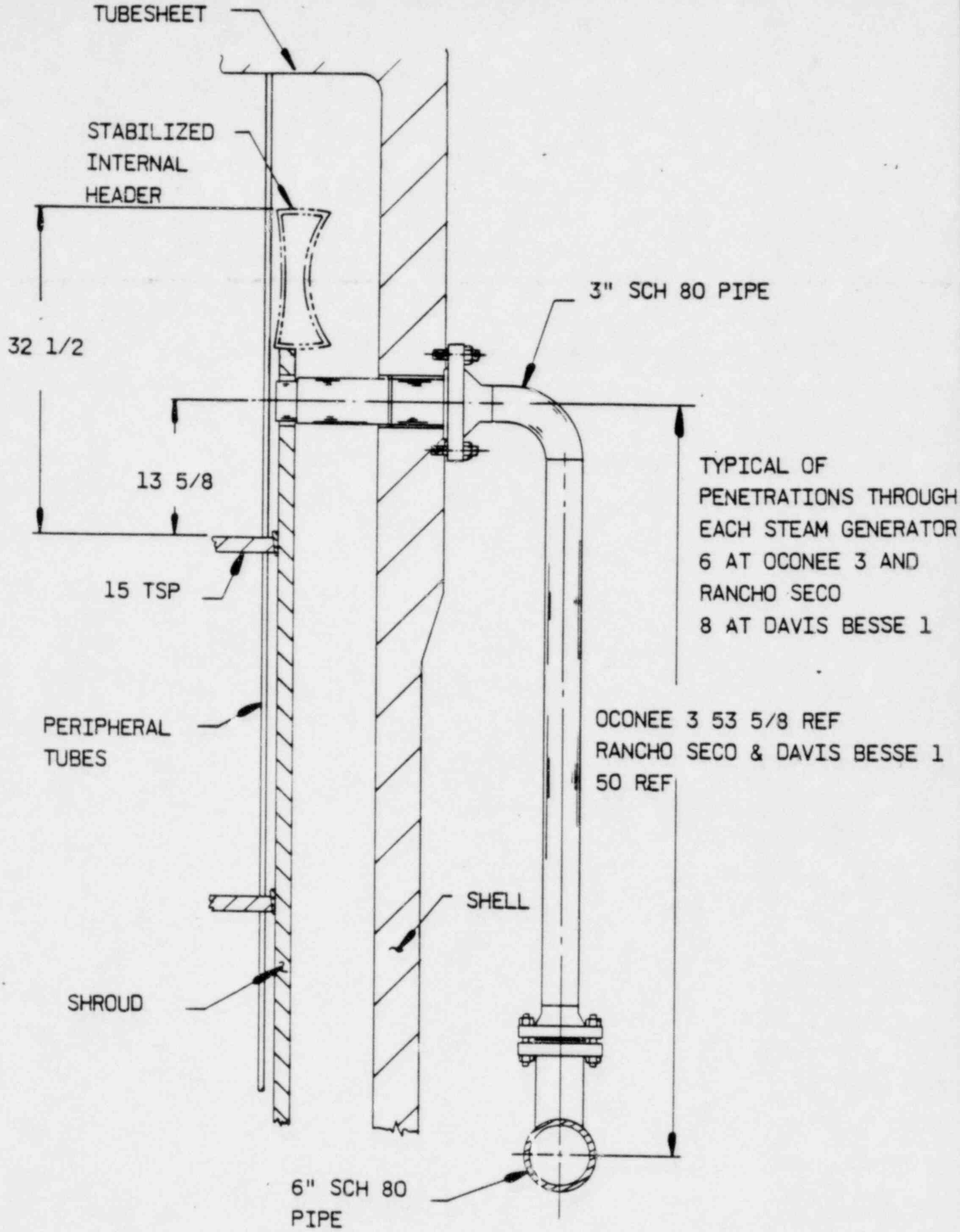
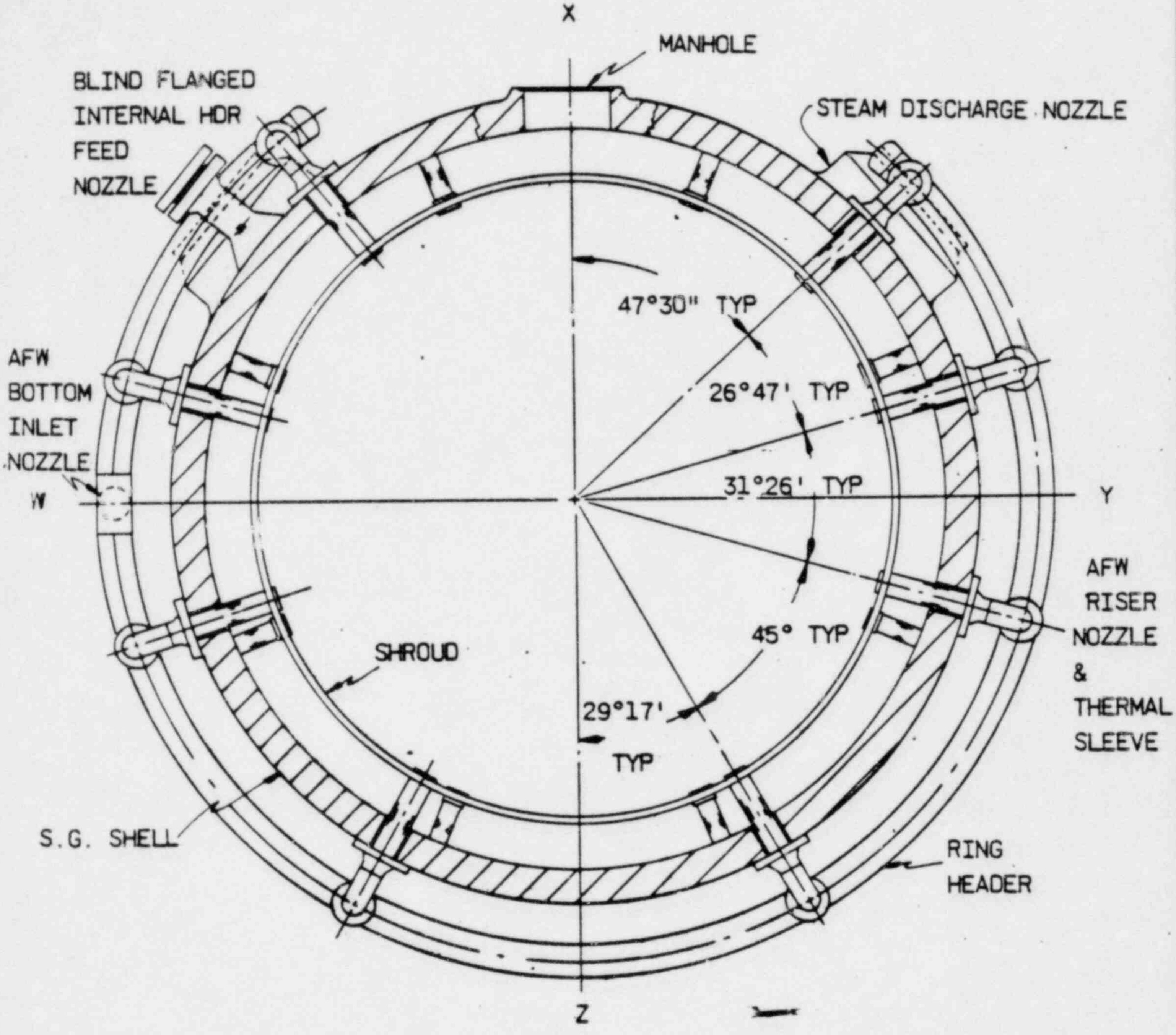


Figure 4-2

ARRANGEMENT OF REPLACEMENT EXTERNAL AFW HEADER-VERTICAL CROSS-SECTION



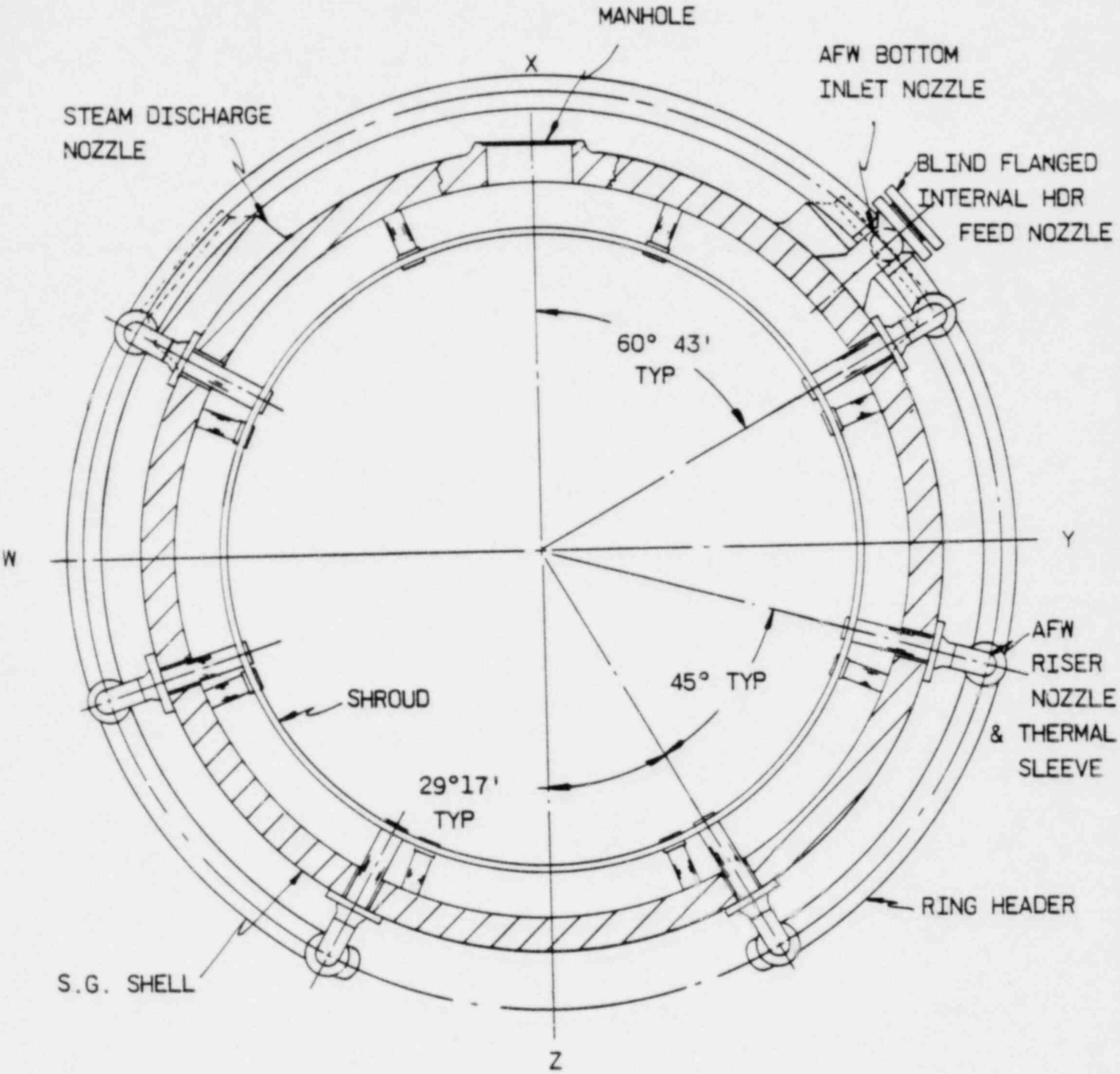
8 NOZZLE CONFIGURATION

DAVIS BESSE 1

Figure 4-3A

ARRANGEMENT OF 8 NOZZLE REPLACEMENT EXTERNAL AFW HEADER

-PLAN VIEW-



6 NOZZLE CONFIGURATION

SMUD

0-3

Figure 4-3B

ARRANGEMENT OF 6 NOZZLE REPLACEMENT EXTERNAL AFW HEADER
-PLAN VIEW-

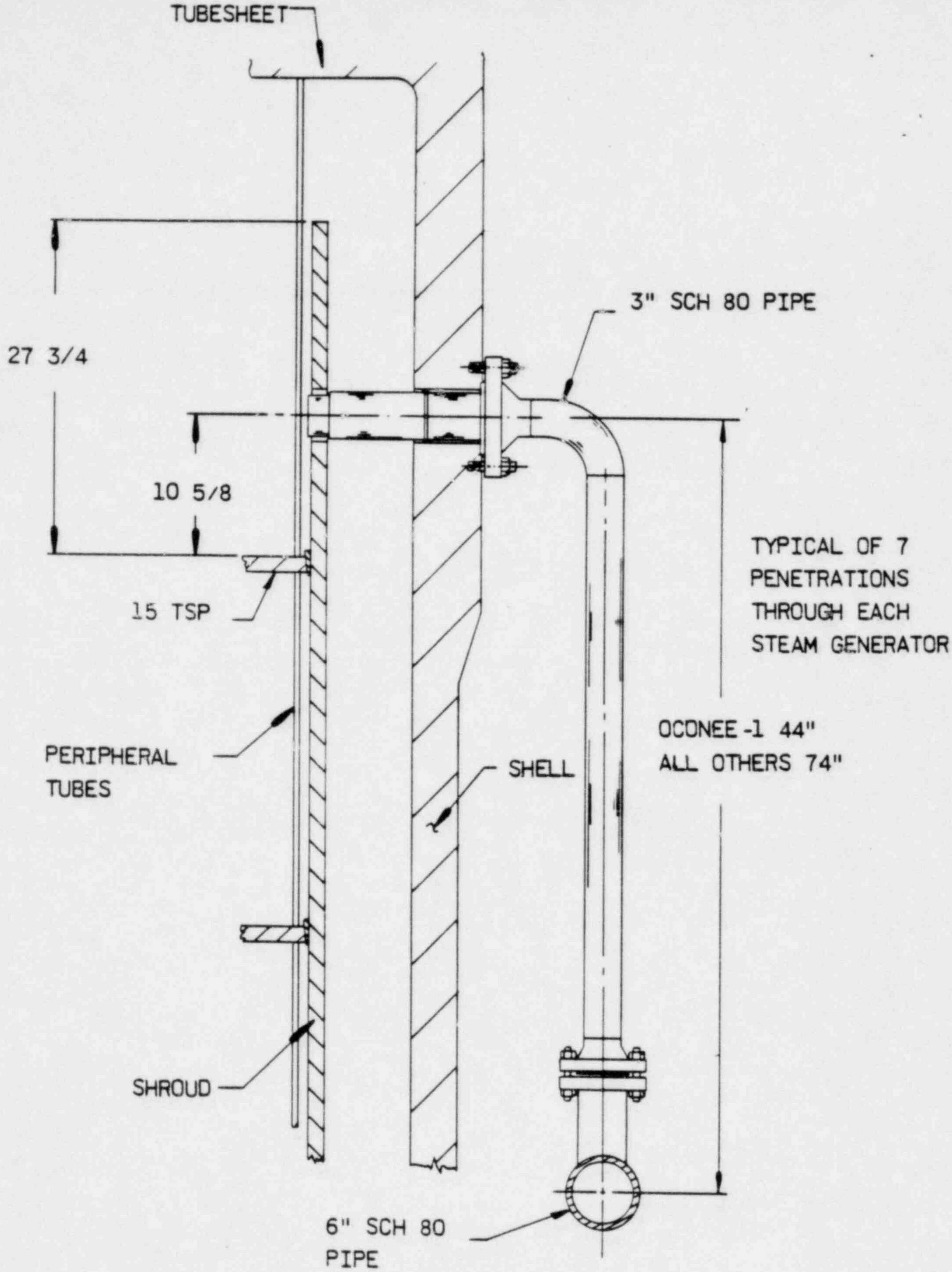


FIGURE 4-4

ARRANGEMENT OF EXISTING EXTERNAL AFW HEADER - VERTICAL CROSS-SECTION

5.0 Pre-Operational Tests

Shop and field hydrostatic tests will be performed on the new external header piping, ring header, and risers and on the internal AFW header inlet nozzle and blind flange. These tests will be in accordance with the ASME code requirements.

A leak test of the secondary side will be made after external AFW header shell flange and nozzle installation.

Finally a cold flow demonstration test will be run to verify that all lines are clear and free from obstructions.

6.0 Post Operation Inspections

The following post operation inspections are planned:

Selected special interest peripheral tubes will be EC inspected in conjunction with other EC tube inspections as required by technical specifications but will not be considered as a part of those required inspections.

Visual inspections will be made of the secured internal header, attachment welds and external header thermal sleeves through selected opening(s) during the next two refuelings and at the 10 year ISI.

The AFW external header inspection will be included in the ISI program.

7.0 Safety Assessment and Summary

B&W and the affected Licensees recognize that this repair has safety significance. The retrofitted external header is a component of a safety system whose function is designed to mitigate the following events:[3]

1) Loss of Normal Feedwater (LOMF) - including main feedwater line break

2) Loss of offsite AC Power

3) Main Steam Line Break (SLB)

4) Small Break Loss of Coolant Accident (LOCA) - less than 0.5 ft^2 break

Furthermore, the repair has considered the need to secure the internal header to assure no damage to steam generator tubes. While retaining the shroud extension function.

The first of these two safety functions, the ability of the steam generators to provide decay heat removal for the above events, has been demonstrated at five different plants during more than 22 reactor years of operation.

There are only two differences between these existing AFW external headers and the retrofit external header design that impact this cooling function. Neither have any significant effect on the SG decay heat removal capability.

One is a possible loss of needed flow due to increased pressure drop in the retrofit design the other is a lowered effective cooling due to less wetting of the SG tubes by the injection of cooling water at six or eight 3" nozzle locations (external header) rather than at 60 1 1/2" holes (internal headers).

The small increase in pressure drop for the retrofit design is due to a 3" higher AFW injection point and an increase of 3 psi due to use of orifices to improve flow distribution. Even taken together, this increased ΔP will not have any significant effect on flow capacity and is partially offset by the slightly more open throat diameters in the external sleeves of the retrofit design.

The second concern with distribution and penetration of cooling water to the SG tubes for the external header vs. the internal header design, a B&W study indicated that there is almost no difference in tube wetted surface area (about 1% less for the external header) between the two designs. This is attributed to the greater penetration of the external header design which all but completely offsets the effect of the wider peripheral distribution of cooling water by the internal header.

As in the case of external header careful thought and analysis[7] has been put into the repair of the internal header to assure it is securely fastened in-place. The minimum 1/8" clearance between the header and the tubes will be verified after tie down. As an added precaution any tubes closer to the header than 1/8" will be stabilized and removed from service.

In 1981, a thermal sleeve was removed at Oconee to examine peripheral tubes at an AFW external header injection point. Not only was the sleeve in good condition, but also no damage from jet impingement or flow induced vibration was noted on peripheral tubes. This adds assurance to the validity of B&W analyses that show these two mechanisms not to be a concern for the external header design.[5][6]

Both the retrofitted external header and the secured internal header have had independent evaluations at B&W by in-house Design Review Boards and the affected Licensee's Safety Review Boards have examined the repair program.

In summary, the Licensees working closely with B&W believe they have established a logical cause for the original problem, and have a repair program that fully considers that cause and will preclude its recurrence. In addition the replacement external header is a proven design that has carefully been analyzed and will be tested. As an added precaution, although the redesign considers the full life time of the plant, the repaired units will be inspected at the end of the next fuel cycle to assure no degradation of the units. These facts justify start-up and continued operation of the affected plants.

8.0 References

1. NUREG-0291, NRC-1, An Evaluation of PWR Steam Generator Waterhammer, Final Technical Report, June 1, 1976 - December 31, 1976, by Creare, Inc., Hanover, NH.

2. Engineering Requirement for Internal Header Stabilization B&W Doc. No. 51-1134169-06.

3. Functional Specification for Steam Generator Emergency Feedwater Header B&W Doc. No. 18-1134783-00.

4. Equipment Specification for Steam Generator Auxiliary Feedwater Header B&W Do. No. 08-1134172-01.

5. Response of Tubes to Random Turbulence Excitation - AFW B&W Doc. No. 32-1134728-00.

6. Revised AFW Header Capacity B&W Doc. No. 32-1134729-00.

7. Internal AFW Header Tiedown Analysis B&W Doc. No. 32-1134668-00.