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1.0 INTRODUCTION

Contained in this report are the results of a follow-on investigation to identify and evaluate alternate reactor vessel support structure configurations in order to simplify and improve the support structure configuration shown in Figure 1. The configuration shown is the result of a prior study.

The vessel support structure is part of the reactor installation for the loop-type sodium cooled reactor. The structure is secured to the building concrete and supports and positions the reactor vessel.

The identification and evaluation effort is to encompass the following: (1) establish the requirements, (2) identify and design the alternate configurations, (3) identify the structural characteristics of each, (4) evaluate the configurations against criteria such as structural performance, maintainability, inspectability, constructability, reliability, installation operability, and cost, and (5) choose the recommended concept.

The chosen configuration is to be analyzed for operating temperatures, shielding adequacy, and stress values. Included is to be a description, an installation sequence, and the improved features of the chosen configuration.

This work is part of the Large Systems Improvement Task Work Plan (see Reference 1).

2.0 SUMMARY

The recommended reactor vessel support structure is shown in Figure 2. The configuration is the U ring type of support structure, having three sides and an open top. Alternate types considered were the box ring, integral, tee ring, and tangential beam. Of these, the U ring, box ring and integral support structures were investigated and evaluated.

The U ring support structure is superior in the important categories of structural rigidity, in-service inspection, fabricability, maintainability, operability, and reliability.

A very important consideration is that the support structure is passively cooled.

3.0 OBJECTIVES

The objectives of the investigation are:

- 1) Establish the vessel support structure requirements
- 2) Identify alternate configurations
- 3) Screen out unacceptable configurations
- 4) Investigate the remaining configurations characteristics
- 5) Evaluate the remaining configurations against given criteria
- 6) Choose a recommended configuration
- 7) Describe the installation, operation, and inspection procedures
- 8) Identify the improved features of the recommended configuration.

4.0 REQUIREMENTS

Listed below are the requirements for the reactor support structure.

- 1) Provide support for the following:

Dead weight (million lb)

Support structure	1.1
Vessel with contents	6.2
Deck and plugs	5.4

Seismic loading

	<u>Horizontal</u>	<u>Vertical</u>
OBE (g)	1.3 E-W, 1.6 N-S	1.3
SSE (g)	2.7 E-W, 2.33 N-S	2.2

- 2) Structure is to be passively cooled (goal)
- 3) Guard tank shall be installed prior to installation of vessel support structure.
- 4) Provide part of the upper boundary of cavity containment
- 5) Provide inspection access to vessel flange-to-shell joint
- 6) Provide access to interior of structure for inspection and replacement of hold down bolts and pin keys
- 7) Provide access to the interior of the structure for inspection and maintenance of the weld joints and interior surfaces
- 8) Interface with the embedded ring girder support and the concrete surrounds to carry the imposed dead weight and seismic loads
- 9) Shall contribute to the shielding above the cavity to limit the contributions to the dose rate at the head access area (HAA) to 2 mr/h, maximum during reactor operation
- 10) Shall interface with the vessel flange to carry the vessel imposed dead weight and seismic loads
- 11) Shall be fabricatable at the site
- 12) The temperature of the structure shall not exceed 150°F with the reactor coolant temperature at 1050°F, and the HAA at 90°F

- 13) Shall be constructed to the requirements of the ASME Boiler and Pressure and Vessel Code Section III, Division 1, Sub-section NF, Component Supports.
- 14) The material shall be carbon steel (goal)
- 15) The construction and interfaces shall not require tight dimensional tolerances
- 16) Shall accommodate the radial temperature growth of the reactor vessel.

5.0 CONFIGURATIONS

The configurations developed and briefly described are:

U Ring, Figure 2

Box Ring, Figure 3

Integral, Figure 4

Tee Ring, Figure 5

Tangential Beam, Figures 6 and 7

5.1 U RING SUPPORT

The U ring support, Figure 2, is a circular girder having three sides, the inner wall, bottom plate, and outer wall. There are 30 webs, with caps equally spaced on the circumference and attached to the three sides of the structure. Between each web are 2 guessts. The inner wall has a ledge which supports the vessel.

The structure is supported over the greater part of its bottom surface by the embedded ring girder. It is attached to the embedment by bolts. The structure is position on and attached to the embedment to function as a cantilever type of vessel support.

FIGURE 3 - BOX RING VESSEL
SUPPORT STRUCTURE

FIGURE 4 -
INTEGRAL VESSEL
SUPPORT STRUCTURE

FIGURE 6 - TANGENTIAL BEAM VESSEL
SUPPORT STRUCTURES
(PLAN VIEW)

FIGURE 7 - TANGENTIAL BEAM VESSEL
SUPPORT STRUCTURE
(ELEVATION)

The top of the U ring support structure is open to allow natural convection and radiation cooling as well as to provide easy access to its interior for inspection and maintenance.

The structure material is carbon steel.

Access for inspection to the flange-to-shell weld joint is through ports in the inner wall of the structure. The interior surface, weld joints, pin keys and hold-down bolts are easily accessible for inspection, replacement or repair. The bolts attaching the vessel to the support structure are accessible for inspection by removal of the plugs in the seal plate between the support structure and the vessel flange.

5.2 BOX RING SUPPORT STRUCTURE

The box ring support structure, Figure 3, is an enclosed ring girder having four sides. There are 30 internal webs and a gusset positioned between each web. The box ring material is carbon steel. It is supported by and attached to the embedded ring girder at the structure's outer periphery. The structure functions as a torsional ring to support the vessel. As the structure is fully enclosed, stack convection cooling is required. Access to the interior of the structure is through manholes in the structure's top plate. Access to the vessel flange-to-shell weld joint is through ports provided in the structure's inner wall.

5.3 INTEGRAL SUPPORT STRUCTURE

The integral support structure, Figure 4, is a box ring structure welded to the outer surface of the vessel flange, the vessel flange becoming the inner wall of the structure. The material of the structure is stainless steel, it being the same material as the vessel flange to avoid dissimilar metal weld joints. The structure, therefore, is to be made to the same code requirements as the vessel.

The structure is supported by and attached to the embedded ring girder at the structure's outer periphery. The structure functions as a torsional ring to support the vessel. As the structure is fully enclosed, stack convection cooling is required. Access to the interior is through manholes in the structure's top plate. Access to the flange-to-shell weld joint is through pipes located in the embedded ring girder.

5.4 TEE RING SUPPORT STRUCTURE

The tee ring support structure, Figure 5, is a weldment made of three parts — the upper ring, the horizontal plate, and the lower ring. It is supported by the embedded ring girder over a greater portion of the horizontal plate. The structure acts as a torsional ring to support the vessel. The structure is passively cooled. Access to the vessel flange-to-shell weld joint is through channels located below the horizontal plate member. The material is carbon steel. Vertical keys are shown between the support and vessel flange, however, pin type keys are acceptable.

The structure is not acceptable as sufficient structural stiffness is not available, therefore, the tee ring support structure is eliminated in the following evaluations.

5.5 TANGENTIAL BEAM SUPPORT STRUCTURE

Figure 6 shows six types of tangential beam support structures having 6, 7, 8, 9, or 12 tangential beams for the main structural members. Figure 7 shows the elevation of a typical tangential beam structure. This type of structure is not acceptable as the internal space for fabrication access is not sufficient, therefore, the concept was not developed and is eliminated in the following evaluations.

6.0 STRUCTURAL CHARACTERISTICS SUMMARY AND COMPARISON

The summary of the structural characteristics of the three vessel support structures is shown in Table 1. The overall comparison is given in Table 2.

The U support has the lowest stress of the three structures at the critical section A-A. The number of cycles to reach critical flaw length are high because of the lower stress, and the bolt stresses are low.

The maximum deflection during OBE is low for the U support structure; much less than 0.10 in. The detailed structural analysis is given in Reference 2.

7.0 EVALUATION

The evaluation of the vessel support configurations is summarized in Table 3. The evaluation criteria are:

Structural performance

Maintainability

Inspectability

Constructability

Reliability

Installation

Operability

Cost

TABLE 1

VESSEL SUPPORT STRUCTURAL CHARACTERISTICS SUMMARY

	U Ring		Box Ring		Integral	
	Calc.	Allow	Calc.	Allow	Calc.	Allow
Bolt Stress ksi						
Dead load	~0.0	-	9.0	-	5.4	-
OBE	50.0	-	66.3	-	47.5	-
Dead Load + OBE	50.0	82.5 SA-540 GR-B21	75.3	82.5 SA-540 GR-B21	52.9	82.5 SA-540 GR-B21
Structure Stress ksi	At Section A-A		At Section A-A		At Point "A"	
Dead Load	2.0	-	4.7	-	3.0	-
OBE	14.8	-	34.9	-	19.7	-
Dead Load + Obe	16.8	40 SA-533	39.6	40 SA-533	22.7	30 SA-240
Cycle to reach Critical Flaw Length	5.7×10^5		4×10^4		NOT AVAILABLE	
Vertical deflection (OBE + deadweight) inch	<<0.10		0.291		0.10	

TABLE 2
COMPARISON SUMMARY
VESSEL SUPPORT STRUCTURE

	U Ring	Box Ring	Integral
Weight (million lb)	1.1	1.5	1.1
Height (in.)	67	77	108
Width (in.)	70	87	60
Cooling	Natural Convection	Stack Convection	Stack Convection
Cavity Sealing	Easy	Easy	Difficult
Installation	Easy	Easy	Difficult

TABLE 3
VESSEL SUPPORT EVALUATION

	U Ring	Box Ring	Tee Ring	Tangent	Integral
Structural performance	Low deflection	Higher deflection	Deflection too great — Unacceptable	↑	Low deflection
Maintainability	Good	Same	↓	↑	Same
Inspectability	Good	Same	↓	↑	Acceptable — stainless steel limits inspection to visual
Constructibility	Relatively easy	Same	↓	Cannot be fabricated due to lack of space — Unacceptable	Difficult makes support a pressure boundary as it is welded to vessel
Reliability	Extremely good	Good	↓	↓	Good
Installation	Relatively easy	Same	↓	↓	More difficult — larger diameter vessel and vault seal
Operability	Very good	Same	↓	↓	Same
Cost	Relatively low	Same	↓	↓	Higher due to use of stainless steel

7.1 Definition and Discussion of Evaluation Criteria

The following is a definition of each of the evaluation criteria and a discussion of its application to each of the three support configurations.

7.1.1 Structural Performance

This category includes: radial deflection, vertical deflection, attachment bolt stresses, stress in the structure (box), and a number of cycles to reach critical flow length in a crack in the support structure.

The heights of the integral and box ring supports are greater than the U ring support in order to provide adequate stiffness of the support structure.

The radial and vertical deflections of the U ring support are low when compared to the deflections of the box and integral support. The amount of deflection is important where the support is integral with the vessel as the bending moment could be high at the point of vessel attachment to the vessel flange. The deflection of a separate support structure does not cause the above effect as the structure is not attached to the vessel flange.

The vessel flange attachment bolts bending stresses are higher in the box ring than in the U ring support due to the great deflection of the box ring support.

The stresses are lower in the U ring support structure than in the box and integral supports as the U ring support is rigidly attached to the embedment.

The number of cycles occurring to reach critical flaw (crack) length is greater for the U ring support than for the box support; however, the number is conservative for both concepts.

The U ring support has a high frequency as it is firmly attached to the embedment. The integral and box ring supports have a lower frequency as they are attached at their outer edge to the embedment which makes them structurally softer than the U ring support.

Summarizing, the U ring support structure is a better structure than the box ring and integral support. The stress and deflection numbers are lower, the frequencies and allowable cycles are higher, and the height of the structure is the lowest of the three.

7.1.2 Maintainability

Maintainability means it can be easily maintained, which relates to the least number of pieces, is not difficult to repair or replace, is not difficult to inspect, and has easy access for inspection, repair and replacement.

The U ring structure has the better maintainability of the three structures. Of the three, the height is the lowest, the number of pieces in the structure are less, and the lengths of welds are less.

Access to the interior is easy as the top is open and there are no internal cooling ducts and baffles to interfere with access to the walls, floor, and welds of the structure.

Summarizing, the U ring support structure has the best maintainability of the three supports.

7.1.3 Inspectability

Inspectability means that the weld joints and surfaces can be easily seen, the type of inspection is meaningful, the inspection equipment can be easily used in all areas, repair areas are accessible for inspection, bolts are accessible for inspection and are replaceable without breaking containment.

The U ring support structure's top is open which allows easy visibility, access, and space for inspection operations, whereas the other structures have a closed top.

The integral structure is made of stainless steel. Ultrasonic inspection of the weld joints and plates is not meaningful on stainless steel material. Dye penetrant inspection can be used which locates only surface flaws. The vault containment is broken when replacing the base attachment bolts.

The box support has more interior surface and welds to inspect than the U ring support and access to the interior is through the manhole in the top of the structure.

Inspection of the weld joints and plate in the U ring and box ring structures can be done by ultrasonic and penetrant inspection. Interference with the inspection process would occur with the box and integral supports due to the presence of the internal baffles and ducts.

Summarizing, the U ring structure has better inspectability characteristics than the integral and box ring supports although the differences between the U ring and box ring support structures are small.

7.1.4 Constructability

Constructability covers the areas of design, materials, fabrication, inspection, testing, and installation and testing at the site.

The U ring and box ring supports are comparable in terms of constructability. Both have relatively simple shapes and are made as separate entities. At the site, either support is installed before the vessel, therefore, access is available below the support to weld the vault sealing members to the bottom of the support, thus a greater part of the support structure is not vault boundary containment. The vessel

and its integral support are installed as a unit, therefore, the vault seal is outside of the support which makes the support a part of the vault boundary containment.

The vessel, with only the flange attached, is easier to fabricate than the vessel with the integral support as the size of the vessel is smaller in diameter and weighs less making it easier to handle and transport during fabrication and installation.

A disadvantage of the U ring and box ring supports is the need for heat treat of the carbon steel weldment whereas the integral support, being stainless, does not require heat treatment of the weldment. Heat treatment of the carbon steel support weldment is feasible but with added cost.

The integral support, being built to the same code and with the same material as the reactor vessel, requires greater and more stringent controls on the materials and process than the U ring and box ring supports which are built to a different requirement level of the code. These requirements add time to the schedule and cost to the integral support structure.

Summarizing, the constructability of the U ring and box ring supports are about the same with the integral support being more difficult and costly.

7.1.5 Reliability

Reliability means the support will serve its function (do what is expected of it) for the life of the plant.

All three of the supports are considered to be reliable structures, although the U ring support is the better of the three. This is due to the following:

Method of supporting the load

Low stresses

7.1.5.1 Method of Supporting the Vessel

The U support carries the weight of the vessel and reactor cover when acting as a cantilever beam. It is bolted securely to the embedded support ring, the overhang supporting the vessel.

Each box could be considered as a short cantilever beam bolted to the embedded ring. Each beam has a central web, top and bottom flanges. Each box has a front vertical plate to pick up the loads from the vessel and distribute those loads to the web and bottom plate. Each box would carry its share of the load.

A series of separate boxes could be used to carry the load except for the vault gas sealing requirement which then requires each box to be attached to the adjacent box to provide sealing — the structure then becomes a continuous U ring structure with the U open on the top side.

In the event of failure of one of the boxes, the load would be transferred to and carried by the adjacent boxes. This sharing of the load would not occur in the box ring and integral structure, as these supports carry the vessel load with the ring in torsion. The capability of the structure of these two concepts depends on the integrity of all of the components and the welds.

7.1.5.2 Stresses

The U ring support structure, for stress analysis purposes, can be considered to consist of a series of boxes positioned side by side and acting as cantilever beams. The stress analysis is relatively simple and considers each box as a cantilever structure supporting its share of the load. The calculated stresses in the U ring support structure are the lowest of the three structures.

The vessels with the integral support structure may have high thermal stresses in the vessel wall. The flange remains cool due to internal cooling of the support structure during reactor operation while there is high temperature sodium in the vessel, which causes a large longitudinal temperature gradient in the vessel wall. This effect is not as great for the U or box ring support as the flange operates at a high temperature as they are not integral with the support structure.

Summarizing, the reliability of the U ring support is the best due to the method of supporting the load and low stresses in the structure.

7.1.6 Installation

Installation means the comparative ease of installation of the vessel and its support into the vault, and the effect on schedule and cost.

The installation of the vessel, and support structure appears to be easier when using the U and box ring supports than when using the integral support structure. Either of the two separate support structures is installed before the vessel is installed. Therefore, access is available to install the simple membrane seal between the vault and the support structure prior to installing the vessel. The additional vault seal required is between the top of the vessel flange and the inner wall of the support structure.

Use of the integral support structure requires additional vault sealing at the top of the outer wall of the structure, at the plug keys in the outer wall of the structure, and at each bolt location in the bottom of the structure as the vault seal cannot be located below the support structure.

The vessel with the integral structure is larger and heavier, therefore, it would require additional handling equipment, and possibly may require more time to set into position. The additional equipment and time means additional cost.

One set less of pin keys is required with the integral support as the vessel flange is part of the support structure.

Summarizing, the U ring structure is the easiest one to install of the three, as the individual weights of the components are less and not as many vault seals are required.

7.1.7 Operability

Operability means the structure can be operated without constant supervision, all the parts function as designed and do so with a minimum of attention, the number of active parts and processes are minimized — preferably all are static components and passive processes — and the operating characteristics are easily predictable in the design phase.

The U ring support is a passively cooled structure whereas the box ring and integral support require stack convective cooling systems which require additional equipment, supervision, and maintenance. The operating temperature of a passively cooled structure is easier to analyze than the convectively cooled structures, therefore the thermal stresses are also easier to determine.

The vessel is supported by the box and U ring supports through lubrite plates, whereas the integral support may not require them. Lubrite plates have been used in many reactor applications and are a proven product and therefore have good operability and can function as designed.

Summarizing, the operability is better for the U ring support structure than for the box and integral support structures.

7.1.8 Cost

Cost means dollars associated with fabrication, material, installation, schedule and operating equipment.

The fabrication cost of the U ring and box ring supports are lower than the integral support due to the difference in type of coded structure. The installation cost of the U and box ring supports are less than the integral support due to the difference in vault sealing and weight and size of the vessel. The difference in cost due to schedule changes does not appear to be different. The operating and maintenance cost of the U ring support structure is less than for the box and integral support structure due to the exclusion of the cooling equipment.

Summarizing, the cost of the U ring is lowest of the three support structures.

7.2 EVALUATION SUMMARY

The selected configuration is the U ring support structure, Figure 2. The reasons for the selection are:

- 1) All carbon steel support
- 2) Low seismic deflection and stresses
- 3) Reliable (redundant) structure
- 4) Passively cooled, no active cooling system required
- 5) Good access for in-service inspection and maintenance
- 6) Cost is low
- 7) Site installation easy due to:
 - a) Support structure separate from vessel
 - b) One seal vault-to-support seal required
- 8) Fabrication of open structure is easy, time required and costs are relatively lower.

8.0 DETAILED DESCRIPTION OF U RING SUPPORT STRUCTURE

The U ring support structure is an open top channel (U) type structure with stiffening webs welded to the three sides of the channel. Gussets are welded to the interior to provide additional stiffness. The interior wall of the structure has a ledge on the inside diameter on which the vessel is supported and is attached by bolts. The upper half of the interior wall is 8.0 in. thick and the lower half is 11.0 in. thick. The support ledge is 9.0 in. thick. The interior wall is made of forgings and plates welded together. The bottom plate is 8.0 in. thick and made from plate stock. The outer wall is 6.0 in. thick and is made from plate stock. The web is a 3 in. thick plate having a 4.0 in. thick by 10.0 in. wide welded cap. There are 30 webs welded to the (U) channel, located on 15° centers (approximately 5-1/2 ft). Two gussets 3.0 in. thick are located between the webs. The walls, bottom plate, webs, caps and gussets are welded together. The space between the webs is called a bay.

The material is carbon steel and is stress relieved after welding. Ports, with gasketed covers, are provided in the inner wall to provide access to the flange-to-shell girth weld joints. The structure is attached to the embedded circular girder by fifteen (15) 2.5 in. dia bolts in each bay. The vessel is attached to the support structure with 3 in. dia. bolts installed through the vessel flange.

During a seismic event, horizontal forces occur between the concrete and the support and between the support and the vessel flange. These forces are transmitted by pin keys. There are 5 pins 5.0 in. dia. in each bay between the support structure and the building concrete. Between the vessel and support structure there are 4 in. dia. pins spaced on 14 in. centers. Providing the pin keys avoids shear stresses on the vessel-to-structure and structure-to-embedment attachment bolts. The pin keys in the inner wall have gasketed covers as the pin key hole penetrates the vault containment boundary.

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Located in the lower inner corner of the support structure are shielding blocks which complement the shielding below the structure to provide the equivalent of 48 in. of steel shielding.

A vault seal is required between the support structure and the vessel flange. The seal is a formed thin plate welded to both the flange and support structure. Plugged access holes may be provided in the seal to allow access for periodic inspection of the vessel-hold-down bolts.

Plates are required above the flange-to-support structure seal to shield the radioactive gas that may collect in the space below the seal in the event the inert vault gas becomes contaminated with radioactive gases.

9.0 ANALYSIS

9.1 THERMAL

The temperature profiles of the U ring support structure for vessel sodium temperatures of 950°F, 1050°F and 500°F are given in Figures 8, 9, 10, and 11. The thermal analysis is given in Reference 3.

The temperature profiles are calculated with the initial support structure configuration, before the improved concept was developed. The latter configuration does not have the steel plates substructure below the support structure and the vertical keys. The temperature differences between the two types of support structures are estimated to be small, not more than 2 to 30°F, the improved structure being the warmer. Representative thermal profiles are shown, additional profiles are found in Reference 3.

Figure 8 shows the temperatures in the support structure for normal reactor operation with 950°F sodium, 70°F HAA, and 90°F piping vault

FIGURE 8 - SUPPORT TEMPERATURE PROFILE,
SODIUM TEMPERATURE 950°F

FIGURE 9-SUPPORT TEMPERATURE PROFILE,
SODIUM TEMPERATURE 950°F

FIGURE 10- SUPPORT TEMPERATURE PROFILE,
SODIUM TEMPERATURE 1050°F

FIGURE 11 - SUPPORT TEMPERATURE PROFILE,
SODIUM TEMPERATURE 500°F

ambient temperatures. The support structure components temperatures are about 93°F in the upper section and 108°F average in the bottom plate, all being much less than the 150°F maximum allowable temperature. The temperature differences between top and bottom are small. The concrete temperature is low, about 110° maximum.

Figure 9 has the same sodium temperature but with 90°F HAA and 120°F piping vault (high) ambient temperatures. The support structure components temperatures are about 110°F in the upper section and 122°F average in the bottom plate.

Figure 10 shows the temperatures in the support structure for an upset condition wherein there is a loss of primary coolant flow and the heat is removed by the decay heat exchangers. Under this condition the sodium and vessel wall temperatures both are 1050°F and the HAA and piping vault temperatures are 90°F and 120°F, respectively.

The upper part of the support structure is about 115°F and about 136°F average in the bottom plate. The concrete temperatures are 136°F maximum, which is below the desired 150°F maximum temperature.

Figure 11 shows the temperatures in the support structure for refueling conditions. The sodium temperature is 500°F and the HAA and piping vault temperatures are 70°F and 90°F respectively. The temperature of the upper part of the structure is about 85°F and about 92°F average in the bottom plate.

The temperature profiles shown in Figures 8, 9, and 11 are shown with an emissivity of 0.5. Other figures are available in Reference 3 showing the temperature profiles for an emissivity of 0.8. The effect is minimal. The support temperature is raised about 2 to 30°F when the emissivity is changed from 0.5 to 0.8 (see Reference 3).

The thermal stresses in the support structure base plate, Figure 10, believed to be the higher of the components, is less than 3000 psi (see Reference 2).

9.2 SHIELDING

Figure 12 shows the location of shielding in the support structure and the 48 in. minimum effective shielding length for the possible paths of gamma and neutron streaming. The shield blocks in the structure are easily removed for inspection of the weld joints and for access to the flange-to-shell weld joint inspection port.

10.0 INSTALLATION

The installation procedure for the U ring support structure is presented. Refer to Figure 2 for component identification.

- 1) Place the circular girder and cooling ducts in their proper location and place the concrete below. After the concrete hardens, the embedded circular girder is filled with concrete.
- 2) Complete the installation of the vault cooling liner, header box and test.
- 3) Install guard tank with insulation attached. There are 3 in. of radial installation clearance between the outside of the guard tank insulation and the inner diameter of the circular girder.
- 4) Install the vessel support structure and bolt to the circular girder.
- 5) Install the vault seal between the support structure and the circular girder and test for absence of leaks.

FIGURE 12 - VESSEL SUPPORT
STRUCTURE SHIELDING

- 6) Install the shielding support below support structure.
- 7) Install the shielding and the face plate.
- 8) Install the cooling duct header below the shielding support and test.
- 9) Install the insulation below the shielding support shelf.
- 10) Determine the vessel support ledge on the support structure is flat and level. If not, machine to meet the specified level and flatness requirements.
- 11) Place lubrite plates in position on the support ledge and place the vessel on the lubrite plates.
- 12) Install the vessel hold-down bolts.
- 13) Install the pin keys and their cover plates in the inner and outer walls of the support structure.

The center lines of the pin keys in the vessel flange and the inner member of the support structure must align in order for the pin to fit snugly in the holes. As it appears to be very difficult to final machine the holes in the two members in the shop so they will accurately line up when installed at the site, final machining of the vessel flange pin key hole is to be done at the site after the vessel is bolted into position.

The hole in the support structure is machined to final dimension in the shop. The hole in the vessel flange is final machined to a diameter about 1/2 in. less than the final diameter. These dimensions assume the holes in their respective components are located within a true position tolerance of 1/4 in. dia. Machining equipment is placed in position in the support structure and the hole in the vessel flange is machined to be on the same center line and is the same diameter as the hole in the support structure.

An inflatable rubber dam is installed between the flange and the vessel to capture the machining chips and fluid.

Final machining of the holes in the steel embedment on the outside of the support structure is close in a similar manner.

- 1) The cover flanges for the pin keys are installed and the double O-rings checked for absence of leaks.
- 2) The vault gas seal between the support structure and the vessel flange is installed.

11.0 IN-SERVICE INSPECTION AND MAINTENANCE

The U box support structure is open at the top and allows ample access into its interior for in-service inspection and attendant maintenance.

In-service inspection is possible for all the weld joints, the interior surface, the vessel and structure attachment bolts, the pin keys, the pin key flanges O-rings, and the seal between the vessel flange and support structure.

Ultrasonic inspection (UT) can be done on the weld joints, the interior surface, the pin keys and the hold-down bolts. Dye penetrant inspection can be used on the seal attachment welds.

The bolts can be UT inspected in place. If discrepancies are noted, they can be removed, further inspected, and replaced. The seal weld joints can be repaired in place. The structure weld joints and internal surface discrepancies are repaired in-situ. The pin keys can be UT inspected in-place and easily replaced. The O-rings are easily replaced.

The vessel flange-to-shell joint is visual and penetrant inspected through the holes provided in the lower section of the innerwall of the

support structure. UT inspection can be employed but the results are not very meaningful when used on stainless steel.

Access is available between the vessel flange and the main wall of the support structure to visually inspect, by boroscope, part of the top surface of the support ledge and the sides of the lubrite plates. The outside of the vessel wall, below the support and above the guard tank, may be visually inspected by a fiber boroscope inserted through the flange-to-shell inspection port.

12.0 IMPROVED FEATURES

The initial support structure is shown in Figure 1. The improved support structure is shown in Figure 2. The improvements are:

- 1) Better access for in-service inspection of the vessel flange-to-shell joint. The initial structure had access pipes passing below the support structure in the sub-structure. In addition to the sub-structure, an additional seal membrane is required. The improved design eliminates the sub-structure, the access pipes, and the seal membrane. The vessel flange-to-shell joint is closer to the inspector and can be easily visually in-service inspected.

The vault seal between the support structure and the cavity liner is a double seal which provides greater vault seal reliability.
- 2) The vertical keys between the support and vessel are replaced with pin keys. The initial structure had vertical keys and keyways to position the vessel to the structure as well as to prevent relative movement during a seismic event. Using the pin keys eliminates the welding of the keys on the support

structure, milling the key slots in the flange and installation of shims in the keyway slots. The same undesirable features occurred in the interface between the outside of the support structure and the embedment in the concrete. Pin keys have also replaced vertical keys in this interface position.

The support structure is wider as the pin keys required less space than the vertical keys.

- 3) The pin keys can be removed for in-service inspection on the improved structure, where inspection of the welds in the vertical keys is very difficult. Faulty pin keys can be replaced whereas repair of the vertical key welds is not possible.
- 4) Inspection and replacement of the vessel hold-down bolts is easier for the improved structure as they are located closer to the vault seal located above the bolts.
- 5) The support structure operates at a slightly lower temperature due to the added surface created by increasing the width and height of the structure and by adding internal gussets. The lower temperature lessens the difference between the support structure and the embedded circular girder.

13.0 CONCLUSIONS

Based on this study, the U ring vessel support structure is recommended. Of the three structures investigated — U ring, box ring, and integral — the U support structure is better because the stress and deflections are lower, there is better access for in-service inspection, the results of the inspection are meaningful, the fabrication is easier, the reliability is better, the maintenance effort is smaller, the space required is less, the installation is easier, and the structure can be passively cooled.