ARIZONA NUCLEAR POWER PROJECT

PALO VERDE NUCLEAR GENERATING STATION, UNITS 1, 2 & 3

RESPONSE TO

NRC IE BULLETIN 84-03

REFUELING CAVITY WATER SEAL

SUMMARY REPORT

APRIL 30, 1985

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RESPONSE TO IE BULLETIN NO. 84-03:

REFUELING CAVITY WATER SEAL

SUMMARY REPORT

## 1.0 SCOPE

This summary report evaluates the potential for and consequences of a refueling cavity water seal failure, as required by NRC Inspection and Enforcement Bulletin No. 84-03. Consideration has been given to: gross seal failure; maximum leak rate due to failure of active components such as inflated seals; makeup capacity; time to cladding damage without operator action; potential effect on stored fuel and fuel in transfer; and emergency operating procedures.

## 2.0 SUMMARY

The considerations of the I&E Bulletin have been addressed by this summary report. A conservative estimate of the seal failure events that could potentially lead to the uncovering of spent fuel assemblies was found to be less than $1x10^{-6}$/RY (Reactor Year) even without operator action.

## 3.0 INTRODUCTION

### 3.1 General Arrangement

The general arrangement of the System 80 containment and spent fuel building is shown on Figure 1. The specific details of the PVNGS reactor cavity pool and the spent fuel pool are shown on Figures 2, 3, and 4. The pools are connected by a fuel transfer tube through which the fuel assemblies from the fuel building are transported to the containment building. The locations of the fuel transfer tube valve, fuel transfer system canal, intermediate fuel storage racks, etc. are also defined for reference.

## 3.2 Reactor Cavity Pool Seal

The reactor cavity pool seal assembly at PVNGS (Figure 5) consists of a circular stainless steel seal plate from which two inflatable pneumatic seals are supported (inner and outer). The assembly is installed on and seals to the two 2 inch annular gaps between the reactor vessel flange and the reactor cavity embedment ring. This permits the reactor cavity pool to be flooded during refueling operations. The reactor cavity pool seal assembly weighs approximately 15,000 pounds and supports a head of approximately 24 feet of water under normal static conditions.

Two 1-7/16 inch diameter alignment pins on the embedment ring ensure correct positioning of the reactor cavity pool seal assembly. The seal plate is supported by twenty four stainless steel ribs. These ribs provide structural support and provide correct positioning of the elastomer seals.

The elastomer seals provide two separate seals as shown in figures 6 and 7. First, the seal wedge lodges securely between the seal plate and either the reactor vessel or embedment ring. Secondly, the bulb seal inflates to seal the lower edges of the gap between the vessel and the seal plate (inner seal). In addition, the gap between the seal plate and the embedment ring (outer seal) is also sealed. Inflating the bulb also pulls the upper wedge portion into the gap, thereby effecting a double seal. This arrangement permits testing of both primary and secondary seals prior to filling the reactor cavity pool.

The elastomer seals are fabricated from fabric reinforced EPDM (an ethylene propylene compound) by the Presray Corporation of Pawling NY. Reinforcing pins are incorporated in the elastomer seal flange at 3" intervals to provide seal rigidity during handling, installation and postulated seismic events. The elastomer seal design has been successfully tested to withstand loads equivalent of 100 foot head of water even with gap widths in excess of the design criteria.

### 3.3 Differences between PVNGS and Haddam Neck Seals

Several significant differences exist between the PVNGS reactor cavity pool seal assembly and that utilized at Haddam Neck. These include:

| Item | PVNGS | Haddam Neck |
|---|---|---|
| 1) Elastomer Compound - Flange | Durometer Rating 60 | Durometer Rating 40 |
| - Bulb | Durometer Rating 40 | Durometer Rating 40 |
| 2) Annulus Gap Width | 2" Nominal | 2-1/8" Nominal |
| 3) Air Pressure Requirements | 25 psi | 40 psi |
| 4) Seal Assembly Alignment | Alignment Locating pins for fixed positioning | Requires adjustment and is subject to misalignment |
| 5) Rib Supports | 24 | 9 |
| 6) Seal Support Pin Spacing | 3 inches on center | None |

These differences represent an improved design in that there is a much greater amount of structural support and seal assembly alignment at PVNGS.

## 4.0 POSTULATED FAILURES

Design bases have been established to ensure that the PVNGS reactor cavity pool seal will function properly even during postulated failure conditions.

### 4.1 Design Bases

The reactor cavity pool seal shall withstand overinflation, underinflation, puncture, a seismic event, or a load drop without gross seal failure.

### 4.2 Design Evaluation

4.2.1 Overinflation - A pressure relief valve of adequate size is installed to preclude overpressurization.

4.2.2 Underinflation/Puncture - The wedge seal ensures adequate sealing even in the event that air pressure is lost after the pool is filled since the hydrostatic presure on top of the seal keeps the wedge in position.

4.2.3 Seismic Event - The maximum gap between the vessel and seal plate (or the seal plate and the embedment ring) was calculated for maximum seismic movement due to the 0.2g PVNGS Safe Shutdown Earthquake. Testing has shown that the cavity seal held an equivalent of 100 ft. head of water even with the most adverse seal alignment possible by plant layout. (Refer to Appendix A, Test Summary No. 2 & 3).

4.2.4 Load Drop - The following objects or equipment that are carried or move over the cavity seal assembly were reviewed:

4.2.4.1 The refueling machine and control element assembly (CEA) change platform are designed such that they, or any portion thereof, will not fail and fall into the pool during a seismic event. Also, the refueling machine is designed not to drop a fuel assembly during a seismic event.

4.2.4.2 Upper guide structure (UGS) lift rig, reactor vessel head, CEA transport containers and incore instrumentation transport containers are moved over the seal assembly. However, there is no fuel assembly in the refueling machine being transferred at this time and the fuel transfer valve is closed.

4.2.4.3 If a fuel assembly were dropped upon the seal, the maximum seal displacement would be limited by the seal support pins spaced every three inches. For a PVNGS element, at most three pins could be damaged (refer to figure 8). This would result in, at

most, a 12 inch sectional gap. As the plate to ring gap is 2 inches, the leak would be limited to 24 square inches. This does not constitute gross seal failure. The event consequences of this amount of leakage are described in Section 9.0 and 10.0.

## 5.0 RELIABILITY EVALUATION

5.1 An analysis was performed to highlight the various failure modes and establish a logical sequence of events which could lead to seal failure and ultimately expose irradiated fuel to the environment.

The failure mode established was the dropping of a fuel assembly onto the elastomer seal followed by no corrective operator action. The results indicate that the probability of seal failure and resulting fuel assembly damage from this condition is $8.5 \times 10^{-7}$/RY.

5.2 With the current cavity seal design, gross failure of the cavity seal has been determined to be quite improbable. Testing at C-E (Refer to Appendix A Test Summary No. 5) has disclosed that, even if a fuel assembly is dropped directly onto the elastomer seal, gross seal failure would not result. In addition, the most effective way to minimize the probability for fuel damage is to have emergency procedures in place and operators trained such that, in the unlikely event of a seal failure, (a) fuel in the refueling machine can be placed into a safe condition, (b) the transfer tube valve can be closed, and (c) equipment is available to add water to the refueling cavity and fuel pool if needed.

## 6.0 GROSS SEAL FAILURE

Gross seal failure is precluded by the PVNGS design as described in Section 4.2.

## 7.0 MAXIMUM CREDIBLE LEAK DETERMINATION

The maximum initial leak rate which results from the 24 square inch leak path is approximately 3000 gpm.

## 8.0 MAKEUP CAPACITY - MITIGATING TECHNIQUES

8.1 Given a seal failure leak path of 24 square inches, operator actions can be taken to maintain the required water level in the refueling cavity pool. Water can be added to the pools from the condensate storage tank, or the safety injection tanks. The condensate transfer pumps each have a capacity of 100 gpm. Each of the four Safety Injection Tanks consist of 1900 cubic feet of borated water. After a leak has been identified, the LPSI, containment spray (CS) and HPSI pumps could be aligned to take suction from the containment recirculation sump.

Recirculation can be established by any of the following: 2-LPSI pumps at 4000 gpm each, 2-Containment Spray (CS) Pumps at 3500 gpm each and 2-HPSI pumps at approximately 1000 gpm each. Normally one LPSI pump is in operation during refueling operation. The Technical Specifications (Section 3/4.9.8) require at least one shutdown cooling loop shall be OPERABLE and in operation. However, the Technical Specifications also allow up to 1 hour per 8 hour period removal of the loop from operation. If a leak event took place during one of the temporary outages, it is estimated that the time to properly align the valves and start the LPSI pump to be no more than 5 minutes from the time of notification. It is estimated that the operator would be able to react to the signals due to the leak within 10 minutes of the event. Thus, total reaction time is estimated at 15 minutes. Specific guidelines for maintaining water inventory will be incorporated into the appropriate operating procedures prior to the pool seals use.

## 9.0 TIME TO CLADDING DAMAGE WITHOUT OPERATOR ACTION

9.1 In the event of a failure of the reactor cavity seal as a result of a dropped fuel assembly followed by no corrective operator action, the water level will drop in both the reactor cavity pool and in the spent fuel pool (unless the transfer tube valve is closed).

Such a drop in water level will lead to increased dose rates due to a reduction in water shield thickness. This section addresses the time span, following an assumed seal failure of 24 square inches, to uncover the active fuel. The analysis is summarized below:

REFUELING POOL
TIME FOR CLADDING DAMAGE
(FUEL TRANSFER VALVE CLOSED)

| EVENT | HOURS | CUMULATIVE HOURS |
|---|---|---|
| 1. Maximum credible Leak to Cavity Seal Elevation | 4.3 | 4.3 |
| 2. Boil off to top of fuel | 93.7 | 98.0 |
| 3. Fuel Uncovery and Damage (Est) | 0.2 | 98.2 |

REFUELING POOL
TIME FOR CLADDING DAMAGE
(FUEL TRANSFER VALVE OPEN)

| EVENT | HOURS | CUMULATIVE HOURS |
|---|---|---|
| 1. Maximum credible Leak to Cavity Seal Elevation | 6.0 | 6.0 |
| 2. Boil off to top of fuel | 94.8 | 100.8 |
| 3. Fuel Uncovery and Damage (Est) | 0.2 | 101.0 |

SPENT FUEL POOL
TIME FOR CLADDING DAMAGE
(FUEL TRANSFER VALVE OPEN)

| EVENT | HOURS | CUMULATIVE HOURS |
|---|---|---|
| 1. Maximum credible Leak to Cavity Seal Elevation | 6.0 | 6.0 |
| 2. Boil off to top of fuel | 12.1 | 18.1 |
| 3. Fuel Uncovery and Damage (Est) | 0.2 | 18.3 |

10.0 POTENTIAL EFFECT ON STORED FUEL AND FUEL IN TRANSFER

10.1 Fuel in the reactor vessel, intermediate fuel storage racks, transfer system fuel carrier, and the spent fuel storage racks will remain covered with water and adequately cooled following a pool seal failure and subsequent leak down to the reactor vessel flange. By use of the mitigating techniques described in Section 8.0, operator action can assure that these assemblies remain covered.

11.0 EMERGENCY OPERATING PROCEDURES

11.1 Emergency operating procedures will be revised or written as necessary based upon the overall PVNGS review conducted in response to the Haddam Neck pool seal failure event. These procedures will be in place 90 days prior to the first scheduled refueling outage for Unit 1. If it should become necessary to utiize the pool seal in Unit 1 prior to then, these procedures will be completed and approved prior to pool seal use.

12.0 SYSTEM ADDITIONS AND MODIFICATIONS

12.1 The pneumatic seals have been modified by the addition of the 3/16 inch diameter reinforcing pins in the top flange (see Figures 6 and 7).

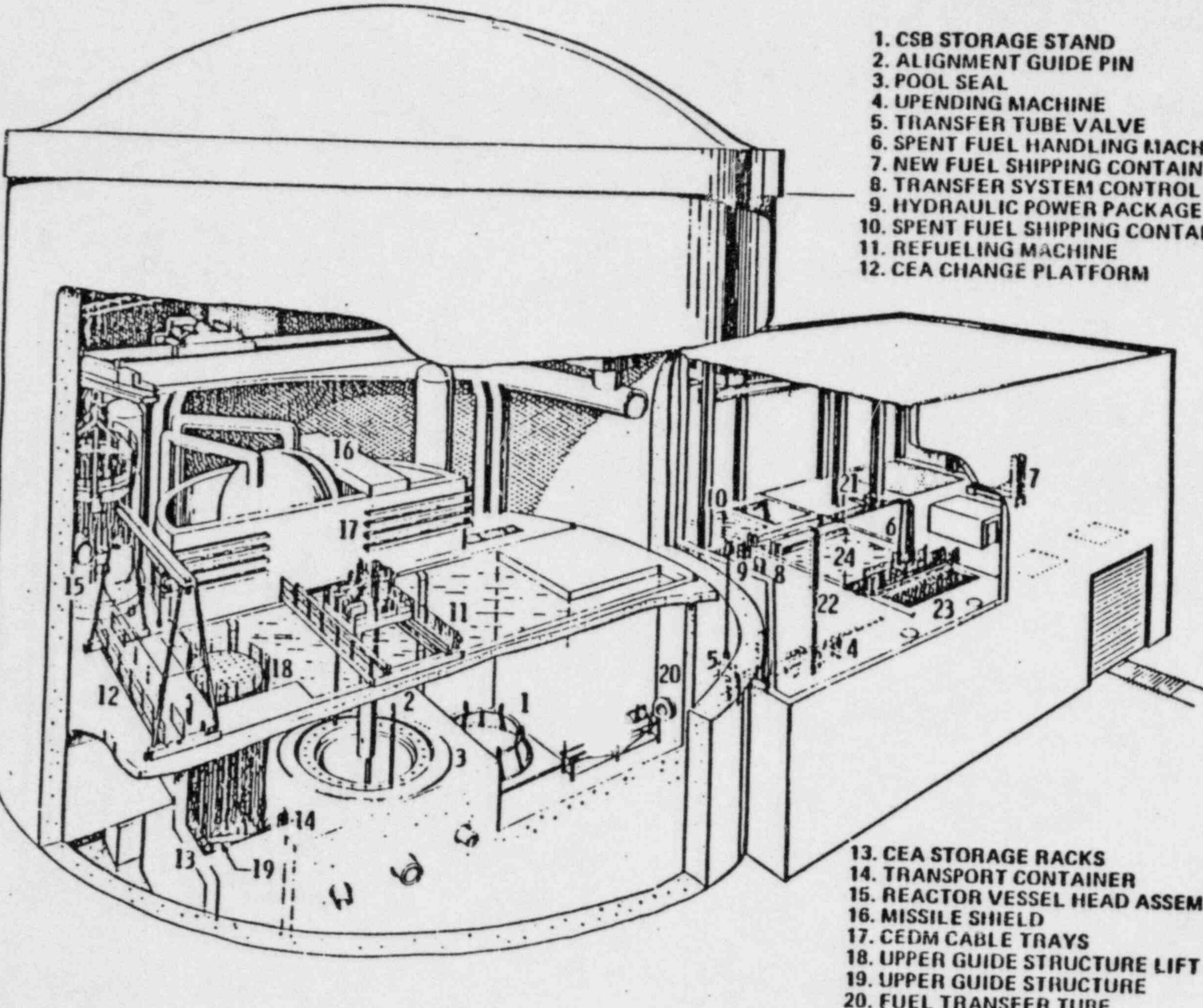
12.2 An audible alarm is being added to the fuel building to alert any personnel to a reduction in water level.

12.3 Based upon the review of the I&E Bulletin, Combustion Engineering is revising "Guidelines for Reactor Vessel Pool Seal Ring Installation, Test, Operation and Removal" Procedure. ANPP Operating, Inspection and Maintenance Procedures will be reviewed and revised accordingly. These procedures will be in place 90 days prior to the first scheduled refueling outage for Unit 1 or prior to any unscheduled use of the seals.

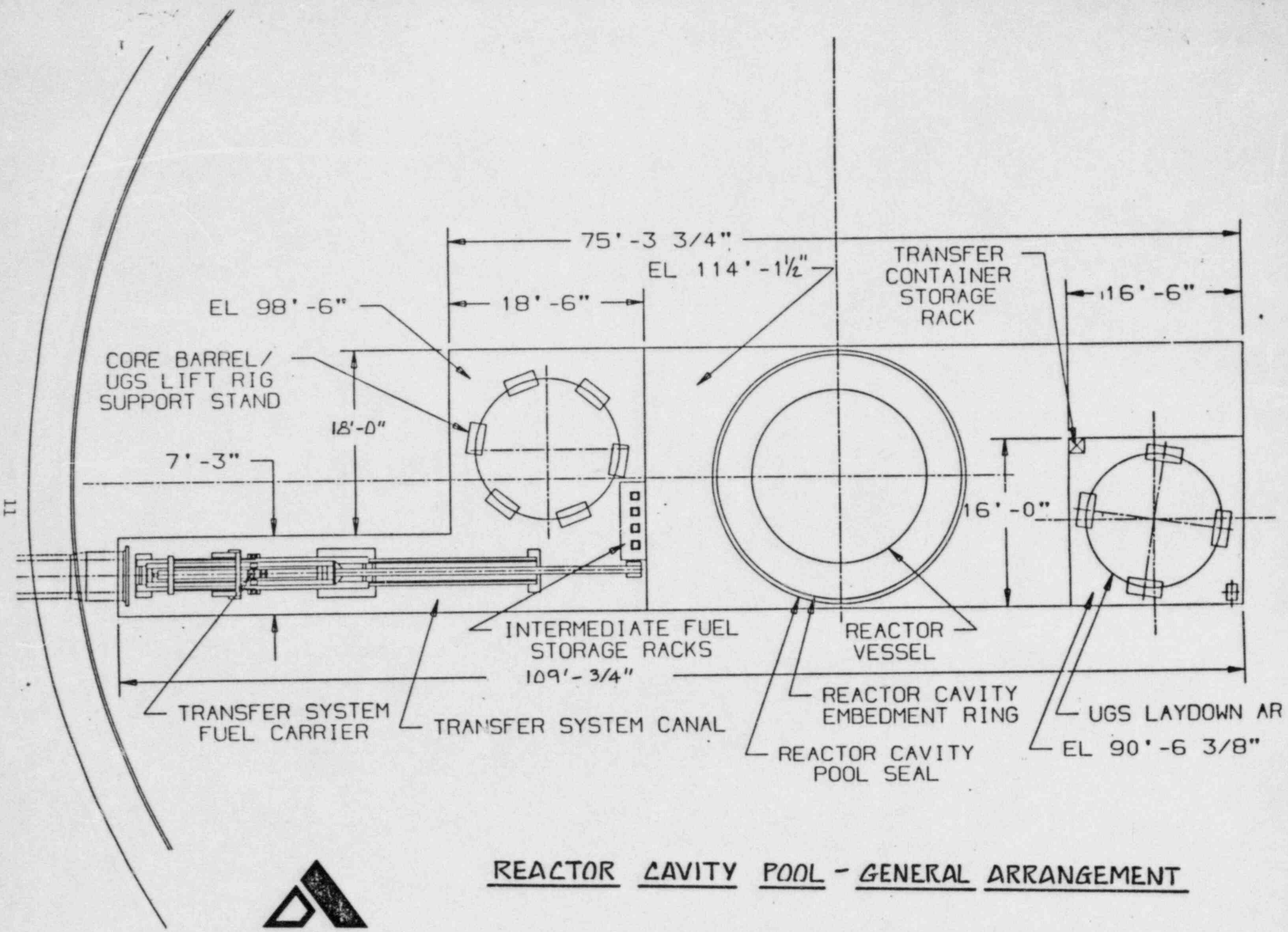
POWER SYSTEMS
COMBUSTION ENGINEERING, INC.

FUEL HANDLING EQUIPMENT ARRANGEMENT

Figure 1




1. CSB STORAGE STAND
2. ALIGNMENT GUIDE PIN
3. POOL SEAL
4. UPENDING MACHINE
5. TRANSFER TUBE VALVE
6. SPENT FUEL HANDLING MACHINE
7. NEW FUEL SHIPPING CONTAINER
8. TRANSFER SYSTEM CONTROL CONSOLE
9. HYDRAULIC POWER PACKAGE
10. SPENT FUEL SHIPPING CONTAINER PIT
11. REFUELING MACHINE
12. CEA CHANGE PLATFORM
13. CEA STORAGE RACKS
14. TRANSPORT CONTAINER
15. REACTOR VESSEL HEAD ASSEMBLY
16. MISSILE SHIELD
17. CEDM CABLE TRAYS
18. UPPER GUIDE STRUCTURE LIFT RIG
19. UPPER GUIDE STRUCTURE
20. FUEL TRANSFER TUBE
21. TRANSFER SYSTEM WINCH
22. NEW FUEL ELEVATOR




REACTOR CAVITY POOL - GENERAL ARRANGEMENT

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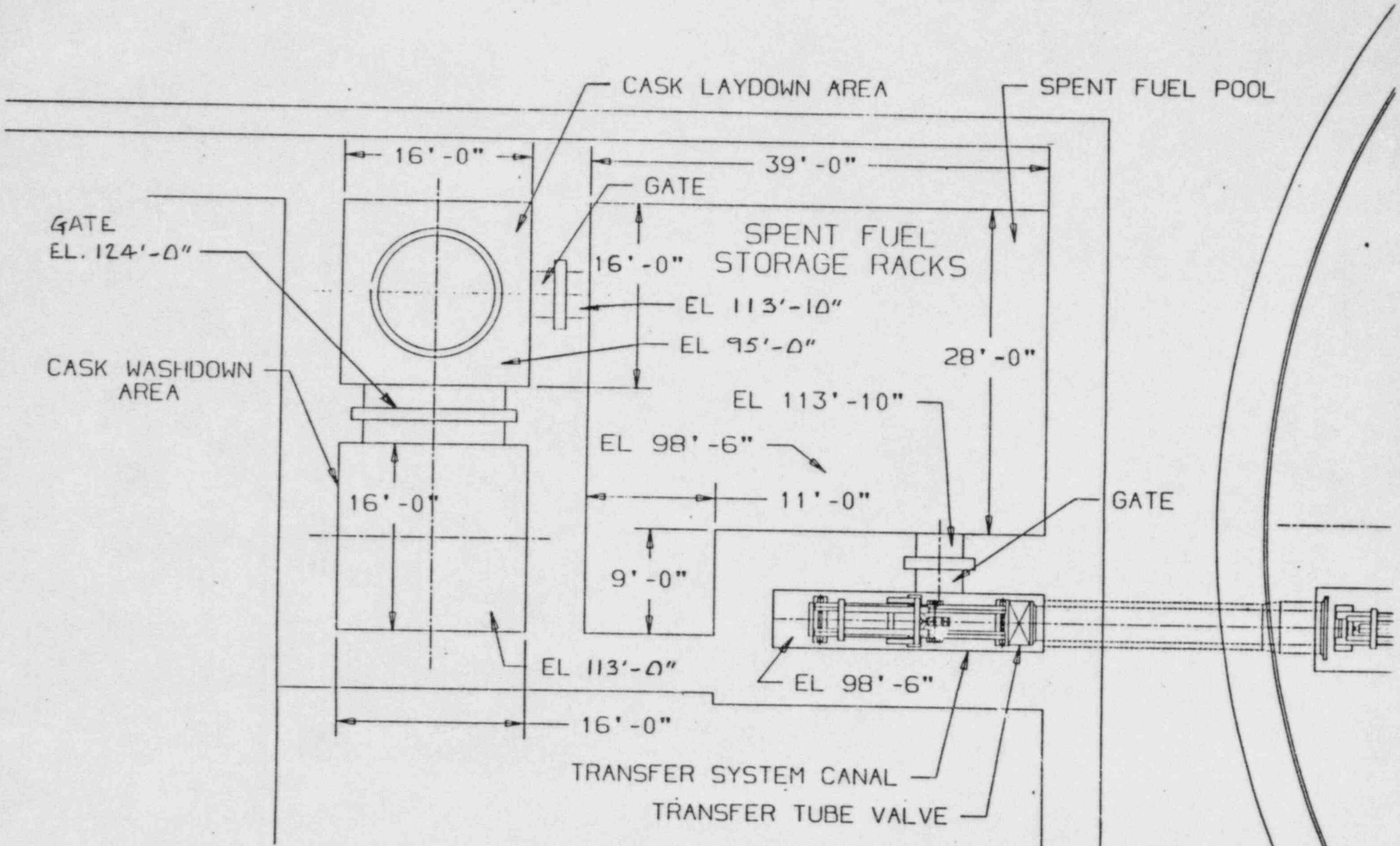
FIG. 2

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## SPENT FUEL POOL - GENERAL ARRANGEMENT

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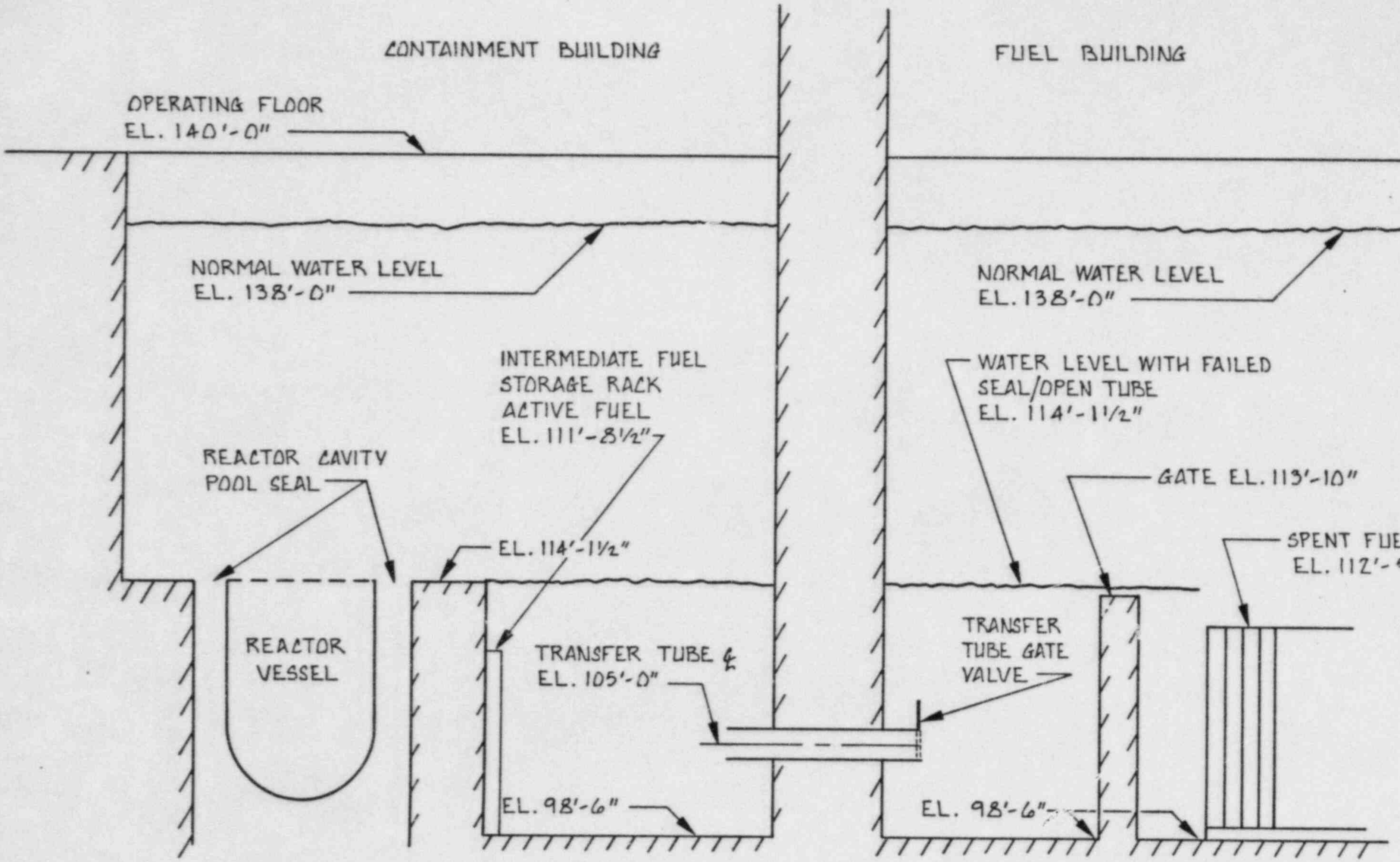
FIG. 3




SCHEMATIC OF REACTOR CAVITY

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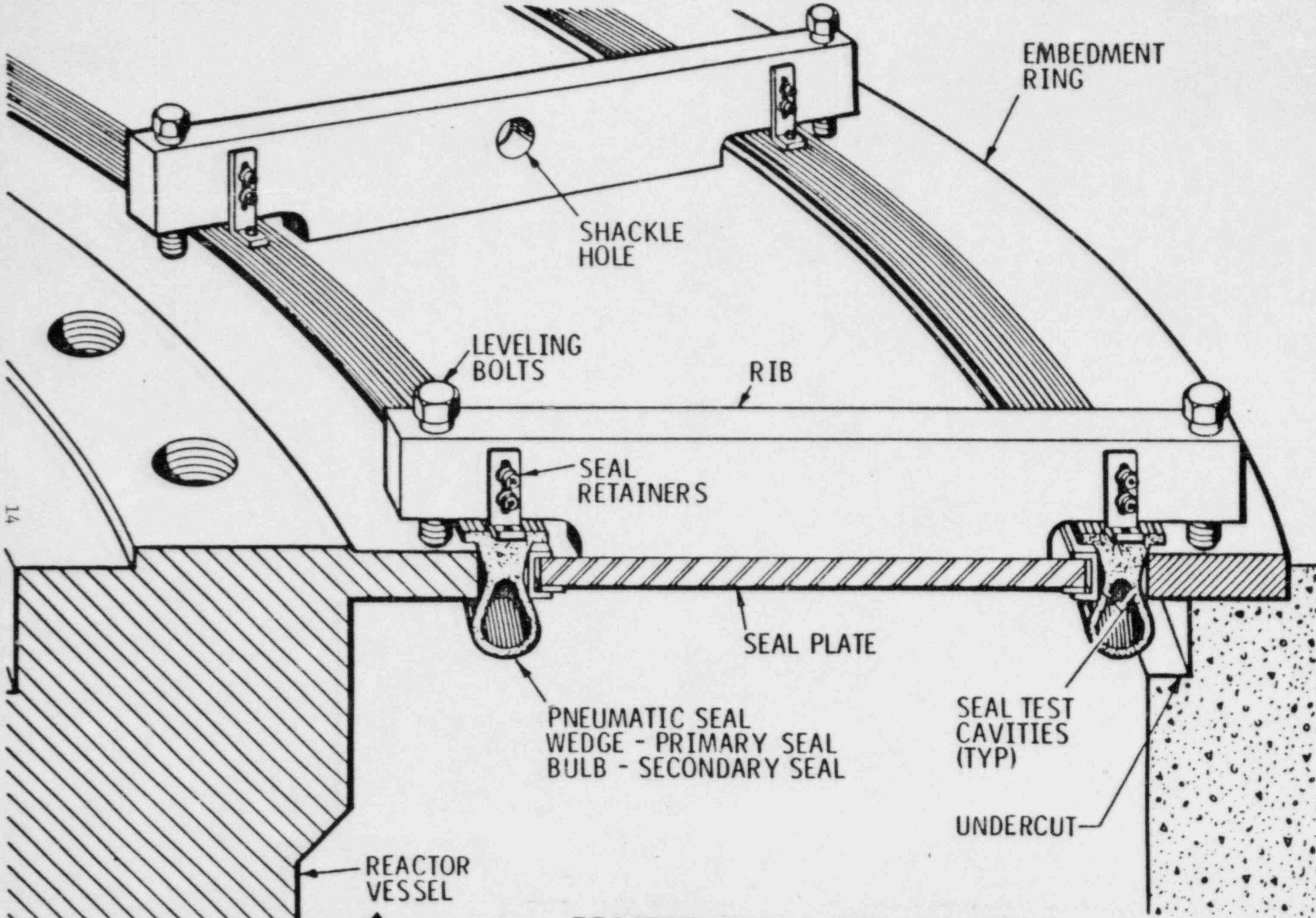
FIG. 4




REACTOR CAVITY SEAL ASSEMBLY

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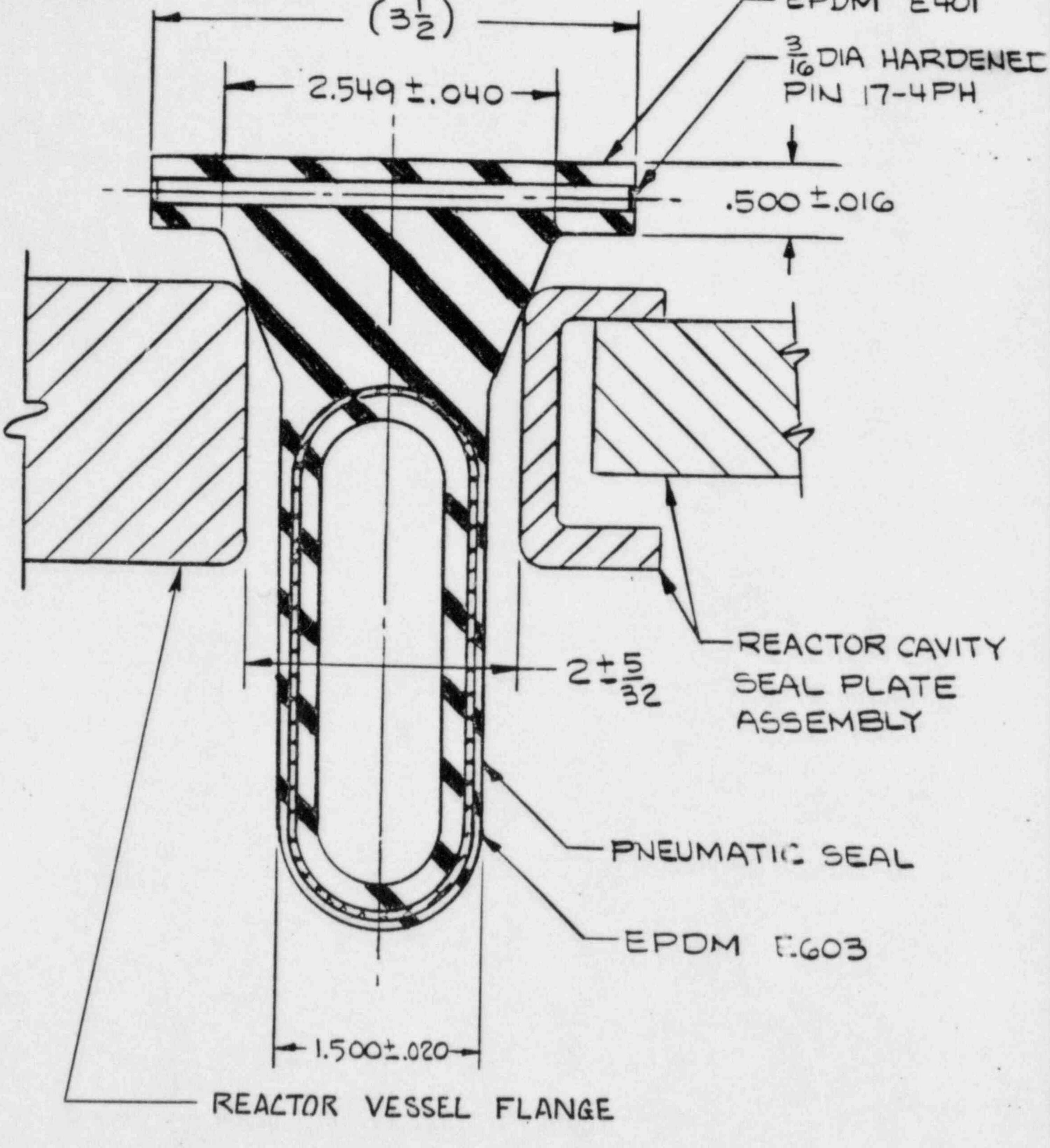
FIG. 5




REACTOR CAVITY SEAL DETAILS
(INNER SEAL SHOWN)

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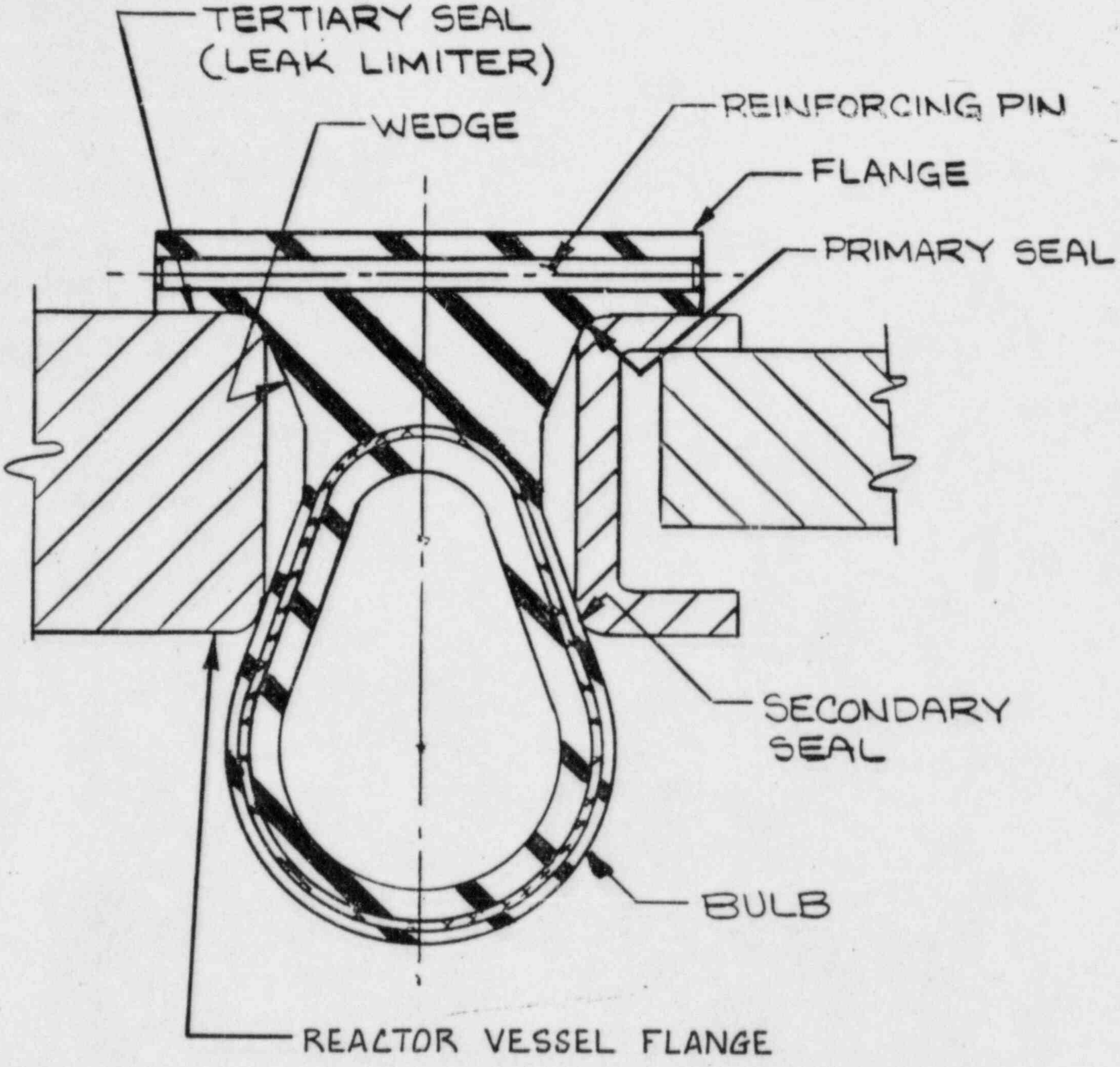
FIG. 6




REACTOR CAVITY SEAL INSTALLATION

(INNER SEAL SHOWN)

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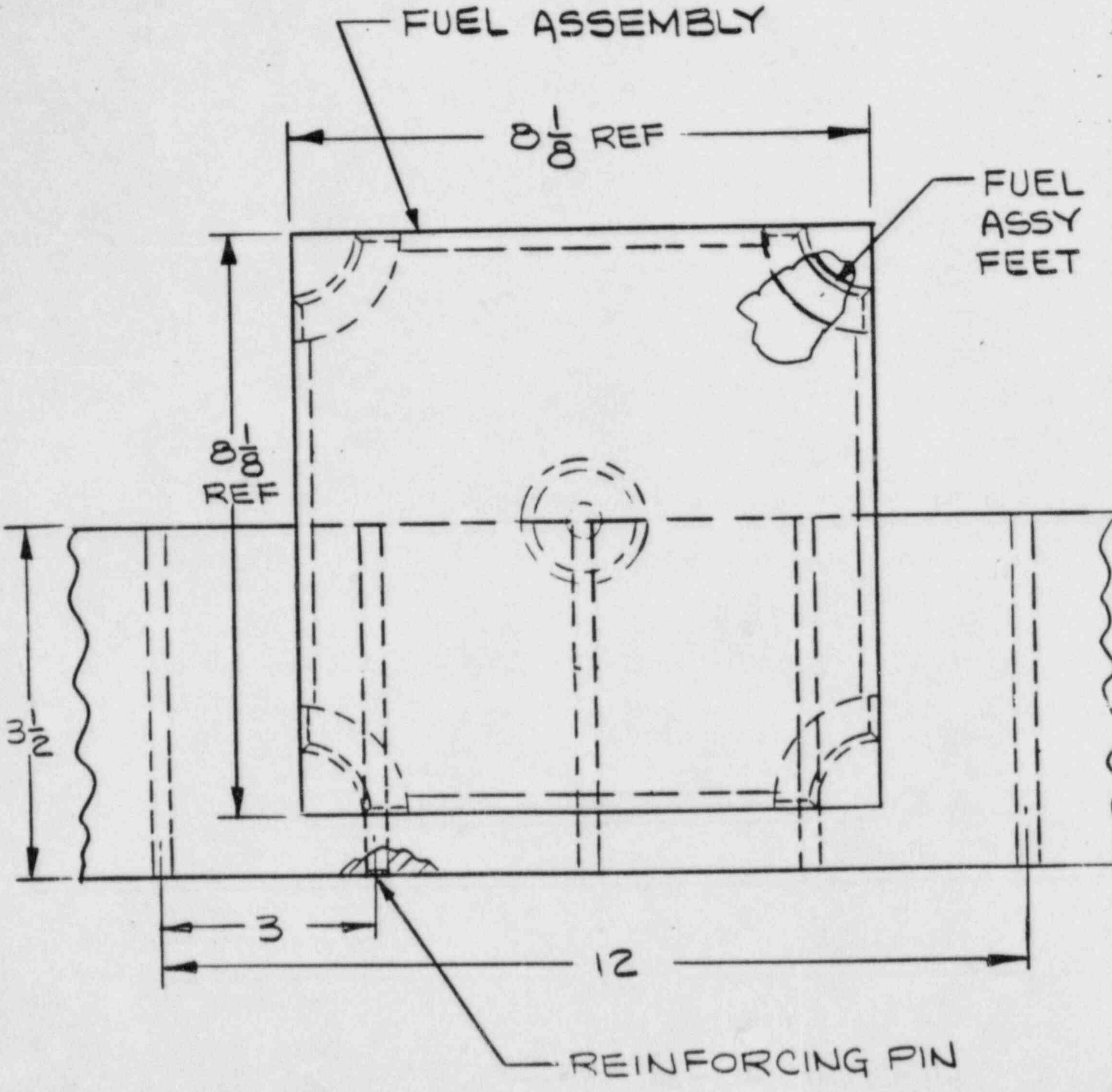
FIG. 7




PLAN VIEW OF REACTOR CAVITY POOL SEAL WITH DROPPED FUEL ASSEMBLY

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FIG. 8

## APPENDIX A

## COMBUSTION ENGINEERING TEST SUMMARY

(1) Reactor Pool Seal Load Test

Purpose: Determine push through force of cavity seal elastomer with reinforcing pins and without reinforcing pins at gap variations of 2 inch, 2-1/8 inch, and 2-1/4 inch.

Summary: The unreinforced seal yielded at an equivalent of 73 ft. head of water when the gap was 2 inch and at 29.5 ft. head of water when the gap was 2-1/4 inches. The reinforced seal held at an equivalent of 100 ft. head of water regardless of the gap width.

(2) Reactor Pool Seal Proof Test

Purpose: Determine push through force of cavity seal elastomer with reinforcing pins at gap variations of 2-1/2 inches and 2-5/8 inches and elevation variations of 1/4 inch.

Summary: The reinforced cavity seal held at an equivalent of 100 ft. head of water.

(3) Reactor Pool Seal Proof Test

Purpose: Determine push through force of cavity seal elastomer with reinforcing pins at a gap of 2-5/8 inch and elevation variation of 1/4 inch. This test differed from test number (2), above, in that the force was applied to the seal with a 1" diameter rod rather than a 1/2 inch diameter rod.

Summary: The reinforced seal held at an equivalent of 100 ft. head of water.

(4) Reactor Vessel Pool Seal Pin Pull Out Test

Purpose: Determine push through force of cavity seal elastomer with reinforcing pins at a gap of 2-5/8 inch. Instead of pushing down on the seal the load was applied up through the air bladder.

Summary: The reinforced seal held at an equivalent of 100 ft. head of water. The bladder and wedge separated at a equivalent of 112 ft. head of water.

(5) Reactor Pool Seal Penetration Test

Purpose: Determine the push through force of the cavity seal elastomer with reinforcing pins when loaded with a System 80 fuel bundle lower end fitting. The gap was set at 2-1/4 inches.

Summary: The seal was not pushed through the gap. However, the seal was damaged and the pins were bent.