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USNRC REGION II
ATLANTA, GEORGIA

TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401
1630 Chestnut Street Tower II

84 DEC 11 A9: 20

December 6, 1984

U.S. Nuclear Regulatory Commission
Region II
Attn: Mr. James P. O'Reilly, Regional Administrator
101 Marietta Street, NW, Suite 2900
Atlanta, Georgia 30323

Dear Mr. O'Reilly:

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2 - IE BULLETIN 84-03 REFUELING CAVITY WATER SEAL

This letter is in response to IE Bulletin 84-03 issued August 24, 1984. In accordance with item 2 of the subject Bulletin, enclosed is an evaluation of the potential for and consequences of a refueling cavity water seal failure for the Watts Bar Nuclear Plant. NRC-OIE Inspector P. E. Fredrickson was notified on November 26, 1984 that this response would be several days late.

If you have any questions, please get in touch with R. H. Shell at FTS 858-2688.

To the best of my knowledge, I declare the statements contained herein are complete and true.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

J. W. Hufham

J. W. Hufham, Manager
Licensing and Regulations

Enclosure

cc: Mr. Richard C. DeYoung, Director (Enclosure)
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Records Center (Enclosure)
Institute of Nuclear Power Operations
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IE11

ENCLOSURE

WATTS BAR NUCLEAR PLANT
IE BULLETIN 84-03
REFUELING CAVITY WATER SEAL

Description of the Reactor Cavity Annulus Seal at Watts Bar

The opening between the reactor vessel flange and the reactor cavity liner (support ring) is a nominal two-inch-wide annulus. During refueling, the annulus opening is sealed by a passive mechanism using a single reactor cavity seal. The seal (reference figure 1) is a Presray Pneuma-Seal PRS 585. The seal is composed of an inflatable bladder with a wedge/T-section at the top. The elastomeric portions of the seal are constructed of high strength radiation resistant EPDM compound No. E603. The seal is constructed of one piece (i.e., no splice joints) and has a layer of reinforcing fabric to provide additional structural integrity and to ensure better resistance to rupture or tear. The reactor vessel flange and support ring which the seal rests on has been hand and machine smoothed, respectively, to accommodate the seal and to prevent sharp edges from damaging the seal (reference figure 2).

The seal is placed in the annulus opening and compressed by hand. The bladder is then inflated to 30 lb/in^2 g ($\pm$ 5). Direct indication of the pressure in the bladder is provided by a pressure gauge. Air for this operation is supplied by the service air system with bottled air as a backup. A relief valve, set at 35 lb/in^2 g, is installed to ensure that the seal is not overinflated. The air supply system is provided with two check valves; one at the bottled air supply connection in the event of a loss of plant air supply, and one at the cavity seal connections in the event of a loss of both air supplies.

The main advantages of this passive seal arrangement are its simplicity, ease of installation and removal, and sealing characteristics. As can be seen in figure 2, the compression of the wedge-shaped portion of the seal into the annulus opening and the inflation of the bladder is designed to ensure that the seal will remain in place. The wedge-shaped portion of the seal also ensures good sealing characteristics between the seal and the reactor vessel flange/reactor cavity liner.

Comparison of Watts Bar to Haddam Neck

A comparison of the Watts Bar and Haddam Neck reactor cavity seal mechanisms indicates that there are major differences in the seal mechanism at the two plants. Watts Bar utilizes a passive seal mechanism which requires only that a single seal be placed in a two-inch-wide annulus opening. Haddam Neck utilizes an active seal mechanism which requires the arrangement of two seals and a seal ring to cover an annulus opening of approximately 1 foot-6 inches in width with inflatable seals filling a 2.125-inch annulus on both sides of the seal ring (see figure 3). The seal ring and seals must therefore be properly aligned to ensure the integrity of this system.

The seal used at Watts Bar has a larger area in the wedge/T-section than the seal used at Haddam Neck (see figure 4). In addition, the wedge/T-section of the Watts Bar seal utilizes a harder material compound (E603 at Watts Bar, E401 at Haddam Neck). These differences result in Watts Bar having a seal which is stronger and stiffer at that portion of the seal which must carry the load and which has been identified as the failure point at the Haddam Neck plant.

Potential for Seal Failure

The failure mechanism at the Haddam Neck facility is understood to have been a deformation of the top flange of the seal (see figure 4). The net effect of this deformation was to reduce the effective width of the wedge portion of the seal. This condition resulted in a reduction in the stiffness of the seal and is believed to have led to the failure. (Reference W. G. Counsil's, Connecticut Yankee Atomic Power Company, letter to D. M. Crutchfield, U.S. NRC, dated August 31, 1984.)

TVA does not believe that this type failure is creditable utilizing the Watts Bar Presray Pneuma-Seal PRS 585. To support this position, TVA has performed analytical calculations and actual testing on a spare seal.

Analytical Calculation

At TVA's request, Impell's engineering staff performed simplified calculations concerning the stability of the seal used at Sequoyah. The seal used at Sequoyah is exactly the same seal used at Watts Bar, and the dimensions of the annulus between the reactor vessel flange and the support ring are also the same. The maximum downward deflection of the head of the pressure seal was computed using a beam model. This model accounts for the properties of rubber as well as the geometry of the seal. The model does not include frictional forces due to the edges supporting the seal and the maximum internal pressure of 35 lb/in^2. These assumptions resulted in a conservative value for the deflection of the seal due to the water pressure. Incorporating a safety factor of 1.5 for a water level of 24 feet deep, the maximum deflection of the top of the head of the seal is 0.22 inch. Results of this calculation indicates that the 24 feet of water with a safety factor of 1.5 could not result in the movement of a properly installed seal through the gap between the reactor pressure vessel and the cavity liner.

Test

An actual test was conducted on a spare seal at Sequoyah (see figure 5). A test rig was constructed which simulated a 1-foot section of the annulus. The seal was installed on the test rig in a deflated configuration. Before the test, both the seal and the fixtures on the test rig were wetted down. A total force of 432 pounds was then exerted through a 2-inch by 12-inch rectangular plate mounted on the upper surface of the seal. The test conditions simulated a stress on the seal of 1.5 times the normal stress on the seal during refueling operations (12 lb/in^2 during refueling, 18 lb/in^2 test). Total deflection of the seal with 18 lb/in^2 applied was 0.095 inch. No unusual configuration of the seal was observed during the test which would have rendered the seal unacceptable of performing its design function during refueling operations. The seal surfaces showed no indications of damage upon inspection following the test. Since the seal and the dimensions of the annulus are the same, the results of this test are therefore applicable to Watts Bar.

The results of these two activities (analytical and testing) provide sufficient data to conclude that a gross failure of the Watts Bar seal is not a creditable event.

Maximum Leak Rate Due to Seal Deflection

Assuming a gap of 1/16 inch were to develop between the deflated seal and the reactor vessel flange (see figure 6), the maximum leak rate would be approximately 3176 gal/min. (Note that this is extremely unlikely because the lower edge of the wedge/T-section of the deflated seal would still be pressed against the flange.) The reactor cavity, when flooded to 24 feet above the flange, has approximately 224,340 gallons of water which, based on the maximum leak rate, will take a minimum of 70 minutes for the cavity alone to drain to the vessel flange at the seal. If a leak were to occur, the reactor operator will have adequate time and several means available to detect the leak and mitigate the consequences. If the refueling cavity is connected to the spent fuel pit, the leak can be detected by a low spent fuel pit level alarm in the main control room or by a high level alarm from the reactor cavity sump pit located below the reactor vessel. The leak will also take a minimum of 94.5 minutes to drain both volumes to the vessel flange level. In addition, fuel handling instructions (FHIs) require that TV cameras be placed in the reactor cavity to monitor potential leaks. Another source of information is visual observation by the refueling personnel that the level in the refueling cavity is decreasing. Upon determining that a leak has occurred, the operator will terminate all fuel handling operations and several options are available to the fuel handling supervisor to accomplish this task. Two of these are (1) replace the fuel assembly in the vessel, or (2) place the assembly in the spent fuel pit. The fuel transfer gate valve will be closed as soon as possible and this action will isolate the spent fuel pit pool from the leak.

Loss of inventory from the spent fuel pit pool due to small leaks can be easily made up by providing borated water from the refueling water storage tank via the refueling water purification pumps, or by running a temporary line from the boric acid blender located in the chemical volume control system (CVCS) into the pit. Flow from the CVCS to the spent fuel pit will be provided by the primary water makeup pumps taking suction from the primary water storage tank. In an extreme situation, additional makeup can also be supplied by the fire protection system using nearby fire hydrants. If spent fuel pit cooling is lost due to loss of suction head, the pool water temperature would approach boiling. At maximum decay heat production, the water loss by evaporation would be about 55 gal/min, and the above makeup sources are more than adequate to meet this demand.

For large leaks, approaching 3176 gal/min, the residual heat removal (RHR) pumps can provide initial makeup. However, the total makeup will be limited because of the low level in the refueling water storage tank (RWST) during refueling. If the water level in the refueling cavity decreases to the elevation of the reactor vessel flange before the spent fuel pit can be isolated from the refueling cavity, there will still be two feet of water above the top of the spent fuel racks in the spent fuel pit pool. If during this time, a spent fuel bundle were in transit between the core and the spent fuel pit pool and was in the upright position, it could become uncovered.

However, the time and makeup capacity available are sufficient to allow all fuel assemblies in transit to be placed in a position where they will not be uncovered. Even if one assembly was completely uncovered, the consequences of uncovering the spent fuel assembly would be bounded by the FSAR design basis analysis for a fuel handling accident. However, it is a relatively simple operation to lower the bundle into the horizontal position (normally used for fuel transfer). In the horizontal position the spent fuel bundle will be covered by a minimum of 13.5 feet of water. After the spent fuel pit pool is isolated, makeup can be supplied by the equipment as previously described. The flow capacities for these devices are listed in the attachment.

Since the water level will never decrease below the reactor vessel flanges, the reactor core will remain covered and cooled by the RHR system. During refueling, the RHR pumps are aligned to take suction from the hot leg on reactor loop No. 4 and discharge the fluid through the RHR heat exchangers. From the RHR heat exchangers the fluid is returned to the reactor vessel via the cold leg injection line. The maximum flow capacity of each RHR pump is 5000 gal/min. Therefore core cooling will not be jeopardized by the loss of fluid from the refueling cavity.

Preventive Maintenance

To ensure that the properties of the seal are not degraded during storage, handling, and use, preventive maintenance program will be implemented for storage and inspection of the seal. Maintenance Instruction 68.1, "Removal and Replacement of RPV Head and Attachments," will be revised to require visual inspection and durometer readings of the seal before use.

Additional Precautions

The abnormal operating instructions (AOIs) will be revised to assist the reactor operator in diagnosing the symptoms of a potential reactor cavity seal leakage during refueling and the corrective actions needed to mitigate the event.

Conclusion

TVA has demonstrated, utilizing analytical calculations, actual test, and engineering judgment, that a gross seal failure of the type experienced at Haddam Neck is not a creditable event at Watts Bar and that all potential seal leakage can be adequately mitigated.

ATTACHMENT 1

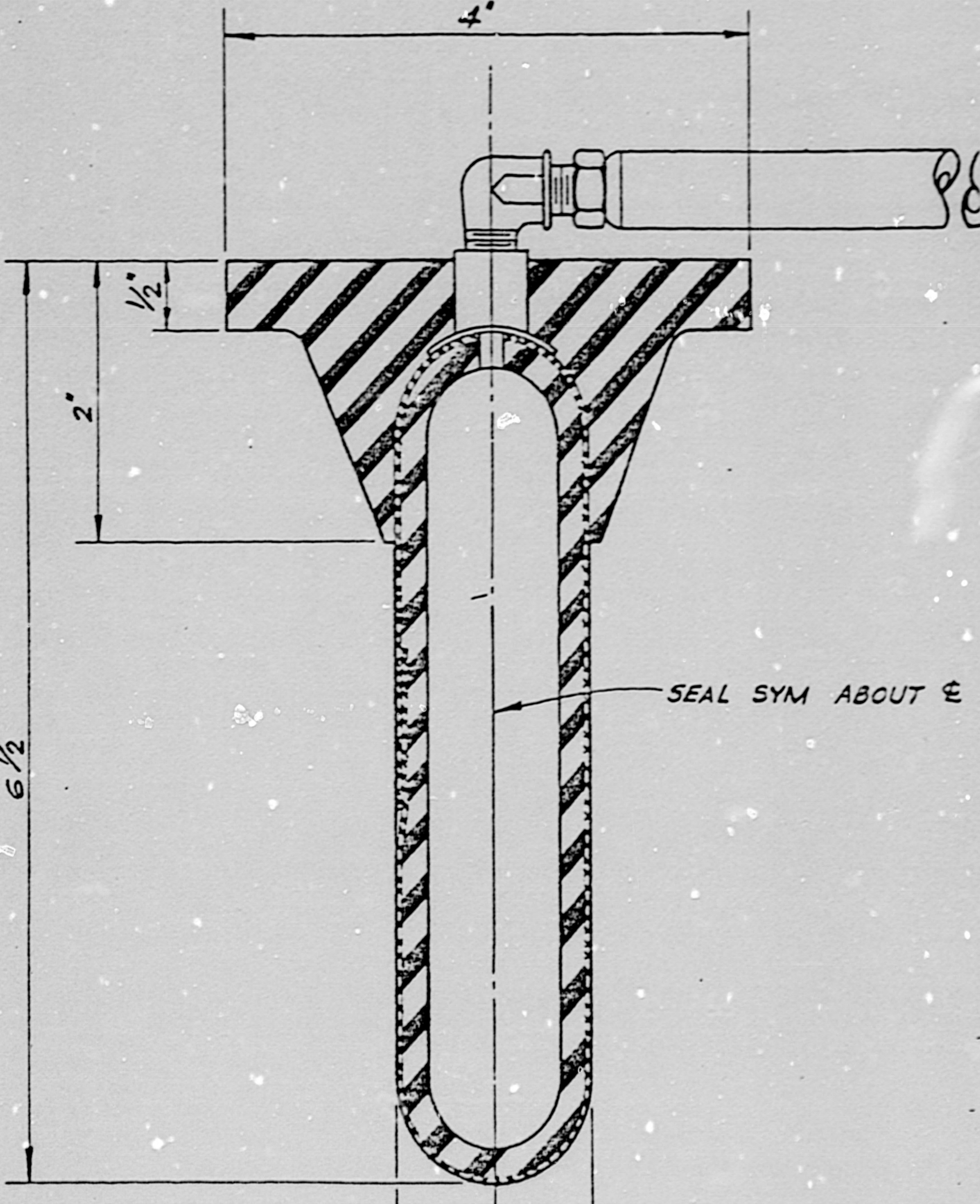
MAKEUP SOURCES TO THE SPENT FUEL PIT

	Makeup Capabilities	Water Source	Maximum Capacities
*1.	RHR Pumps (2)	RWST	5000 gal/min/each
**2.	Water Purification Pumps (2)	RWST	200 gal/min/each
***3.	Primary Water Makeup Pumps (2)	Primary Water Storage Tank	150 gal/min/each
4.	Fire Hydrants (2)	Raw Service Water	100 gal/min/each

*The supply of water from the RWST will be limited due to initial low level. (The RWST is used to initially flood the reactor cavity.)

**The water purification pumps can be aligned to the RWST on either unit.

***The primary water storage tank can be replenished by the demineralized water makeup system.



B3 - B3
12" = 1'-0"

FIG-1

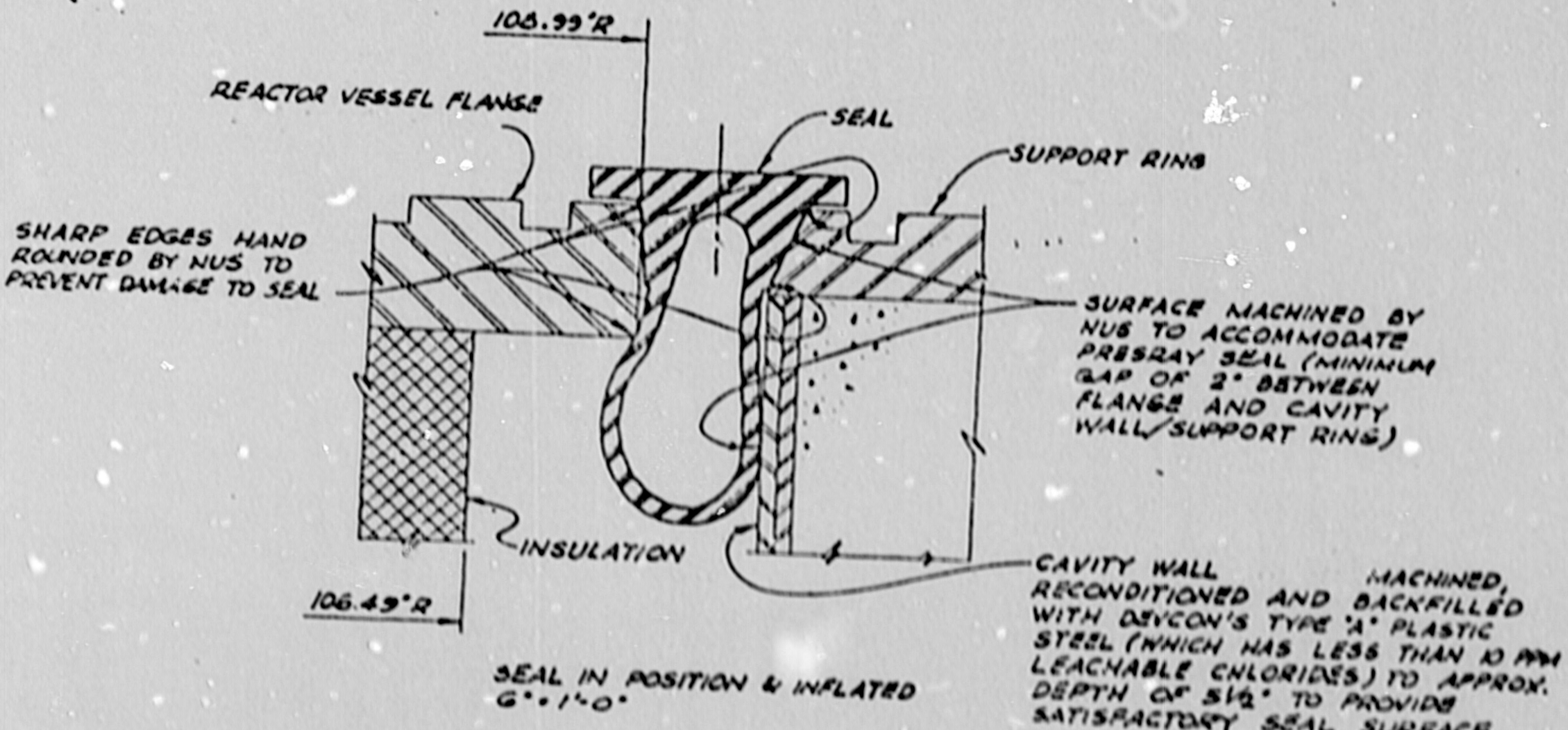

108.99"R
REACTOR VESSEL FLANGE
SEAL
SUPPORT RING
SHARP EDGES HAND ROUNDED BY NUS TO PREVENT DAMAGE TO SEAL
SURFACE MACHINED BY NUS TO ACCOMMODATE PRESRAY SEAL (MINIMUM GAP OF 2" BETWEEN FLANGE AND CAVITY WALL/SUPPORT RING)
INSULATION
106.49"R
CAVITY WALL MACHINED, RECONDITIONED AND BACKFILLED WITH DEVCON'S TYPE "A" PLASTIC STEEL (WHICH HAS LESS THAN 10 PPM LEACHABLE CHLORIDES) TO APPROX. DEPTH OF 5½" TO PROVIDE SATISFACTORY SEAL SURFACE
SEAL IN POSITION & INFLATED
6"=1'-0"

FIG-2

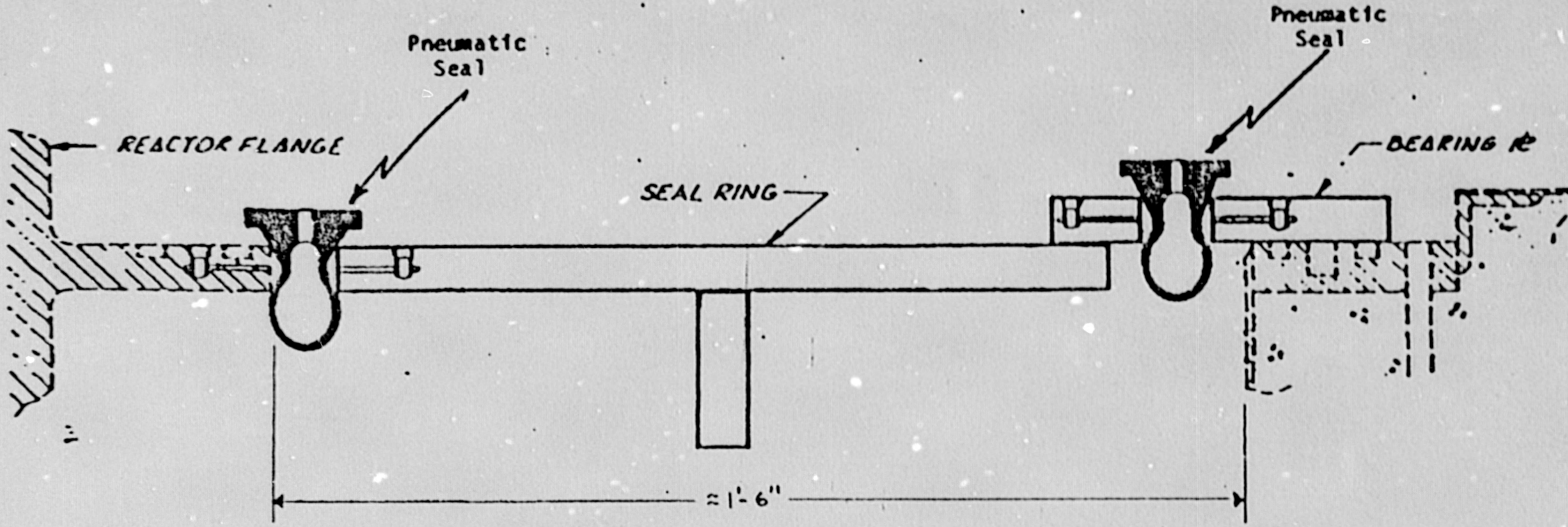


Figure 3 - Haddam Neck Refueling Cavity Water Seal

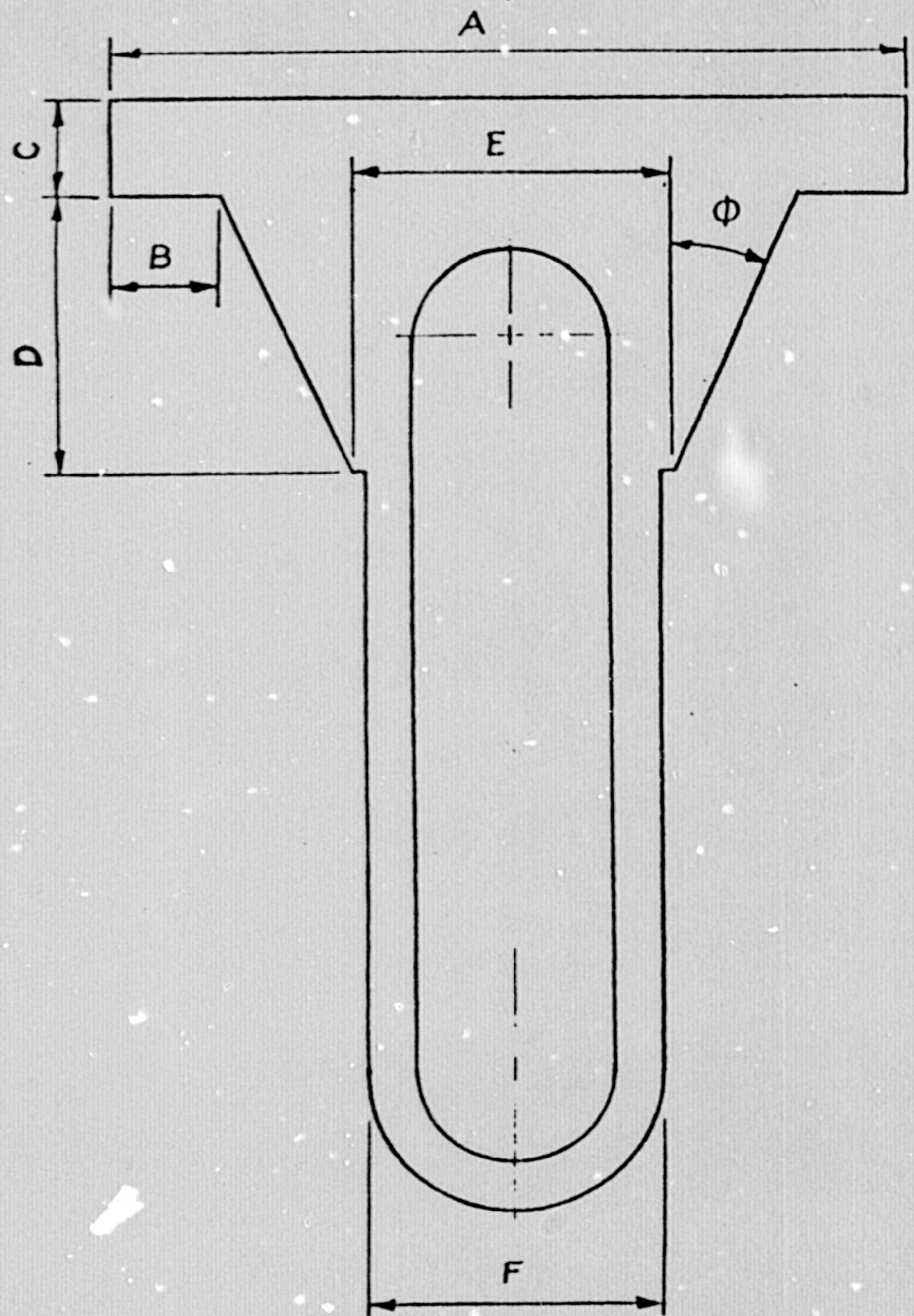


FIG-4

DIMENSIONS	
HADDAM NECK	WATTS BAR
A 3.5"	A 4"
B 0.350"	B 0.5625
C 0.5"	C 0.5"
D 1.125"	D 1.5
E 1.5"	E 1.6875
F 1.5"	F 1.5"
Φ 30°	Φ 20°
CAVITY GAP ≈ 1'-6"	CAVITY GAP 2"
EPDM T/WEDGE E 401	EPDM T/WEDGE E 603
EPDM BLADDER E 603	EPDM BLADDER E 603

CAVITY SEAL TEST

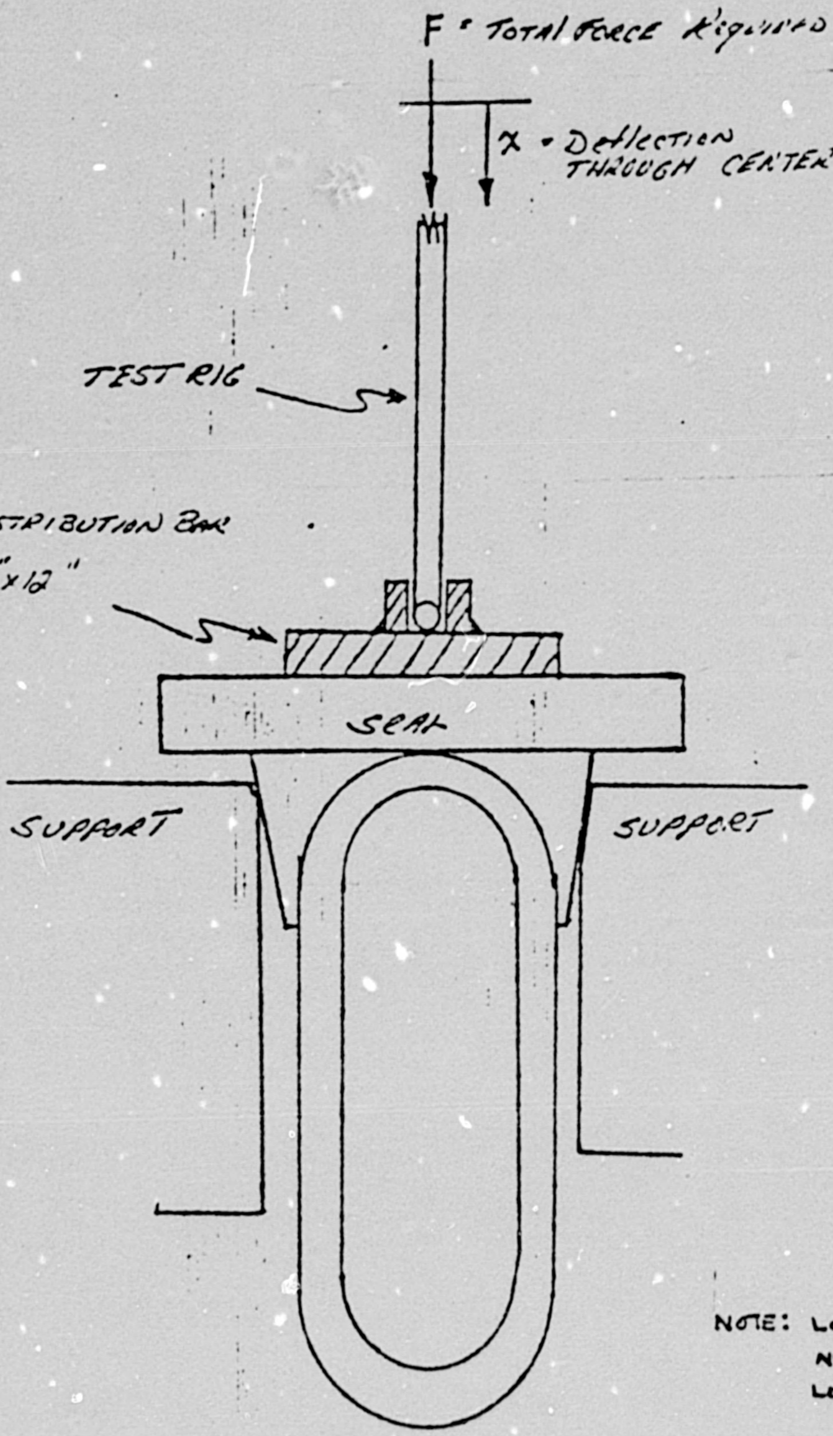


FIG-5

NOTE: LOAD BEAM WEIGHT WAS NOT CONSIDERED IN THE LOAD CONNECTIONS.

Calculations:

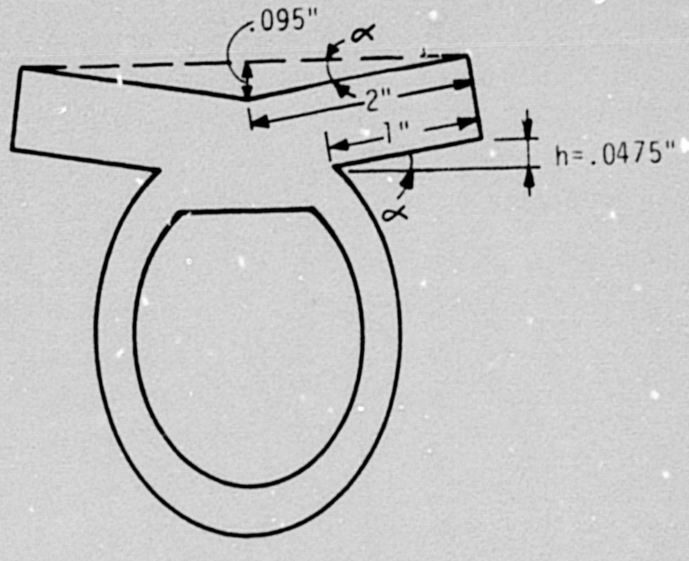
F = (SAFETY FACTOR)(HEAD PRESSURE$_{H_2O}$)(AREA of DIST. BAR)

= (1.5)(12 lb/in²)(24 in²)

= 432 lb.

where: HEAD PRESSURE$_{H_2O}$ = 26' of H_2O over Seal Surface

F = total Force Required to exert 18 psi or 1.5(12 PSI) on seal surface.



$\text{SIN } \alpha = .095/2 = .0475$

$\alpha = 2.7226°$

h = GAP PRODUCED AT THE END OF SEAL FLANGE BY THE DEFLECTION COMPUTED BY TESTING OF THE SEAL (SEE FIGURE 5)

$h = (1") \text{ SIN } \alpha = .0475$ INCHES

TO COMPUTE LEAK AREA

FOR CONSERVATISM ASSUME GAP TO BE 1/16" = .0625" > .0475", THEREFORE THE APPROXIMATE LEAK AREA IS:

$A = 2\pi r \times h = 3.14\ (18)\ (.0625/12) = .29\ FT^2 = .3\ FT^2$

FIGURE 6