Public Service Electric and Gas Company P.O. Box 236 Hancocks Bridge, New Jersey 08038

Nuclear Department

TITLE: IE BULLETIN 84-03:
REFUELING CAVITY WATER SEAL

1.0 PURPOSE:

The purpose of this Safety Evaluation is to evaluate the potential for and consequences of a refueling cavity water seal failure as requested by IE Bulletin No. 84-03.

2.0 SCOPE:

This Safety Evaluation and its conclusions are applicable to both Units of the Salem Nuclear Generating Station during a refueling outage.

3.0 REFERENCES:

3.1 IE Bulletin No. 84-03: "Refueling Water Cavity Seal", August 24, 1984.

3.2 Operating Plant Experiences 8-27 OE1117 "Connecticut Yankee Leakage Past the Reactor Cavity Pool Seal".

3.3 Telecon From C. R. Gerstberger to G. Dillion August 24, 1984 "Connecticut Yankee Sealing Ring Incident".

3.4 PSE&G Design Calculation, S-C-N300-MDC-079 "Effects of a Gross Seal Failure of Refueling Cavity Water Seal".

3.5 PSE&G Safety Evaluation SGS/M-SE-037, "Inflatable Reactor Cavity Refueling Seal Restraints".

3.6 Sandia Laboratories Report: "Spent Fuel Heatup Following Loss of Water During Storage", March 1979.

3.7 Maintenance Procedure, M8H, "Reactor Cavity Inflatable Seal Installation and Handling".

3.8 Maintenance Procedure, M8C, "Reactor Vessel Head and Internals Removal and Installation".

3.9 Operating Instructions II-8.3.8, "Emergency Filling of the Spent Fuel Pool from the RWST".

3.10 Operating Instructions II-8.3.1, "Filling the Spent Fuel Pit".

8501080280 841219
PDR ADOCK 05000272
Q PDR

3.11 212358 A 8874, "Refueling Canal Inspection Plugs and Structural Concrete Forms".

3.12 205213 A 8760, "Demineralized Water Make Up".

3.13 205229 A 8761, "Chemical and Volume Control Boric Acid Recovery".

3.14 205230 A 8761, "Chemical and Volume Control Primary Water Recovery".

3.15 205234 A 8760, "Safety Injection".

3.16 PSBP 112177, "Reactor Vessel Cavity Seal Assembly and Details".

3.17 PSBP 145161, "Fuel Assembly Outline and Reprocessing Drawing".

3.18 PSBP 148820, "Spent Fuel Module (9 x 10)".

3.19 Technical Specification 3.9.5, "Refueling Operations - Communications".

3.20 Technical Specification 3.9.8, "Refueling Operations - Coolant Circulation".

3.21 PSE&G Alarm Book.

3.22 Letter to Mr. Theodore Hollander, Jr. from R. T. Stanley dated November 6, 1984 entitled "Refueling Cavity Water Seal."

4.0 BACKGROUND:

On August 21, 1984, the Connecticut Yankee Haddam Neck plant experienced a failure of the refueling cavity water seal with the refueling cavity flooded. The seal assembly consisted of an annular plate seal ring (approximately two feet across) with two Presray inflatable seals to fill two inch openings on either side of the seal ring (See Figure 1). The outer seal was subject to a gross seal failure which allowed 1/4 of the seal to fall through the annulus. Contributing factors to the failure were the inflation pressure, use of lubricants, and the size and configuration of the gap to seal dimensions. These conditions resulted in bowing of the top of the seal which allowed it to be pulled through the annulus.

The seal failure caused the refueling water cavity to drain its entire volume, approximately 200,000 gallons, in 22 minutes. No fuel had been in transfer at the time of the failure. If fuel had been in transfer, it could have been partially or completely uncovered with possible high radiation levels. If the fuel was exposed for a significant amount of time and allowed to increase in temperature, the possibility of fuel cladding failure and release of radioactivity may exist. Furthermore, if the fuel transfer tube had been open, the spent fuel pool could have drained to a level which may lead to the uncovering of the top of the fuel.

5.0 DISCUSSION:

5.1 DIFFERENCES

The refueling cavity water seal used by the Salem Nuclear Generating Station is only slightly similar in design to that used at Haddam Neck. However, there are great differences in the dimensions, material, and utilization of the seal.

The annulus surrounding the reactor at the Salem Station is much smaller than that at Haddam Neck, two inches as opposed to two feet four inches, therefore no seal ring is necessary. Only one Presray inflatable refueling seal is used to form a secure closure between the reactor vessel seal ledge and the cavity wall. Prior to the initial installation of the seal at the Salem Station, the cavity wall ledge was beveled to a 20° angle, the same angle as the wedge portion of the seal. This produced a dependable cavity wall seal surface by providing an area contact as opposed to the line contact seen at Haddam Neck. If the seal becomes dislodged and begins to slip, the beveled area also provides an increase in frictional contact. This increased frictional contact will aid in retaining the proper placement of the seal. Many additional precautions were taken at the Salem Station prior to the initial use of the Presray seal. Any irregular or interupted seal surfaces were reconditioned and backfilled. All local annulus surface conditions of weld splatter, grout, rough or sharp metal edges were removed. The cavity wall side was machined to smooth and contour the surface. The reactor vessel seal ledge side surface was hand deburred and cleaned. All this was completed to provide a smooth surface finish necessary for inflatable - seal support, protection and seal surface development.

The inflatable portion of the seal at the Salem Station is exposed to a greater amount of surface contact area from the annulus walls, 2 1/4 inches on one side and full length contact on the other side (See Figure 2). Connecticut Yankee has an equal amount of surface contact on each side, 1 5/8 inches. Thus, the seal at the Salem Station will balloon out only on the reactor flange side while the seal at Connecticut Yankee will experience this on both sides. At the Salem Station less directional force will be exerted on the seal that tends to pull the seal downward. Therefore, the annulus design at the Salem Station leads to an increase in the margin of safety.

In addition to the dimensional differences in the annulus at Haddam Neck and the Salem Station, the seals themselves differ in size. The seals used at the Salem Station are 4 inches wide across the top wedge portion, as opposed to 3 1/2 inches at Haddam Neck. Both of these seals are used to secure a two inch area. Therefore, the seal size will aid in prohibiting the seal at the Salem Station from pulling through the annulus.

The material difference between the seals also increases the margin of safety at the Salem Station. The Salem seal is 60 durometer, while the seal used at Haddam Neck is 40 durometer. This increase in hardness will assist in the prevention of the seal failure. The hardness will impede the seal from bowing and bending and therefore hinder it from being pulled through the two inch annulus opening.

Prior to each installation of the seal at Haddam Neck, a lubricant such as silicone grease is applied to the annulus. This is done in conjuction with the air tight test that is performed to test the seal for proper seating. This lubricant will actually aid in the failure of the seal by reducing the frictional resistance the seal would experience from the annulus wall. At the Salem Station no lubricant is used, thus reducing the chances of seal failure.

To further increase the safety margin at Salem Stations, brackets are placed on top of the Presray seal (Reference 3.5). No such brackets are used at Haddam Neck. Haddam Neck does utilize a seal support, but this is employed only during the initial placement of the seal. It does not aid in retaining proper positioning or support the seal during use.

The brackets at the Salem Station are a minimum of three inches in diameter, therefore fully covering the reactor cavity annulus of two inches. The additional coverage of the brackets will reinforce the seal capabilities. The brackets are used to assure that the inflatable refueling seal will not become dislodged from the reactor cavity seal ledge. The use of brackets also aid in the prevention of bowing of the top of the seal.

Possible failures of the Presray seal used at the Salem Nuclear Generating Station have previously been reviewed in a Safety Evaluation. The results provided necessary assurance that the seal will function as required without the possibility of dislodgement from the reactor cavity seal ledge (Reference 3.5).

Maintenance procedure inspection hold points will further assure the inflatable seal is in proper position. The procedure for the reactor cavity seal installation (Reference 3.7) contains Supervisor/ Witness inspection hold points and twice confirms proper placement of the seal. The seal is first inflated to a pressure of 10 psig and inspected for positioning. If the seating is acceptable, the pressure in the seal will then be increased to 30 psig and again reviewed for effective seating. The reactor cavity water level is raised with a Supervisor/Witness present and the validity of the sealing is verified with the Control Room assuring that there is no abnormal running of the Reactor Sump Pump. These added precautions are taken to further assure the reliability of the reactor cavity seal.

Because of the many differences in dimension, material and utilization, and the numerous additional levels of safety at the Salem Station, we forsee no reason why the use of the Presray seal will result in a gross seal failure.

5.2 TEST RESULTS

The qualitative assertions made in our evaluation are very significant assertions. The most significant is the hardness of the rubber. The Connecticut Yankee seal was made of a soft pliable 40 Durameter rubber, which "gives" when loads are applied. Salem uses a

R 1

hard 60 Durameter rubber which is not pliable and does not give. To provide quantitative data we have performed a load test on a section of a seal ring. We have determined that the load required to push the seal through the annulus gap that we have in our reactor cavity is substantially greater than the weight of water on top of the seal during a normal refueling. The first test performed consisted of a one foot long uninflated segment of the seal which was placed in a jig to determine the pull-through loads as shown in Figure 4 attached.

A downward load of 1,100 lbs. was applied to the test specimen to simulate a water head of approximately 120 feet. We found that during the test that there was minimal bowing (less than or equal to 1/64th of an inch) on the top flange of the seal ring. The test was discontinued at 1,100 lbs. because of concerns with the adequacy of the test rig for loads greater than 1,100 lbs. R 1

A second test was performed with a modified arrangement (Figure 5). This time a 1 inch bar was used to apply 2,250 lbs. downward force at the top of a 6 inch long segment of the ring. This downward force is equivalent to a static head of 480 feet of water over the 1.8 inch gap. Again, the test was discontinued as a result of concerns for the adequacy of the test rig. Some deformation did occur, but there was no pull-through nor was there any permanent deformation nor damage beyond some surface cuts and scuffing (see Figure 6).

The inflatable portion of our seal is 1 1/2" wide and the upper half of the inflatable seal is located in the 1.8" gap of the reactor cavity annulus area. Consequently, when the seal is pressurized the deflection of the upper half of the seal is very limited. After installation and pressurization no concave bowing has been noted; on the contrary, through observations in past refuelings, a slight convex bowing has been noted.

Actual measurements were taken of the Unit 2 refueling cavity gap. The gap measured between 1.633 and 1.800 inches. This is below the value assumed in the previous qualitative analysis, 2 inches.

5.3 GENERAL INTRODUCTION

Although a gross seal failure during a refueling operation is highly unlikely to occur, the consequences of this event have been evaluated. The flowrate of the liquid through the annulus would vary according to the height of the liquid. In the case of the Salem Nuclear Generating Station, if the entire seal were to fail the maximum flow rate would be 104,000 GPM (Reference 3.4).

The time to drain the volume of liquid to the level of the seal would depend on a number of items including the percentage of the seal which fails, if the fuel transfer tube were open to the Transfer Pool, and if the canal gates were open to the Spent Fuel Storage Pool. Assuming the entire seal failed, it would take 4 minutes, 47 seconds to drain the Refueling Area alone (248,000 gallons). In order to drain both the Transfer Pool and the Refueling Area (332,000 gallons total), the fuel transfer tube must be open and 6 minutes, 23 seconds must pass. If both the fuel transfer tube and the canal gates were open, the time to drain the Spent Fuel Storage Pool, Transfer Pool and the Refueling Area (525,000 gallons total) is slightly over ten minutes (Reference 3.4).

5.4 FUEL IN TRANSFER

The worst case possible resulting from this failure situation for fuel in transfer would come about if four fuel assemblies were between the Reactor and the Transfer Pool: two in the Rod Cluster Control carriage compartment (included in analysis although no longer used at Salem Station), the third in the upender, and the fourth fuel assembly in the manipulator crane. If an assembly were in the upender, it must be layed down to prevent exposure. Any fuel assembly that may be in transfer at the time of the seal failure must either be returned to the reactor or placed in the upender, if available, and set down. If the assembly were half-way through the transfer process, it would take less than five minutes to move the assembly to either safe position. The top of the assembly in the Rod Cluster Control carriage compartment would become exposed to the atmosphere.

R1

With no operator action cladding damage may occur to the fuel assemblies in the manipulator crane and in the Rod Cluster Control carriage compartment. An extremely conservative estimate for time to cladding damage would be two hours (Reference 3.6). This estimate is based on an analysis done for a full core unloading in an emptied spent fuel pool. As a result of the differences in number of fuel assemblies involved, a maximum of 3 in actuality as opposed to 193 in the analysis, and the distance between assemblies, the two hour estimate is a worst case situation. The actual time to possible cladding rupture would be increased. Cladding damage to the other assembly in the upender would not occur until 24 days after initial drainage to the seal because of the large volume of water surrounding it.

5.5 FUEL IN REACTOR

If the water in the Refueling Area has drained to the level of the refueling seal, the water remaining in the reactor will begin to increase in temperature if there was no circulation. This will be relieved by the Residual Heat Removal System (RHRS) which is functioning during the refueling process according to Technical Specifications (Reference 3.20). The RHRS will remove the heat energy from the core and the Reactor Coolant System by recirculating a minimum of 3000 GPM through the system. Therefore there is no possibility of cladding damage even if no operator action is taken because the RHR System is functioning during any refueling procedure.

The make-up capabilities to the reactor are supplied from two sources. The first is the remaining water in the Refueling Water Storage Tank. This tank will contain over 100,000 gallons of water available for use. An alternative source of make-up comes from the Reactor Sump. Use of this sump would recirculate the drained water into the reactor, therefore achieving minimal water losses due to the seal failure.

5.6 FUEL IN SPENT FUEL POOL

Once the liquid has drained to the level of the refueling cavity seal, another situation may arise. The liquid in the Spent Fuel Pool will begin to increase in temperature and may begin to boil resulting in the possibility of exposing spent fuel. The worst case considered is when a full core load is removed from the reactor 400 hours after shutdown.

Although the Technical Specifications allow for fuel removal after 100 hours, it is not expected that any unloading will occur until at least 400 hours have passed. This is a result of all other procedures which must take place prior to the actual unloading of fuel during a refueling outage. It would take three hours twenty-three minutes for the water in the Spent Fuel Pool to reach the boiling temperature of 212 °F. The water would then boil off at a rate or 52 GPM resulting in the water level to drop at a rate of 4 3/4 inches per hour. Since the active portion of the fuel assembly is only three inches below the level of the refueling seal, the fuel will be exposed approximately four hours after the initial drainage occurs (Reference 3.4).

If no operator action was taken, the fuel rods would become exposed to the atmosphere. If no credit for any cooling by water or steam is taken after the water level drops to the active portion of the fuel (an extremely conservative assumption) there is a possibility of cladding failure two hours after the active fuel is first uncovered (Reference 3.6) or six hours after drainage to the seal level. In actuality, it would take almost thirty hours to boil off the total volume of liquid. The majority of heat generated from the fuel rods is produced in the central region, which will remain covered with water for fifteen hours.

The boiling water in the Spent Fuel Pool can be replaced from the Demineralized Water System, Holdup Tanks, Primary Water Tanks and the Refueling Water Storage Tanks, as outlined in the Operating Instructions (Reference 3.9 and 3.10). The Demineralized Water System contains two 500,000 gallon tanks with a pumping capability of 650 GPM to the Spent Fuel Pool. There are three 63,500 gallon hold-up tanks connected to a pump that supplies 500 GPM to the Spent Fuel Pool. A third source of make-up water comes from the 250,000 gallon Primary Water Tank and pumps that provide up to 200 GPM of water. Any of these three sources can be made available within 30 minutes. Water can also be taken from the 100,000 gallons remaining in the Refueling Water Storage Tank. This can assure 100 GPM through the Refueling Water Purification Pump given a 6 hour preparation period to properly align piping. This total make-up water supply will more than replace any water lost from boil off in the Spent Fuel Pool.

5.7 CONSEQUENCES OF A DROPPED FUEL ASSEMBLY

As noted in the test section above, we tested a 6 inch segment to a load of 2,250 lbs. without pushing through the segment and without any permanent deformation. It is our judgement that the seal can withstand even greater loads than this. Since the maximum height that the fuel assembly is allowed to drop is approximately 2 feet (as a result of limits on the manipulator crane) it is our judgement that the load drop on a seal from this height will not result in the seal being dislodged from the annulus.

To address this concern on a long term basis, we intend on doing a test to demonstrate that the worst anticipated load drop will not dislodge the seal.

5.8 FLOW LIMITING DEVICE

As stated previously there are sufficient design differences between our seal and the Connecticut Yankee seal to assure us that the seal failure incident at Salem is not credible. The testing that we have performed confirms these statements. For this reason it is our belief that flow limiting designs such as those installed in the Haddam Neck design are not required at Salem. R I

Although the seal failure is deemed incredible we are, never the less, in the process of instructing operators with a integrated refueling procedure to assure that they will take mitigating actions to address a postulated seal failure.

5.9 FAILURE MECHANISMS

The failure mechanisms of overpressurization or loss of air pressure have been reviewed and we have determined that in our seal design the overpressurization incident is not credible. Our air supply line contains a manual regulator and a relief valve set to 35 lbs. Furthermore, with our seal design we have determined that overpressurization will not result in the same type of failure as Haddam Neck. At Salem the upper half of the inflatable portion of the seal is within the refueling cavity and will not balloon out to any significant amount. As the seal is pressurized, this portion of the seal will have almost full surface contact with the ledge and will resist vertical movement. One side of the lower half is likewise restricted against ballooning out.

In comparison, the Haddam Neck design results in considerable ballooning of the seal tending to pull the wedge down with little surface contact between the inflated portion and the cavity to resist the downward vertical force. With respect to the incidence of air loss, our seal has been designed to provide the necessary sealing capabilities uninflated.

5.10 REDUNDANT FEATURES

As stated previously we have taken the necessary actions to mitigate any credible accidents as a result of seal failure. Our seal does have redundant sealing methods. One is the inflatable portion which inflates in the 1.8 inch wide cavity. The second is the wedge on the top of the seal which is held down by brackets. We do not feel there are any credible events which could lead to a significant seal failure because of the high safety margins that the seal testing has demonstrated. R 1

5.11 RECOMMENDATIONS

The following recommendations shall be implemented prior to refueling.

1. Inspect and replace if necessary the internals of valves 2WL2, 2WL3 and 2WL221 (if installed). Tag closed these valves prior to filling the cavity. These valves are potential drainage paths out of the refueling canal.

2. Keep the removable handwheel attached to the transfer tube valve whenever the valve is open. Close the valve when fuel is not being transferred (e.g. after core unload, but prior to reload).

3. Manipulate only one fuel assembly in the refueling cavity so only one fuel assembly that is inside the Containment Building, but outside the core could be in the vertical position at any given time. A Fuel Assembly can be in the process of being transferred to the Fuel Transfer Canal while a Fuel Assembly is

in the Manipulator Crane provided that the Fuel Assembly in the Transfer System is in the horizontal position.

4. The RCC Change Fixture located in the refueling cavity shall not be used for temporay storage of fuel assemblies.

5. Prior to flooding the Reactor Cavity, an "Integrated Procedure "shall be prepared with appropriate personnel properly trained. The Integrated Procedure shall incorporate conditions that indicate a loss of Refueling Cavity water level and the subsequent emergency actions. The emergency actions shall include instructions to place fuel assemblies in the safest location, closing the Fuel Transfer Tube Isolation Gate Valve, establishing flow paths for make-up water to the Reactor and Spend Fuel Pit. R 1

6. The air supply to the inflatable Reactor Cavity Water Seal shall be regulated to 20 psig (operating pressure) and shall include a relief valve set at 35 psig.

7. Measure the deflection of the top surface of the Refueling Cavity Water Seal as soon as the seal has been installed and inflated. Inform Systems Engineering of the results.

6.0 CONCLUSION/SUMMARY

There are a number of substantial differences between the refueling cavity water seal design used at Connecticut Yankee's Haddam Neck and that used at the Salem Nuclear Generating Station. At the Salem Station the cavity wall ledge is beveled to a 20° angle and has been machined and backfilled forming a smooth surface finish. In addition, the reactor vessel seal edge has been hand deburred to produce a more effective seal surface. The inflatable seal used at Salem Station is wider across the wedge portion and is used to seal the same size area. The seal material is harder than that used in manufacturing the Haddam Neck seal and will aid in the prevention of bowing and bending. Haddam Neck also utilizes a lubricant in seating the seal, which is not done at the Salem Station. To increase the safety margin at the Salem Station, brackets are placed on top of the Presray seal to further assure a secure closure.

Maintenance procedures at the Salem Station further confirm proper placement and utilization of the seal. As a result of the numerous differences, the probability of seal failure at the Salem Station is considered significantly lower than at Haddam Neck and a gross seal failure is considered highly unlikely to occur. These conclusions have been confirmed through rigorous tests on the seal used at the Salem Station. R1

Although precautions have been taken to assure the reliability of the refueling cavity water seal at the Salem Nuclear Generating Station, the consequences of a seal failure have been evaluated. There are adequate means of detecting a seal failure and subsequently preventing fuel failure through existing signals, procedures and Technical Specifications. Implementation of the recommended "Integrated Procedure" that addresses a loss of Refueling Cavity water level will further increase the safety margin at the Salem Station. In addition, during extended periods of time where there are no core alterations or fuel transfer, the Fuel Transfer Tube isolation valve shall be closed.

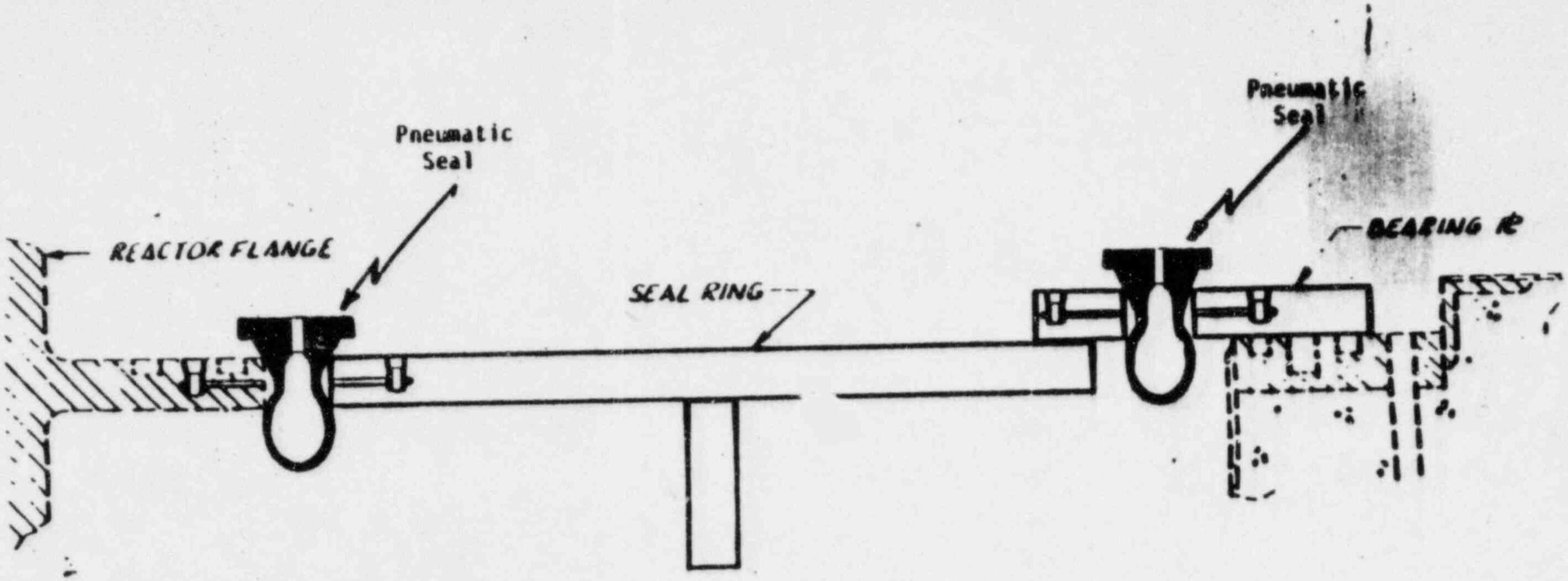


Figure 1 - Haddam Neck Refueling Cavity Water Seal

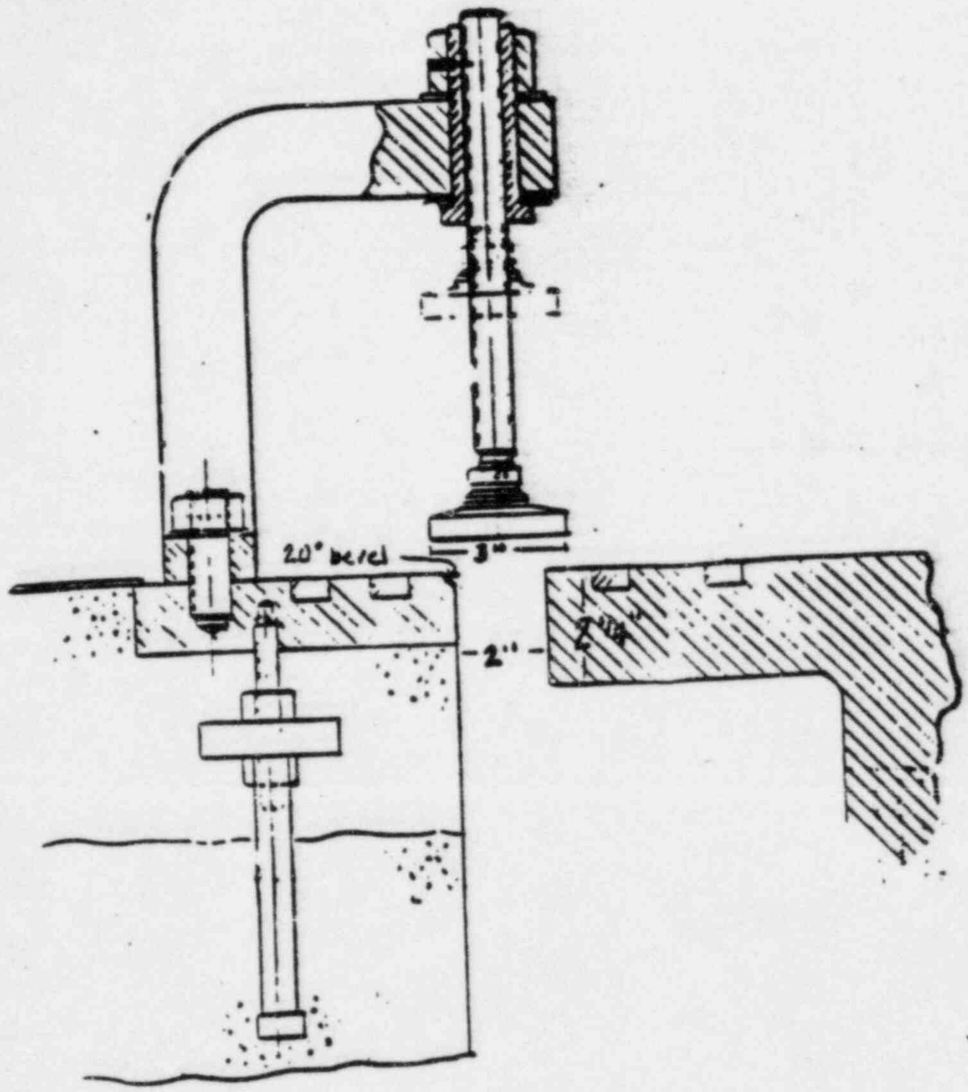


FIGURE 2 - Salem Nuclear Generating Station
Refueling Cavity and Bracket Design

FIGURE 3 - Salem Nuclear Generating Station
Inflatable Seal Design

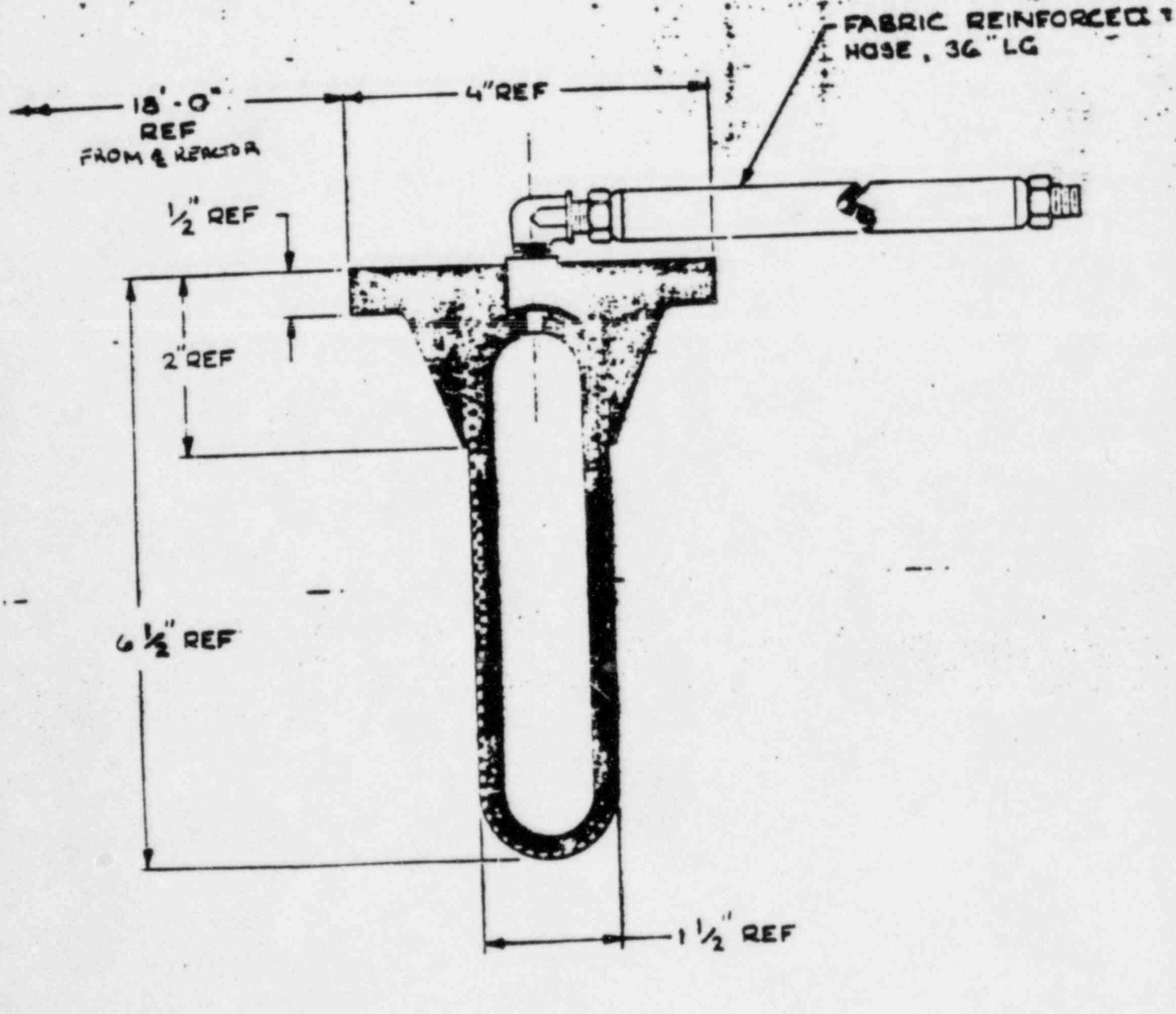


FIGURE 9

REFUELING CAVITY WATER SEAL TEST #1

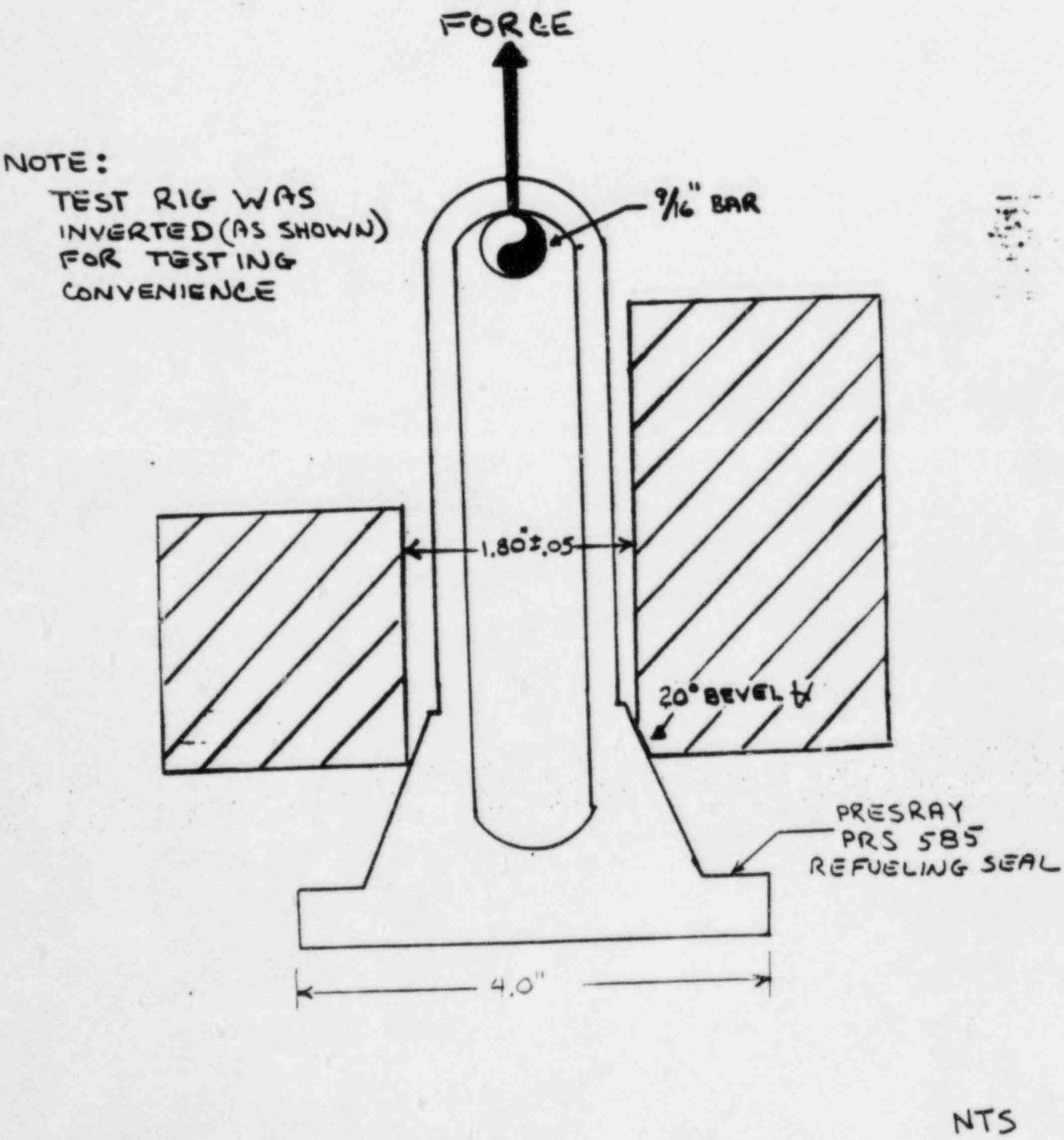
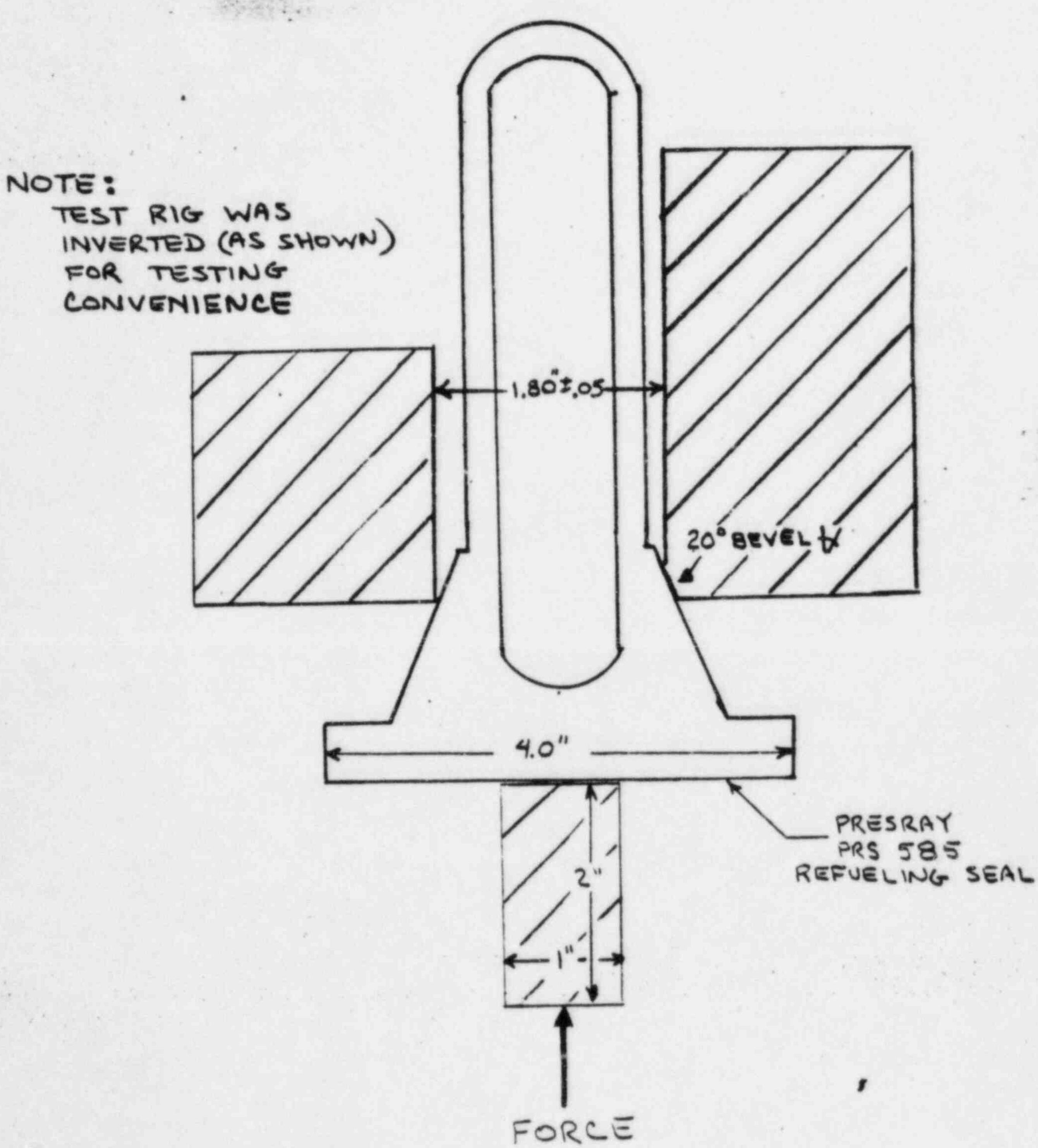


FIGURE 5

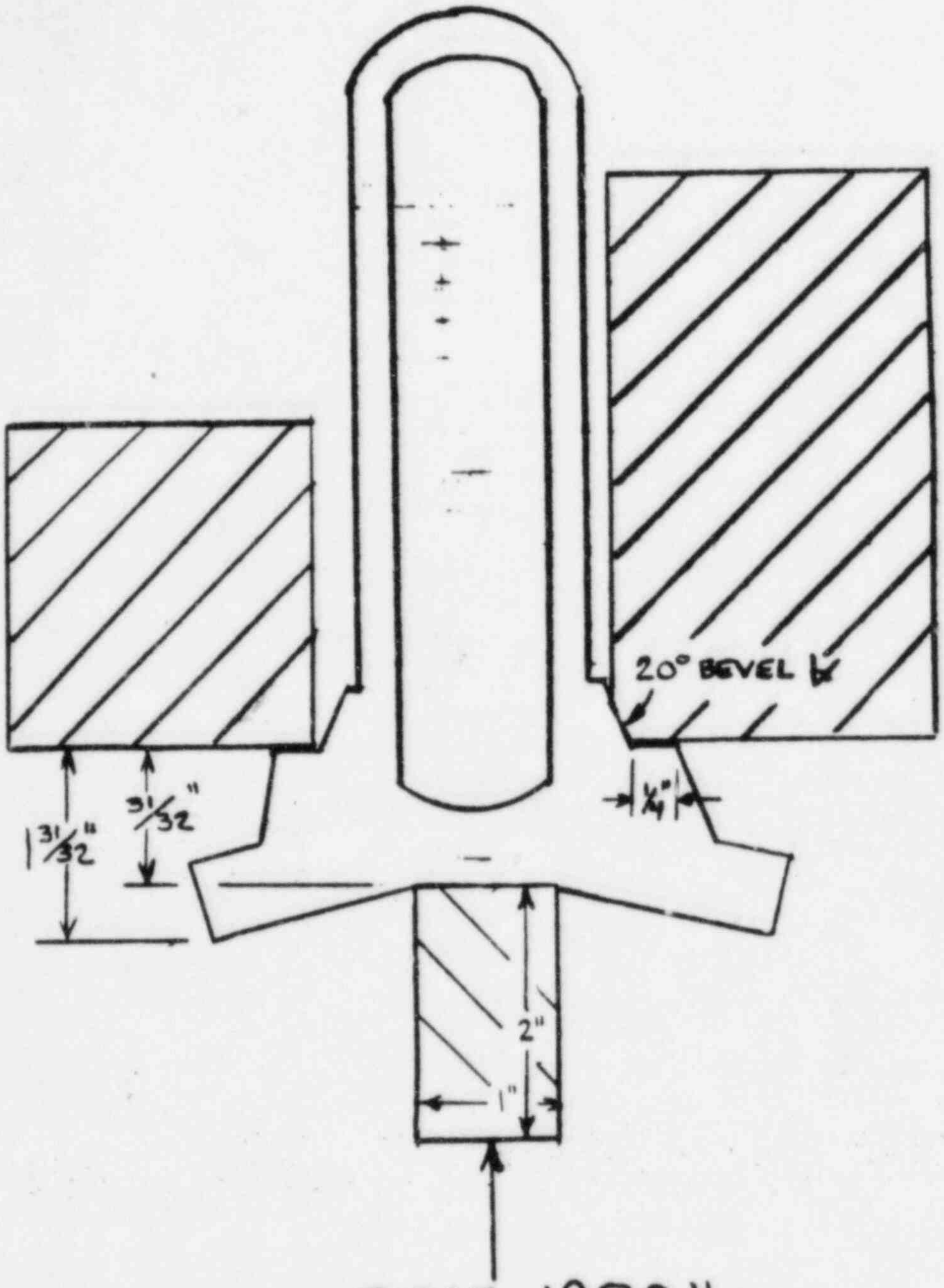
REFUELING CAVITY WATER SEAL TEST #2



NTS

FIGURE 6

TEST #2 - MEASURED DEFLECTIONS @ 1980 lb



NTS