REFUELING CAVITY WATER SEAL EVALUATION

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1.0 INTRODUCTION

An evaluation of the potential for loss of refueling water in the shield tank cavity at the Yankee Nuclear Power Station has been completed. The evaluation has been prepared in accordance with the requests and recommendations contained in References 1, 2 and 3 and includes an evaluation of the cavity seal ring, cavity penetrations, operating procedures, and failure consequences.

2.0 CAVITY SEAL RING

In 1970 Yankee modified its refueling operations with the introduction of a Presray "T-slot" inflatable seal ring. This ring is inserted into the annulus between the reactor vessel flange and reactor cavity prior to cavity fill. This seal ring is constructed of a molded 60 durometer elastomer material with a fabric reinforced bladder section. The cavity seal ring is shown in Figure 1. The inflatable portion of the seal is fully contained within the annulus. This design assures that the air pressure within the seal bladder is directed to the seating surfaces thus maximizing seal efficiency.

As shown in Figure 1, the ring has a corrugated horizontal flange at the top. This "T" shape design allows the pressure of the water head in the cavity to help seat the redundant corrugated seals on both sides of the annulus opening.

The neutron shield tank flange is designed to accommodate the "T-slot" cavity seal. The flange consists of a steel ring and skirt welded to the top of the neutron shield tank. It is constructed of ASTM A-516 Grade 70 material. This flange incorporates a lower ledge ring on the underneath side of the flange. The ledge ring is not stressed under normal operating conditions. This ledge ring effectively reduces the annulus to 3/8 inch from the nominal 15/16 inch. The major benefit of the ledge ring is that it acts as a secondary seal.

2.1 Cavity Seal Ring Pressurization System

Cavity seal ring air pressure is presently controlled via a pressure regulator, pressure gauge and bleed valve. This system does not fully protect against overpressurization and underpressurization of the bladder. Therefore, the cavity seal pressurization system will be modified prior to the next scheduled refueling to include the following components:

1. Air pressure regulator.

   - Inlet air pressure at 100 psi, reduction to 0-50 psi.

* 2. Safety valve with setpoint at 40 psi maximum.

3. Air pressure gauge.

* 4. Flow check valve.

   o Prevents loss of air in the bladder should a leak in the pressure hose occur.

* 5. Audible alarm.

   o Will signal in the event of low air pressure.

(Note: * indicates new features.)

This new design will ensure adequate air supply requirements to the cavity seal.

2.2 Cavity Seal Ring Hydrostatic Test

A hydrostatic test has been performed by Impell Corporation on the YNPS reactor cavity seal ring to demonstrate the integrity of the design and performance. The hydrostatic test report is contained in Reference 4.

A full scale 3 foot segment of the reactor cavity seal ring and annulus was tested at an equivalent refueling cavity water depth of up to 300 feet. The cavity seal ring from which the segment was procured came directly from plant stock. It had been scheduled for use in an upcoming outage.

The following parameters were fully evaluated in the testing program:

1. Bladder Pressure

   o The cavity seal bladder pressure is typically maintained at 25-35 psi. Pressures were varied between 0 psi and 50 psi to examine the effects of overpressurization and

underpressurization. For all bladder pressures tested, the cavity seal ring produced only minimal leakage.

2. Head of Water

- o The cavity seal ring was tested at an equivalent shield tank cavity water depth of up to 300 feet. The seal ring provided a resistance to push through exceeding the capacity of the test apparatus. For all water pressures tested, the cavity seal ring produced only minimal leakage.

3. Leakage

- o Cavity seal ring leakage was measured during all tests. At the normal design head of water (25 feet) with a deflated bladder, the maximum leakage recorded was 2.9 gpm for the entire annulus circumference. This leakage is well within the makeup capacity to the shield tank cavity.

4. Vertical Displacement of the Seal

- o Vertical displacements of the cavity seal ring were measured at three locations to determine the seal elevation through the pressure boundary. For the normal operating and installation parameters (25 foot water head, 30 psi bladder and the as-built annulus gap), the seal displaced into the gap by a nominal .004 inch. The seal ring exhibited no leakage for this condition.

5. Water Temperature

- o The test examined seal behavior at a water temperature of 150^{o}F. This condition simulates a failure of the Shutdown Cooling System during a refueling and represents a credible temperature which could occur under a cooling system failure. The results show slightly more displacement at the elevated temperature; however, it was not detrimental to the seal's push

through resistance. The increase in displacement showed no increase in leakage. Each of the higher temperature tests were terminated after reaching the pressure limit of the test apparatus without incurring failure by push through.

6. Annulus Tolerances

- o Three annulus gaps were evaluated for all tests conducted. The nominal reactor cavity annulus is 15/16 inch wide. A conservative maximum gap of 1-1/16" was chosen to envelope the variations in annulus width. Additionally, an upper bound value of 1-3/16 inches was evaluated to examine the effects of large gaps on seal performance.

  For all annulus gaps tested, the cavity seal ring exhibited exceptional protection against push through and leakage.

7. Sudden Bladder Pressure Loss

- o During selected tests, a sudden loss of bladder pressure was simulated by rapidly decreasing the air pressure. This sudden loss of air pressure produced additional seal displacement into the annulus; however, was not detrimental to the push through resistance of the seal. The loss of bladder pressure showed no measurable increase in leakage.

The YNPS cavity seal ring exhibited exceptional protection against push through and leakage. This testing program is very comprehensive and fully meets the requirements and recommendations in IE Bulletin 84-03 and INPO SOER 85-1.

2.3 Cavity Seal Ring Load Drop Assessment

Postulated falling objects striking the cavity seal were evaluated and result in a negligible effect on seal performance for the following reasons:

1. The bottom of a YNPS fuel assembly has four short equally spaced legs. If an inadvertent drop of a fuel assembly were to occur, two of the legs could impact the cavity seal. The other two legs would impact the flange surfaces. This would preclude the fuel assembly from penetrating deep into the annulus, thus, resulting in only minimal vertical displacement of the cavity seal.

2. The seal's upper "T" section is considered adequate to resistant to puncture. The seal is constructed of 60 durometer EPDM compound which is a very tough material.

3. If any object were to impact the cavity seal causing the seal to displace into the annulus, the cavity seal bladder would be forced in between the reactor flange and lower ledge ring. This configuration has been shown to be totally acceptable via hydrostatic testing in that the bladder effectively seals the gap and eliminates the potential for leakage.

4. In the unlikely event that a sharp falling object punctured the seal bladder it could result in loss of air to the seal. Hydrostatic testing has shown that a sudden loss of bladder pressure has negligible effect on seal performance.

3.0 SHIELD TANK CAVITY

The shield tank cavity above the reactor vessel is an irregular octagonal reinforced concrete container 27 feet deep. It is lined with 16 gauge stainless steel plates which form a watertight barrier. During refueling it contains approximately 130,000 gallons of borated water. It is provided for the purpose of permitting fuel assemblies, control rods and reactor components to be handled under water. It is also a storage area for various reactor internals and handling fixtures during refueling.

The shield tank cavity provides a minimum of a 13 foot water shield over the top of a withdrawn fuel assembly and an 8 foot minimum water shield over the top of a withdrawn control rod.

3.1 Shield Tank Cavity Water Level

At least 32 feet of water is maintained over the top of irradiated fuel assemblies seated within the reactor vessel during movement of fuel assemblies or control rods within the reactor vessel while in Mode 6 (Technical Specification 3.9.10). Typically, the water level is maintained at 34 feet to 35 feet above the top of the reactor core.

A fixed water level measuring board is installed on the side of the shield tank cavity prior to filling. A low and high level float is also installed and wired to an alarm in the Control Room. These measures provide the operators and refueling crew with continuous indications of the water level within the shield tank cavity.

3.2 Shield Tank Cavity Makeup to Control Level

While in Mode 6, at least two of the three charging pumps in the boron injection flow path must be operable (Technical Specification 3.1.2.3). Each pump can deliver a maximum flow of 33 gpm. The charging pumps are demonstrated to be operable at least once per 31 days on a staggered test basis.

The total flow rate of charging for makeup capability is a minimum of 66 gpm. The LPSI and HPSI pumps may be tagged out of service during fuel movement and, therefore, are not credited for providing makeup water to the shield tank cavity

3.3 Shield Tank Cavity Leak Monitoring

During refueling operations, the following locations are periodically monitored for leakage:

a. Inner telltale drain

b. Outer telltale drain

c. Loop No. 4 drain box area located at the bottom of the vapor container

d. Bottom of vapor container adjacent to the fuel chute penetration

e. Cavity recovery system barrel located at the bottom of the vapor container

f. Lower lock valve area of the spent fuel chute including the flange where the fuel chute blank is normally installed

The inner and outer telltale drains are located directly below the reactor vessel and neutron shield tank, respectively. The telltale drains collect shield tank cavity water that may leak past the cavity seal ring or the bellows seal between the neutron shield tank and the concrete support structure. During the fill process the telltale drains are continually monitored for leakage.

Prior to completely filling the shield tank cavity, the water level is set at 40 inches above the reactor vessel flange and is allowed to stand for 30 minutes. During that time, leakage is monitored from the above mentioned sources and recorded. Per Plant Operating Procedure OP-1203, if the leakage is greater than 1 gpm further filling of the tank is suspended and management

is notified. An acceptance limit of approximately 1/2 gpm is specified in OP-1203.

Historically, the average leakage per day from the monitored sources during refueling is approximately 530 gallons in a 24 hour period. This corresponds to a 0.37 gpm leak which is well below the accepted standard.

3.4 Shield Tank Cavity Piping Penetrations

There are three, Type 304 stainless steel pipes which penetrate the shield tank cavity: a 6 inch purification/fill and drain line, a 3 inch fuel chute equalizing line and the spent fuel chute piping.

The 6 inch line (PRT-152-2) penetrates the bottom of the shield tank cavity and can be connected to the low pressure safety injection pumps, the ion exchangers, and the safety injection tank via different valving configurations.

The Low Pressure Safety Injection (LPSI) pumps are used as the primary source of water to initially fill the shield tank cavity to the required height. Prior to filling, the 6 inch cavity drain line is blank flanged and filled with demineralized water, leak tested and then drained. The 1 inch drain valve, CS-V-619, located on PRT-152-2, is closed and capped per Plant Procedure OP-1203. During the fill process, the shield tank cavity inner and outer telltale drain valves are open to the leakage monitor drum beneath the vapor container. The leakage is monitored on a continual basis until the filling process has been completed. If, at any time during filling of the shield tank cavity, the leakage should exceed 1 gpm, the operation is terminated until such time as the leak is rectified or reduced to an acceptable value. When the cavity water has reached the prescribed level, the LPSI pumps are shutdown and the header valves closed. The cavity fill valve, CS-V-601, is also closed at this time.

After completion of the fill process, valves are arranged to activate the Cavity Purification System. Refueling water is skimmed off at the water surface via an adjustable standpipe in the shield tank cavity, and flows by gravity to the No. 6 ion exchanger. The water then flows by gravity to the

safety injection tank (TK-28) and pumped back into the shield tank cavity via the Loop No. 4 injection line.

Complete drainage of the shield tank cavity is not possible through the standpipe skimmer since the flow path is located at the upper water level.

Any leakage back through the 6 inch cavity fill and drain line is prevented administratively by Procedure OP-1203 which requires this line to be isolated manually prior to activating the cavity purification system.

The 3 inch fuel chute equalizing line (PRT-152-4 and -6) also penetrates the bottom of the shield tank cavity and is connected to the fuel chute dewatering pump and the fuel chute piping. The operation of this system is discussed in Section 4.0.

Several drain, pressure test and vent valves are connected to the fuel chute equalizing piping. Per Plant Procedure OP-1203, all of these valves are closed during filling of the the shield tank cavity. Thus, the potential for leakage through these valves is prevented administratively.

4.0 INTEGRITY OF SPENT FUEL POOL AND SPENT FUEL CHUTE

Yankee is unusual in that the spent fuel pool is considerably lower in elevation than the shield tank cavity. The normal spent fuel pool water level is 42 feet below the bottom of the shield tank cavity.

The YNPS design features an inclined spent fuel transfer chute which connects the shield tank cavity to the spent fuel pool. Appropriate interlocks and valves are in place which would preclude a total loss of refueling water event from occurring. If, however, a failure in the shield tank cavity were to occur resulting in drainage of the refueling water, the spent fuel pool water level would be unaffected, thereby protecting the stored spent fuel assemblies.

The spent fuel chute allows transportation of the fuel assemblies and control rods between the spent fuel pool and shield tank cavity. The fuel chute, approximately 50 feet long, is a reinforced concrete octagonal tube and is inclined at 43^{o}. The interior portion of the chute consists of several sections of stainless steel pipe flanged together, a motor-operated lower lock valve and a swing plate upper lock valve at the top of the chute.

The fuel chute is structurally isolated from the vapor container by use of a metal bellows expansion joint. The chute and its joints are watertight. A solid plate flange is used as a water and gas closure to maintain the integrity of the vapor container during reactor operation.

Rails placed in the fuel chute support the fuel transfer carriage and extend the length of the chute except where discontinuous at the lower lock valve and the upper lock valve. The transfer carriage moves by gravity and its travel is controlled by a pair of stainless steel cables wound on a winch in the down direction. These cables are also used in drawing the carriage unit in an upward direction.

When the transfer carriage is moving in the upward direction, it opens the upper lock valve upon contact. The valve is closed by a spring after the passage of the carriage in the downward direction. The movable plate is provided with a replaceable neoprene "O"-ring for sealing purposes so that the

leakage to the spent fuel pool does not exceed two gallons per hour under a head of 25 feet of water.

The lower lock valve is a stainless steel gate valve which remains in the closed position until the carriage reaches a point in the chute above the valve. Indicating lights on the operator's console located on the refueling bridge designate the open, closed or intermediate positions of the valve.

To minimize the loss of borated water from the shield tank cavity to the spent fuel pool during refueling operations, a dewatering system is provided to partially dewater the chute before the transfer carriage passes through the lower lock valve. The dewatering system reduces the water level in the fuel transfer chute to a level approximately equal to the level of the water in the spent fuel pool. The water removed is then returned to the shield tank cavity.

The fuel handling system is tested for operational reliability at each refueling prior to the actual handling of fuel. The testing includes exercising a 900 lb. dummy fuel assembly through the spent fuel chute to verify the reliability of the fuel handling equipment and to ensure that the system interlocks are functioning properly and are sequenced. This procedure is performed within 100 hours of core geometry changes (Technical Specification 4.9.6).

Based on an evaluation of the design and 25 years of operating experience, the spent fuel chute is adequately designed and tested to preclude a total loss of refueling water event from occurring.

5.0 MISCELLANEOUS POTENTIAL LEAKAGE PATHS

Several potential causes of leakage are described in Reference 3 that could result in draining the shield tank cavity. It is recognized that these leakage paths are common to many nuclear power facilities, however, some are not applicable to the Yankee plant due to its design. The following discussion provides a more comprehensive understanding of the systems contained within Yankee which precludes draining of the shield tank cavity during refueling operations:

1. Deflation or other failure of seals on a refueling or spent fuel pool gate.

   Yankee utilizes only one inflatable seal during refueling operations - that being the cavity seal ring located in the annulus between the reactor vessel flange and the neutron shield tank flange. This issue is not applicable to YNPS for refueling operations.

2. Failure of a temporary nozzle dam used to allow simultaneous refueling activities and access to steam generator tube sheets.

   Nozzle dams are not utilized at YNPS. Main coolant loop isolation valves are located in all four loops. When closed, these valves isolate the loops to prevent draining the shield tank cavity water through an open steam generator or disassembled main coolant pump or any other loop piping penetration.

3. Inadvertent opening of a loop isolation valve with an open steam generator or disassembled reactor coolant pump.

   The loop isolation valves are motor-operated having dual contactors with one contactor being key-locked. The breakers connected to the isolation valves are locked open which removes the power source. In addition, the valves are tagged out of service during refueling when loop integrity is not established.

4. Loss of coolant through the RHR System (termed "Shutdown Cooling" at YNPS) such as by opening the isolation valves to the containment sump.

   The Shutdown Cooling System at Yankee is a closed loop system. There are no drain paths to the containment sump.

5. Inadvertent opening of a safety/relief valve.

   Yankee utilizes spring actuated safety valves. Opening of a safety valve is not possible with the Main Coolant System depressurized.

   A solenoid-operated relief valve is located on top of the pressurizer, above the cavity water level. The elevation of the relief valve is such that an inadvertent opening of the relief valve is of no consequence.

6. Failure of the instrumentation port covers.

   Every refueling the instrumentation port covers are fitted with new gaskets and bolts retorqued prior to filling the shield tank cavity. Failure of these covers is unlikely since this is a compression joint. Shear loads are not present in the covers.

7. Inadvertent opening of a valve for the shield tank cavity drain.

   Per Procedure OP-1203, the 1 inch drain valve, CS-V-619, is closed and capped prior to filling the cavity. Filling of the cavity cannot be accomplished until this valve is closed. Draining of the shield tank cavity via this valve is administratively precluded by Plant Procedure OP-1203.

   A flap gate is located on the discharge side of the fill line inside the shield tank cavity. During the fill operation, a halyard is attached to the flap gate and secured in the open position. Upon completion of the cavity fill, the halyard is released, thereby allowing the gate to close. Therefore, loss of

cavity water via a drain line is not possible since the flap gate is in the closed position during refueling operations. This flap gate cannot be reopened until such time as the halyard is raised.

6.0 CONSEQUENCE EVALUATION OF REFUELING WATER LEAKAGE

This section discusses dose rates to the crane operator as a function of water level in the shield tank cavity resulting from a spent fuel assembly.

A single spent fuel assembly with core average burnup and five-day decay is postulated to be standing upright at the bottom of the shield tank cavity. The fuel assembly may be directly connected to the manipulator crane grappling hook, standing freely in the guide tube rack or resting on the fuel assembly upender in preparation for transfer to the spent fuel pool.

The refueling crane bridge is approximately 30 feet above the shield tank cavity floor. The dose rate analysis assumes that the crane operator is in direct line of sight with the spent fuel assembly. This represents the maximum radiation dose to an individual that would be directly above a fuel assembly during the normal course of refueling.

The dose rate to the operator as a function of cavity water level is shown in Figure 2.

As described in Section 4.0, the potential for gross leakage of refueling water through the spent fuel chute is not a credible event. Of the remaining two pipe penetrations into the shield tank cavity, the 6 inch fill and drain line represents the maximum leakage area which could result in drainage of the shield tank cavity. It has been demonstrated in Section 3.4 that a loss of refueling water through this 6 inch penetration is extremely remote. A failure of this 6 inch line has been postulated for the purpose of determining the length of time the operator has to reinsert a spent fuel assembly into the reactor core.

A failure of the 3 inch fuel chute equalizing line is also postulated since this is considered a more credible event, however, does not envelope the bounding condition discussed above.

However, it is reasonable to assume for this event that 5 feet of water coverage over the top of an irradiated fuel assembly is acceptable. This coverage limit is taken directly from Technical Specification 3.9.11.2 which

states that in the spent fuel pool at least 5 feet of water must be maintained over the top of irradiated fuel assemblies while the fuel assemblies are not seated in the storage racks.

The leakage analysis assumes a normal refueling water height of 25 feet above the shield tank cavity floor. When the low water level alarm in the shield tank cavity has sounded, the operator would then verify the shield tank cavity level, the charging pumps would then be activated and would begin to deliver 66 gpm to the shield tank cavity. (This assumes 2 of 3 charging pumps available.)

A fuel assembly is approximately 9 feet in length. Therefore, a minimum height of 14 feet of water must be present in the shield tank cavity to satisfy the coverage limit.

Figure 3 shows the height of water in the shield tank cavity as a function of time for the postulated total failure of the 6 inch fill and drain line. The results show that the crane operator has approximately 23 minutes to relocate a fuel assembly back into the reactor core.

For the postulated failure of the 3 inch fuel chute equalizing line, Figure 4 shows that the crane operator has approximately 100 minutes to reinsert a fuel assembly into the core.

Figure 2 shows that the dose rate to the operator at the hypothetical limit of 5 feet of water coverage above the spent fuel assembly is an acceptable 30 mR/hr for this unlikely event.

A fuel assembly can be relocated into the core in approximately five minutes. It is, therefore, concluded that if a failure of the 6 inch fill and drain line were to occur, the crane operator would have sufficient time to place a fuel assembly into the reactor core. A total failure of the fill and drain line is highly unlikely since it is only subject to hydrostatic pressure of 25 feet of water during the refueling. A failure of the 3 inch fuel chute equalizing line would allow the operator 100 minutes to relocate a fuel assembly back into the reactor core.

7.0 PLANT PROCEDURES AND TRAINING

The Yankee plant refueling procedures and training will be reviewed in detail. Several procedures will be revised prior to the next scheduled refueling to further reduce the potential of a loss of shield tank cavity water. The following sections discuss these changes.

7.1 Cavity Seal Testing and Installation Requirements

Prior to installation of the cavity seal, cleaning of the flange surfaces and annulus is now required by Plant Procedure OP-1100. Reference to a new Procedure OP-1524 will be provided by OP-1100 which will detail the cleaning procedure. All annulus surfaces will be free of scale, rust or any other deposits which could impair the sealing capability of the cavity seal ring. The surfaces are painted following completion of the cleaning process. Inspection of all surfaces will be done by maintenance personnel.

The cavity seal ring will be leak tested per OP-1524 at a bladder pressure of 30 psi prior to installation. Upon acceptance of the leak test, the cavity seal ring is installed between the shield tank cavity flange and the reactor vessel flange and reinflated to 30 psi before the shield tank cavity is flooded.

As described in Section 2.1, Yankee is redesigning the cavity seal ring pressurization system. A check valve will be installed on the air supply fitting. This will prevent loss of bladder pressure in the unlikely event of a leak in the air supply hose.

An alarm will also be installed as part of the cavity seal pressurization system. This alarm will signal on low air pressure. Adjustment of the air pressure is done manually.

7.2 Surveillance Requirements

As described in Section 2.1, the cavity seal pressurization system will be upgraded to ensure maximum sealing capability. An alarm will be connected to this system for the purpose of sensing low air pressure.

Since the instrumentation port covers are potential sources of leaks within the shield tank cavity, further guidance on replacing the port cover gaskets will be detailed in an appropriate procedure. During the 1984 outage the bolts were inspected for defects and the holes were gauged and determined to be acceptable.

Yankee will perform a dimensional verification of the cavity seal annulus during the 1985 outage. This will be done to confirm that the annulus is within the dimensional parameters which were modeled during the recently completed hydrostatic testing program.

7.3 Plant Emergency and Administrative Procedures

INPO SOER 85-1 recommends a review of emergency and administrative procedures for the prevention of a loss of refueling water. Yankee has performed a review of all applicable refueling procedures using the guidelines set forth in Reference 3.

OP-3117, "Refueling Accidents," will be upgraded to include the essential actions to be taken by crane operators, refuelers and others in the refueling work area in the event of a loss of shield tank cavity water. OP-3300, "Classification of Emergencies," shall be initiated as part of the operator action.

Appropriate training on the procedures will be initiated for all licensed personnel supervising fuel movement activities.

8.0 REFERENCES

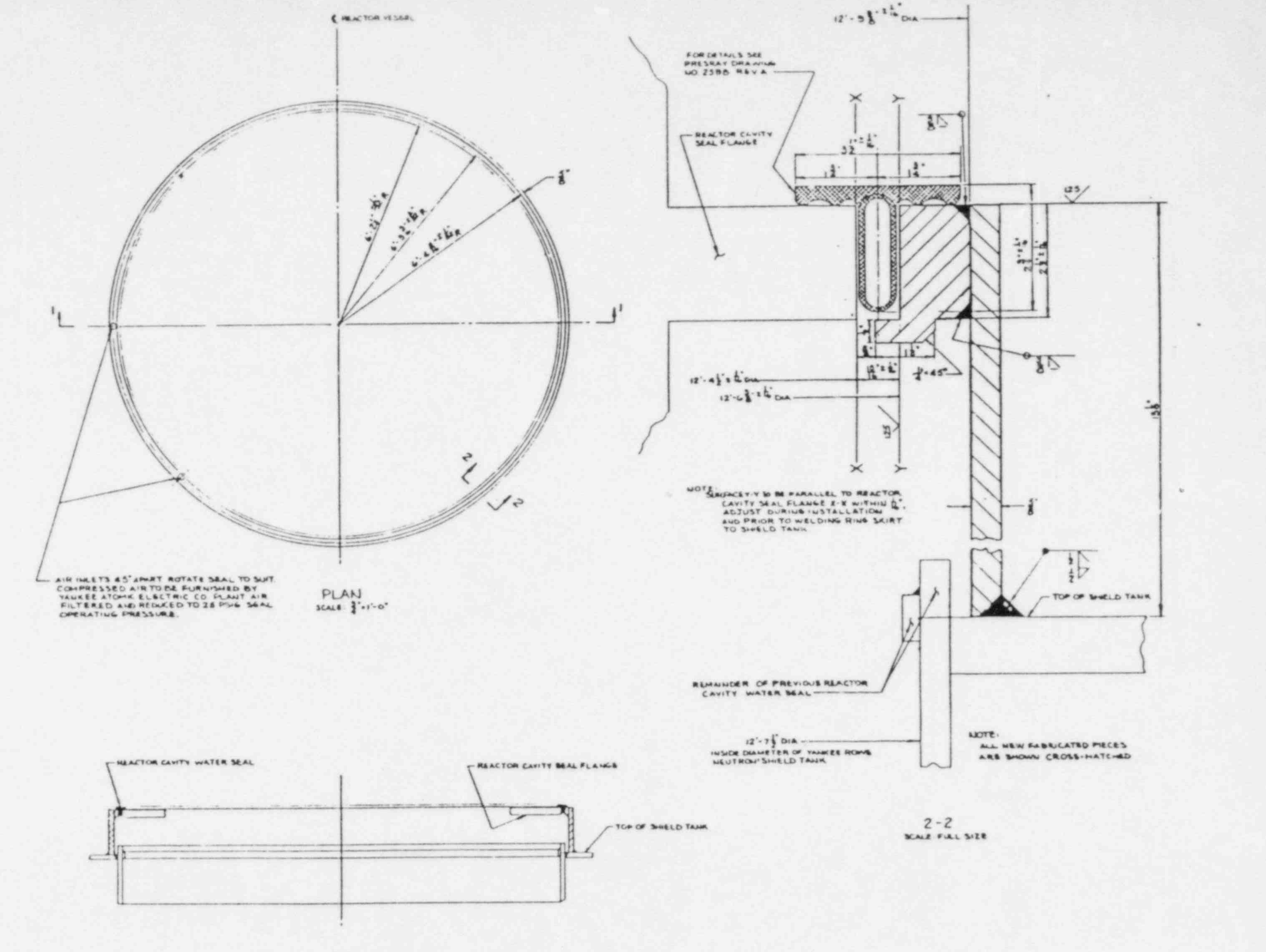
1. IE Bulletin No. 84-03, Refueling Cavity Water Seal, dated August 24, 1984.

2. IE Information Notice No. 84-93, Potential for Loss of Water From the Refueling Cavity, dated December 17, 1984.

3. INPO SOER No. 85-1, Reactor Cavity Seal Failure, dated January 30, 1985.

4. Impell Report No. 03-0570-1101, July 1985. (Attached)

ATTACHMENT B



℄ REACTOR VESSEL
AIR INLETS 45° APART. ROTATE SEAL TO SUIT. COMPRESSED AIR TO BE FURNISHED BY YANKEE ATOMIC ELECTRIC CO. PLANT AIR FILTERED AND REDUCED TO 28 PSIG SEAL OPERATING PRESSURE.
PLAN
SCALE: 3/4"=1'-0"
REACTOR CAVITY WATER SEAL
REACTOR CAVITY SEAL FLANGE
TOP OF SHIELD TANK
1-1
SCALE: 3/4"=1'-0"
FOR DETAILS SEE PRESRAY DRAWING NO. 2588 REV A
REACTOR CAVITY SEAL FLANGE
NOTE: SURFACE Y-Y TO BE PARALLEL TO REACTOR CAVITY SEAL FLANGE X-X WITHIN 1/16". ADJUST DURING INSTALLATION AND PRIOR TO WELDING RING SKIRT TO SHIELD TANK.
REMAINDER OF PREVIOUS REACTOR CAVITY WATER SEAL
INSIDE DIAMETER OF YANKEE ROWE NEUTRON SHIELD TANK
TOP OF SHIELD TANK
NOTE: ALL NEW FABRICATED PIECES ARE SHOWN CROSS-HATCHED
2-2
SCALE FULL SIZE

FIGURE 1

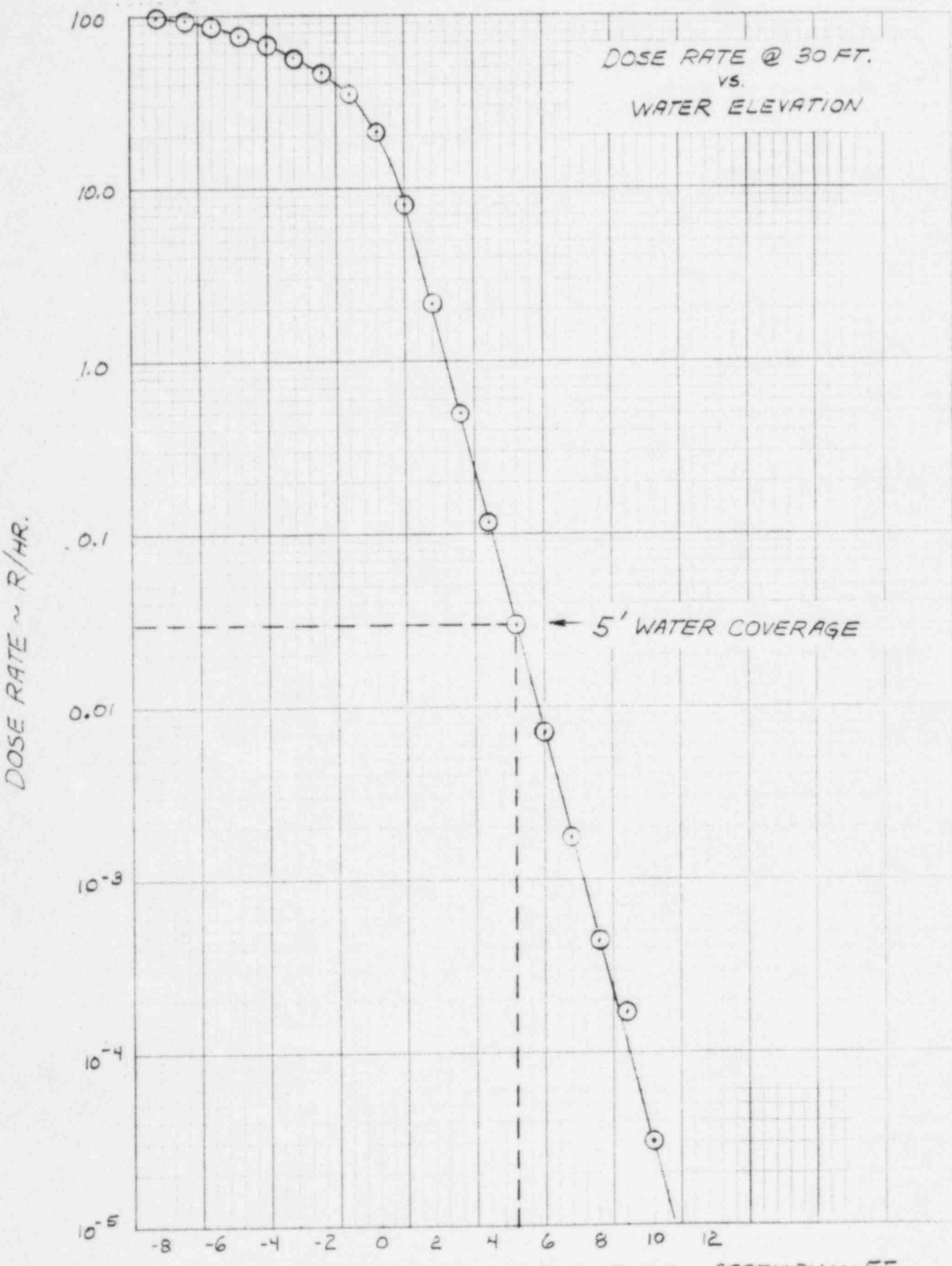

DOSE RATE @ 30 FT.
VS.
WATER ELEVATION
5' WATER COVERAGE
DOSE RATE ~ R/HR.
100
10.0
1.0
0.1
0.01
10^{-3}
10^{-4}
10^{-5}
-8
-6
-4
-2
0
2
4
6
8
10
12
WATER ELEVATION ABOVE TOP OF FUEL ASSEMBLY ~ FT.

FIGURE 2

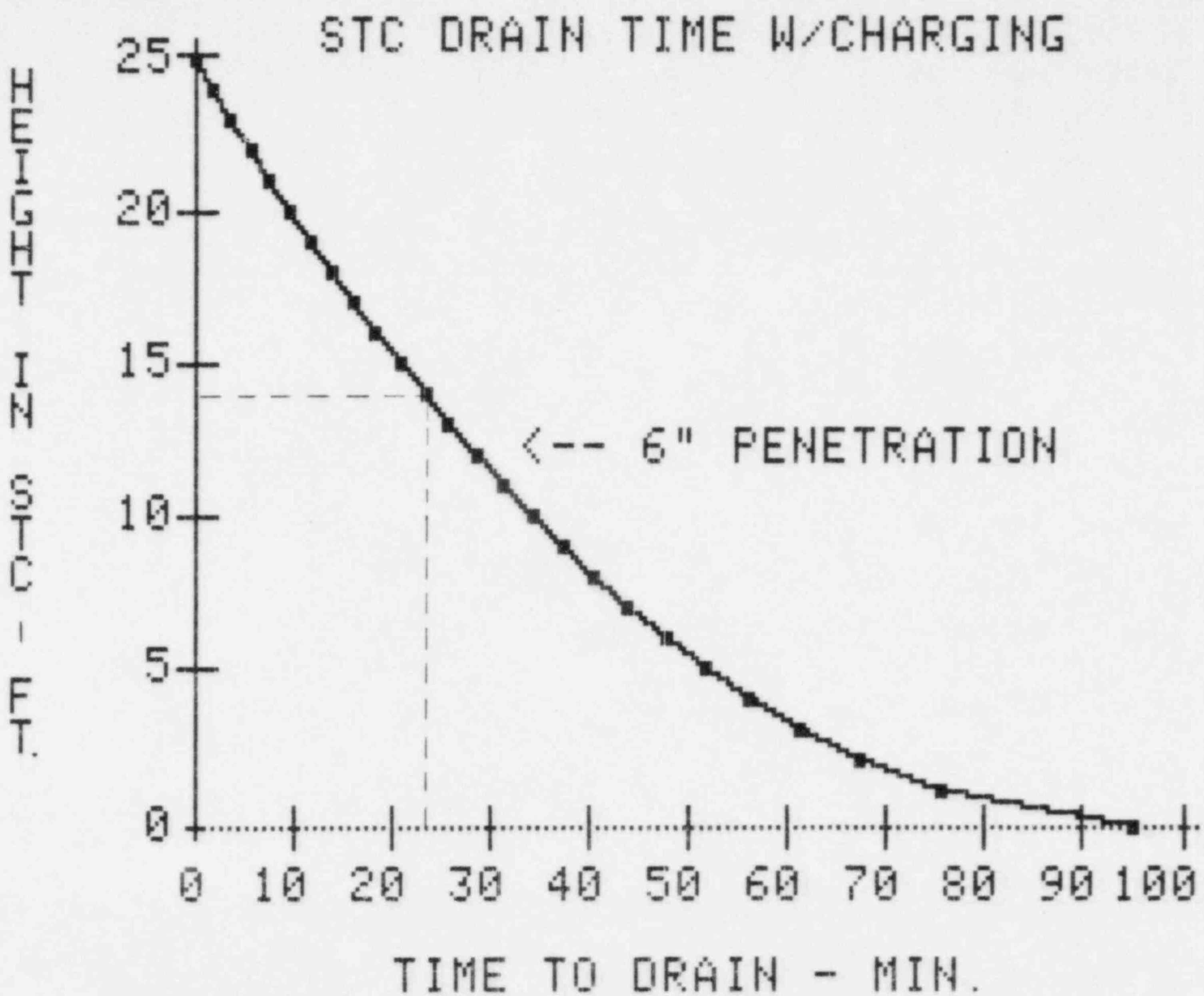

STC DRAIN TIME W/CHARGING
HEIGHT IN STC - FT.
25
20
15
10
5
0
<-- 6" PENETRATION
0
10
20
30
40
50
60
70
80
90
100
TIME TO DRAIN - MIN.

FIGURE 3

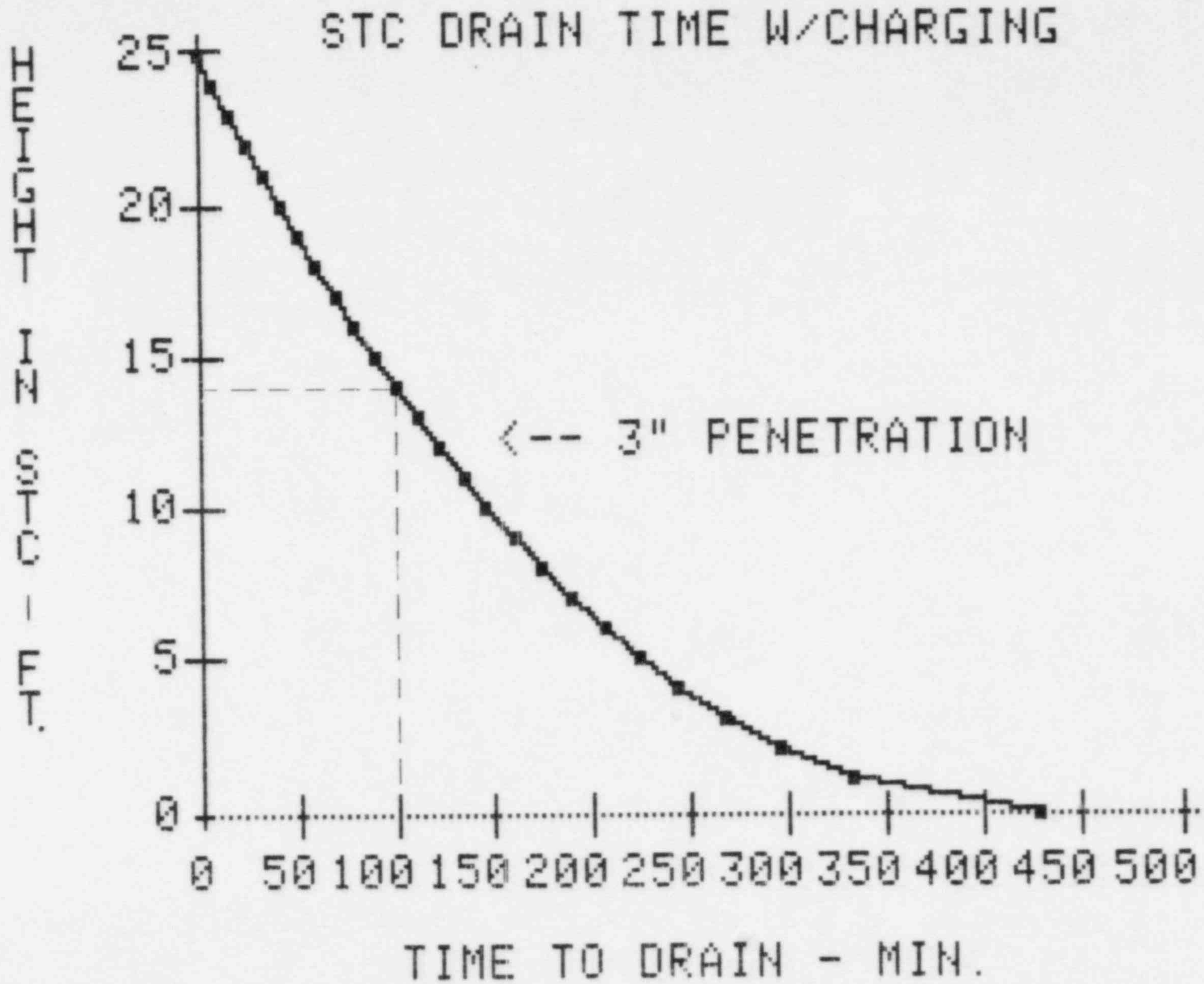

STC DRAIN TIME W/CHARGING
HEIGHT IN STC - FT.
25
20
15
10
5
0
<-- 3" PENETRATION
0 50 100 150 200 250 300 350 400 450 500
TIME TO DRAIN - MIN.

FIGURE 4