Proposed addition to Browns Ferry Nuclear Plant Unit 1
Technical Specifications

Following its initial refueling outage, the unit 1 reactor shall be maintained at a temperature of not less than 500°F and with a rated flow of not less than 30% for an accumulated period of not less than 60 hours before exceeding 5% rated power. Upon completion of this period of operation, the reactor shall be operated for at least 1 hour at 100% rated core flow before exceeding 30% rated power.

**After March 1, 1978, this page should be removed.

BROWNS FERRY UNIT 1 OPERATIONAL SAFETY EVALUATION
LOST SHOE COVER - FALL 1977 REFUELING OUTAGE
DECEMBER 26, 1977

## I. Situation Summary

A rubber shoe cover was dropped into the Browns Ferry unit 1 reactor vessel during the unit's first refueling outage. Repeated attempts to locate the shoe cover failed. Concurrent with the search activities, TVA requested the General Electric Company to perform the necessary testing and safety analysis to determine the effect, if any, on reactor operation with the shoe cover in the primary system. As a result of GE's testing and analysis and TVA's own investigations and evaluation, TVA concludes that by following a prescribed low power heatup program, the unit can subsequently be operated at its licensed power level with no compromise to reactor safety.

## II. Event

A rubber shoe cover was dropped into the unit 1 reactor vessel on September 18, 1977. The moisture separator was in the vessel, B and D residual heat removal (RHR) pumps were running in the shutdown cooling mode, and the recirculation pump B was in operation on the opposite loop. The shoe cover was last seen falling below the mid-support of the moisture separator at the vessel 270° location. Recirculation pump B ran for approximately 6 hours after the shoe cover entered the vessel. RHR pumps B and D ran in shutdown cooling mode until October 2, 1977. During the 14-day period prior to October 2, the moisture separator was removed from the vessel, and all fuel was transferred to the fuel pool. Prior to core unloading, an inspection with binoculars was made of the fuel and upper tie plates. At the completion of the maintenance work in the vessel, a search was initiated to locate the rubber shoe cover.

## III. Search

The search for the shoe cover was divided into two major parts. The in-vessel search was conducted both with binoculars and underwater TV cameras and included inside the shroud in the area above the core support plate, the annulus area between the shroud and vessel wall, and portions of the area below the core support plate. The out-of-vessel search included recirculation loop B piping, RHR heat exchangers and piping, the moisture separator, the fuel pool, the fuel lower tie plates, and the equipment drain sump. No trace of the rubber shoe cover was found in any of the areas. A more detailed description of the techniques used and areas searched are given in Attachment 1.

IV. Test and Analysis

In parallel with the search efforts, TVA began to investigate the effect of the reactor system operating environment on the rubber shoe cover. A test was attempted at the Wylie Laboratories in Huntsville, Alabama; however, this test was unable to reproduce reactor operating conditions, and no valid conclusions could be drawn from the test results. The General Electric Company was then requested to perform tests in their autoclave at Vallecitos in Pleasanton, California. Tingley shoe covers, similar to that lost in the Browns Ferry vessel, were autoclaved at reactor operating temperatures and then placed in a flow loop simulating a fuel support casting, a fuel assembly, and lower tie plate.

The autoclave tests demonstrated that the shoe cover when placed in an environment of 500° F water for a period of 24 hours had no tensile strength. The flow tests showed that such an autoclaved shoe would become brittle and disintegrate if subjected to flow conditions corresponding to 100 gpm in a fuel assembly coolant channel. The flow loop tests could only be run up to a temperature of 192° F; however, the series of tests demonstrated that the higher the flow loop temperatures, the more effective in disintegrating the shoe cover.

Based on a literature survey and tests performed at Vallecitos, GE has concluded that exposure of a shoe cover to high temperature water is more effective than exposure to radiation. From the GE tests, the following conclusion can be drawn. A rubber shoe cover when exposed for 60 hours in a reactor operating environment (temperatures greater than 500° F and flow exceeding 60 gpm in each fuel assembly) will be broken into small pieces so as to be of no consequence to safe reactor operation. In order to prevent transition boiling during this period, the reactor operation should be limited to a bundle power not to exceed 0.6 MWt. With total blockage at either the fuel support piece orifice or at the lower tie plate grid, there is at least $3 \times 10^3$ lbs/hr coolant flow available. With a minimum flow of $3 \times 10^3$ lbs/hr, boiling transition will not occur for bundle powers less than 0.85 MWt. The 0.6 MWt bundle power limit ensures that no fuel damage will result from operation with the rubber shoe cover intact in the reactor vessel.

Consequences other than flow blockage were also evaluated by GE and found to be acceptable. Increased friction may result during control rod drive movement; however, the scram force is greater than any postulated increased resistance from shoe friction, and the scram function of the rod would not be affected. No potential damage to reactor internals or recirculation loop components is postulated for the shoe either in its whole or carbonized state. No deleterious effects on water chemistry or any other chemical property are expected from the presence of the shoe.

GE's detailed analysis is presented in Attachment 2 of this report.

## V. Evaluation

In accordance with TVA Operational Quality Procedure Part II, Section 1.4, a safety evaluation has been performed for reactor operation both prior to and following shoe disintegration, and it was concluded that no compromise is made with regard to reactor safety. The reactor can be operated for 60 hours at at least 500° F and 30 percent rated core flow while maintaining a bundle power of less than 0.6 MWt. Following this 24-hour period, the reactor can be operated at rated power with no additional restriction.

Consideration was also given to the possibility that the shoe cover might be somewhere other than in the reactor vessel. This review identified three possibilities, the recirculation loop piping, the reactor water cleanup system, and the residual heat removal system. If held up in the recirculation system, the shoe cover would be subjected to the same soak as if in the vessel, with results as described in section IV of this evaluation. If held up in the reactor water cleanup system, the shoe cover would be in the same environment as in the recirculation loop until it disintegrated into pieces small enough to pass through the reactor water cleanup system heat exchangers, which have 3/4-inch tubes. Thereafter, the pieces would lodge in the cleanup filter-demineralizers until removed from use with the filter-demineralizer resin. If held up in the residual heat removal system, the shoe cover would become lodged in a residual heat removal heat exchanger. If pieces passed through the heat exchanger, they would be too small to affect reactor safety.

Operation at rated temperature and pressure and at 30 percent of rated core flow, while maintaining a maximum fuel assembly power of less than 0.6 MWt, is achievable. Peaking factors for a given rod sequence can be predicted which will conservatively bracket the actual operating state. Heatup power calculations (based on heatup rates) have been performed on all three Browns Ferry units and have been demonstrated to be conservative. In addition, the 0.6 MWt limit adds further conservatism as discussed in section IV of this evaluation.

Once the reactor has been operated at the recommended conditions for shoe disintegration, full power operation can be achieved with no compromise to reactor safety. It has been demonstrated by testing that the shoe cover, once disintegrated, causes no reduction in bundle flow rates and, therefore, no reduction in operating margin to existing safety limits.

## VI. Unreviewed Safety Question Determination

In accordance with 10 CFR 50.59, an unreviewed safety question determination has been made. The following three paragraphs discuss each aspect of this determination.

The presence of the shoe cover would not prevent the control rod drive system from performing its scram function in the time assumed in the safety analysis. The presence of the shoe cover would have no effect on any other equipment having a safety function; therefore, the probability of occurrence of an accident or malfunction is not increased over that analyzed. Adequate thermal margin is maintained at low power conditions prior to carbonization and disintegration. After disintegration, there is no effect on operating margins. Therefore, the consequences of any accident or malfunction is not increased over that previously analyzed.

No potential for damage to either the reactor internals or recirculation loop components (other than the effect on fuel of flow blockage) is postulated due to the pliable nature of the shoe cover prior to carbonization. Subsequent to carbonization of the shoe cover, no potential for such damage exists due to its frangible nature. The effect of flow blockage on fuel has been evaluated, and thermal margin is maintained at low power prior to and during carbonization of the shoe cover. Subsequent to carbonization and disintegration, flow blockage is of no concern. Therefore, the possibility for an accident of a type other than those previously analyzed is not created.

As discussed above, the shoe will cause no measurable difference in scram insertion times; therefore, the scram times as required by technical specifications will be maintained. Adequate thermal margins are assured at low power assuming total blockage of either the fuel support casting or the lower tie plate grid until the shoe cover has disintegrated. Once the shoe cover is in the carbonized state and has disintegrated, it will have no measurable effect on coolant channel flow or pressure drop. The margin to the safety limit for fuel cladding integrity as defined by the technical specifications is preserved.

Based on the above determinations, operation with the shoe cover in the reactor vessel or adjoining systems does not constitute an unreviewed safety question as defined by 10 CFR 50.59.

ATTACHMENT 1

# SEARCH FOR RUBBER SHOE COVER IN BROWNS FERRY NUCLEAR PLANT UNIT 1

## I. Background

Unit 1 of the Browns Ferry Nuclear Plant was shut down for refueling on September 13, 1977. While workers were removing transfer slot studs from the vessel flange, a rubber shoe cover was dropped into the vessel. The shoe cover was dropped at approximately 270° as shown in Figure 1 and disappeared as it passed the midpoint of the moisture separator between the separator and the vessel wall. At the time the shoe cover was dropped, the B recirculation pump was in operation and the B and D RHR pumps were operating in the shutdown cooling mode from the A recirculation loop. The B recirculation pump was shut down approximately 6 hours later, and the RHR pumps continued in service for another 14 days. During this 14-day period, the moisture separator was removed from the vessel, and all fuel was transferred to the fuel pool. At the completion of the maintenance work in the vessel, a search was initiated to locate the rubber shoe cover, a dosimeter, an inspection mirror, and a channel fastener. All items were quickly found except the shoe cover.

## II. Description of Search

The search for the shoe cover was divided into two parts. The in-vessel search was conducted using binoculars and with underwater TV camera and included the areas where an analysis of the operating conditions at the time the shoe cover was dropped indicated that it might have settled or become lodged. The out-of-vessel search included the RHR heat exchangers, the moisture separator, portions of RHR piping, the fuel pool, the fuel tie plates, and the equipment drain sump.

### A. In-Vessel Search

The initial search for the shoe cover was conducted from the service platform on the vessel flange using binoculars. The search was continued with an underwater TV camera which was lowered through the core upper grid to search above the core support plate. This camera was also lowered into the annulus area between the shroud and the vessel wall. The shaded area in Figure 2 shows the portions of the vessel which were covered by this part of the search.

The next step in the search consisted of removing jet pump #16 shown on Figure 1 which is the closest jet pump to the area where the shoe cover was dropped. The underwater TV camera was then lowered through the jet pump defuser to search the area below the core support plate.

A miniature TV camera was inserted through the suction of each remaining jet pump and the entire periphery of the vessel below the core support plate searched. This camera inspection also showed that each jet pump throat was not obstructed. The conclusion of this portion of the in-vessel search left only the recirculation loops and the interior of the vessel below the core support plate to be searched.

The B recirculation pump was running at the time the shoe cover was dropped, and it is considered unlikely that the shoe cover would have settled in the B recirculation loop piping. The miniature TV camera was lowered into the suction side of the A recirculation loop, and the piping was searched as far as the suction isolation valve shown on Figure 3. (This search included the internals of the isolation valve.) Additionally, the recirculation loop piping on either side of the recirculation pump was isolated and drained. A fiber-optic tool was inserted through blanked flanges to search the piping on the suction side of the pump. Figure 3 shows the piping which was inspected.

The final phase of the in-vessel search involved removing six fuel support castings and six control rod guide tubes to search below the core support plate. The miniature TV camera was lowered through the core support plate in each of the holes marked on Figure 4. The lighting and camera resolution would have allowed positive identification of any foreign objects the size of a shoe cover for a minimum of two guide tubes in any direction. Consequently, the area shaded on Figure 4 is considered to have been searched. During this phase of the search, binoculars were used to inspect the flow holes in the fuel support castings. At least two out of the four flow holes in each casting were inspected, and no indication of the shoe cover or any portions of it were found.

B. Out-of-Vessel Search

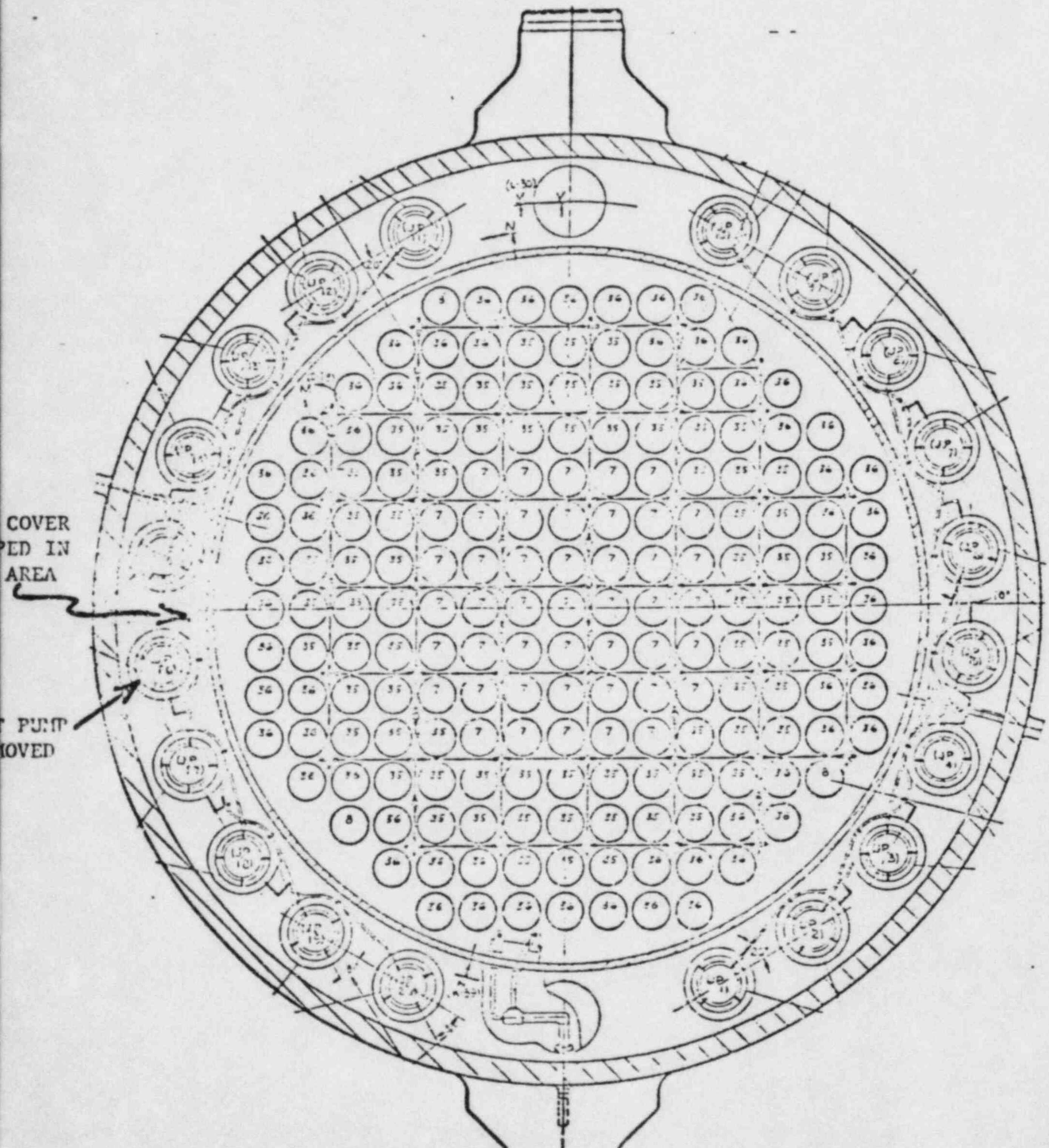
The out-of-vessel search concentrated in four areas. One of these was the RHR piping and heat exchangers on the B and D RHR loop. The heat exchangers were inspected by entering the fiber-optic through a thermal-well on the inlet side of the heat exchanger. This allowed the area in the heat exchanger up to the first baffle to be inspected. The bottom head was also removed on the B heat exchanger but no additional areas could be seen. The piping on either side of the B and D RHR pumps was also inspected using the fiber-optic tool. Drain lines on the suction and discharge piping were used for access. No indication of the shoe cover or any portions of it were found in the section of RHR piping which could be inspected.

The second area searched was the moisture separator which had been moved from the vessel to the storage area after the shoe cover was dropped. Because of its location, a closeup visual inspection was possible and was conducted by several different people to ensure a thorough search.

The fuel pool was searched because of the possibility that the shoe cover could have been transported to pool by a fuel assembly during the unloading of the core. The fuel was sipped, the lower tie plates were drilled and inspected, and the fuel storage locations were shuffled during the outage. The lower tie plates of the seven undrilled fuel assemblies being returned to the vessel for the next cycle were also inspected. It is considered a remote possibility that the shoe cover could have escaped detection in the fuel pool.

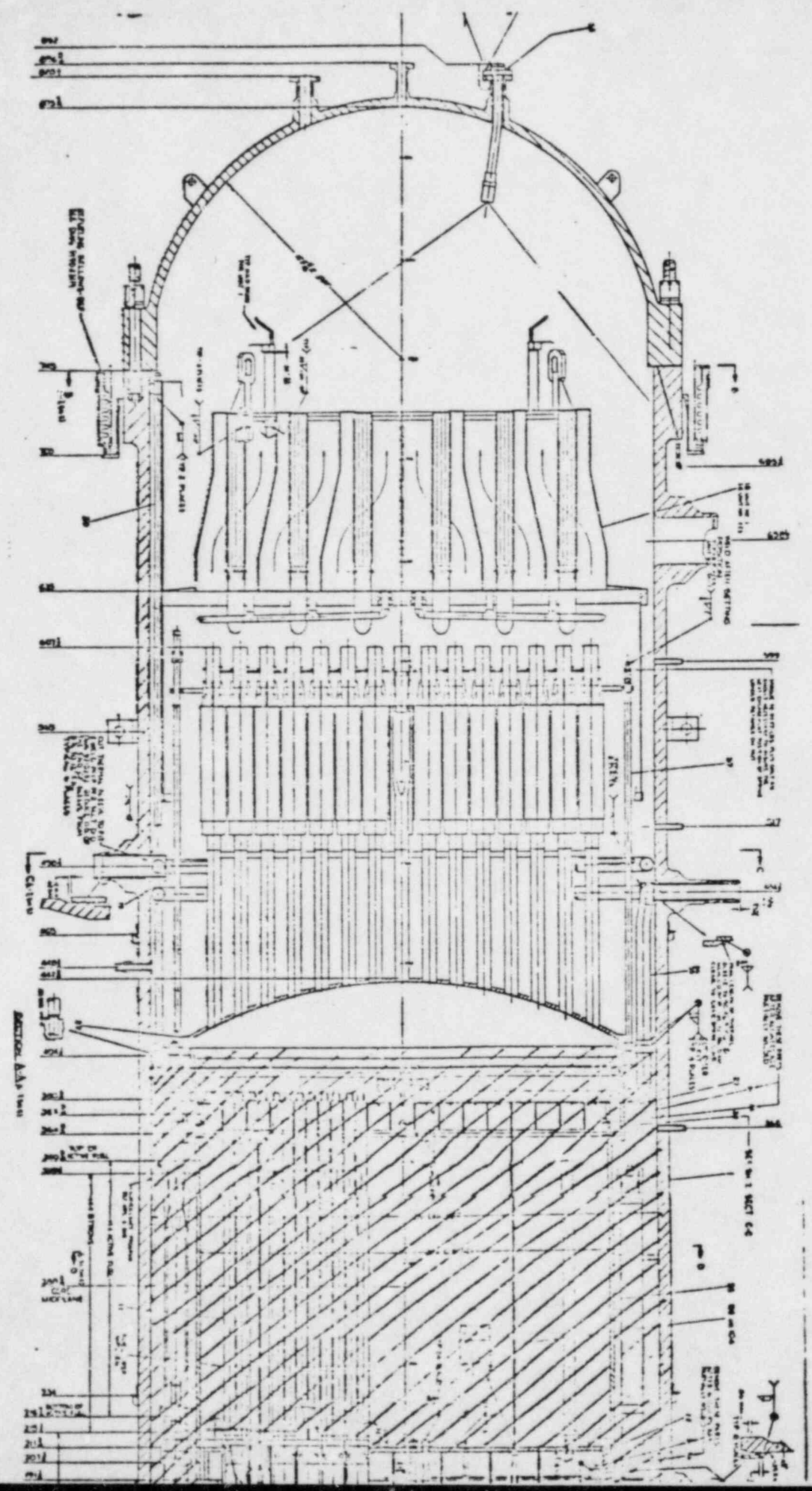
The final area searched outside the vessel was the equipment drain sump in the drywell. Drains from the vessel during maintenance and during draining and flushing of the A recirculation loop piping were directed to this sump, but inspection of the sump and the strainer on the suction of the sump pumps revealed no indication of the rubber shoe cover.

"A" RECIRCULATION LOOP SUCTION




"B" RECIRCULATION LOOP SUCTION

**FIGURE 1: CROSS-SECTION OF REACTOR VESSEL**



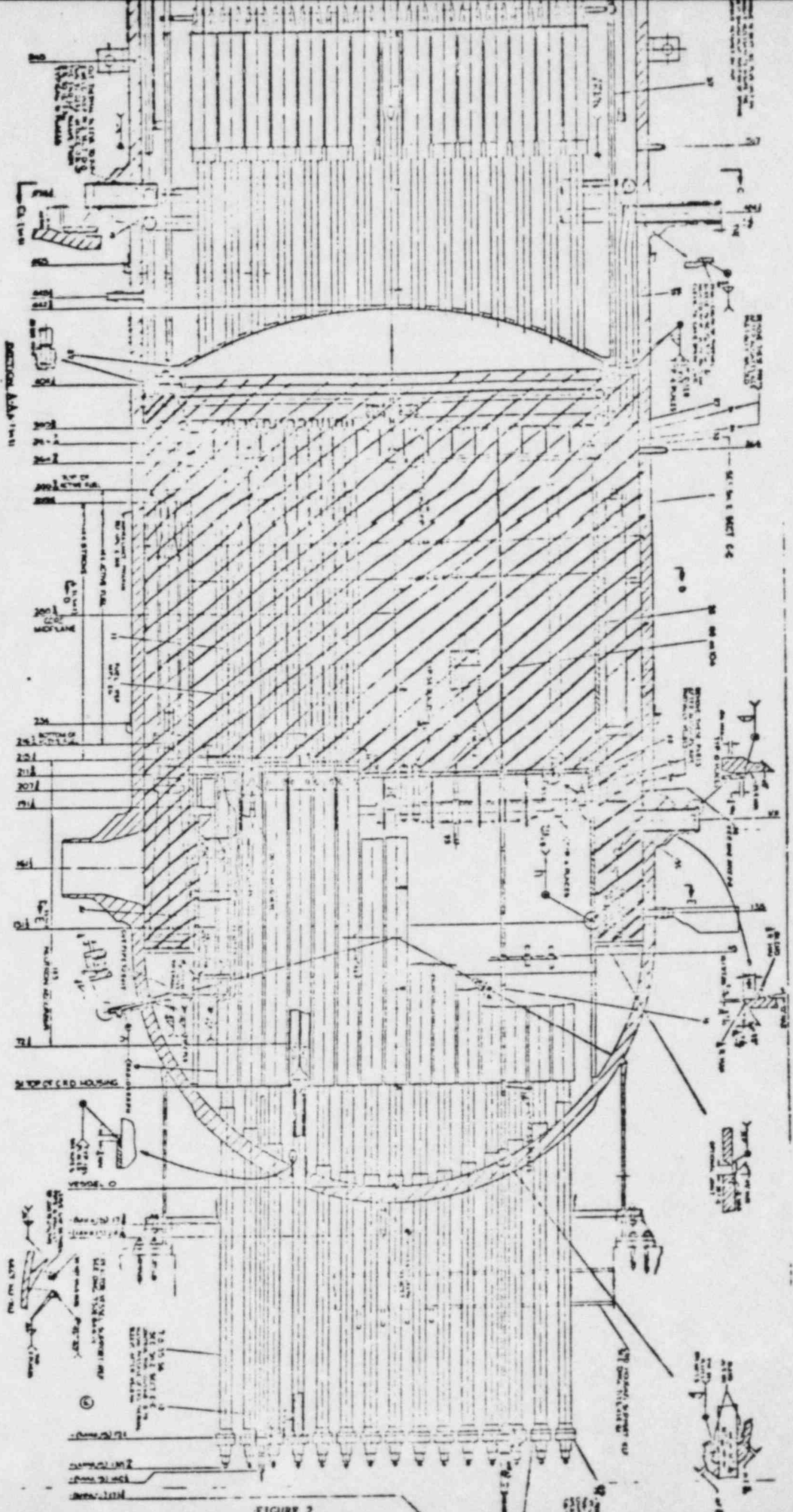
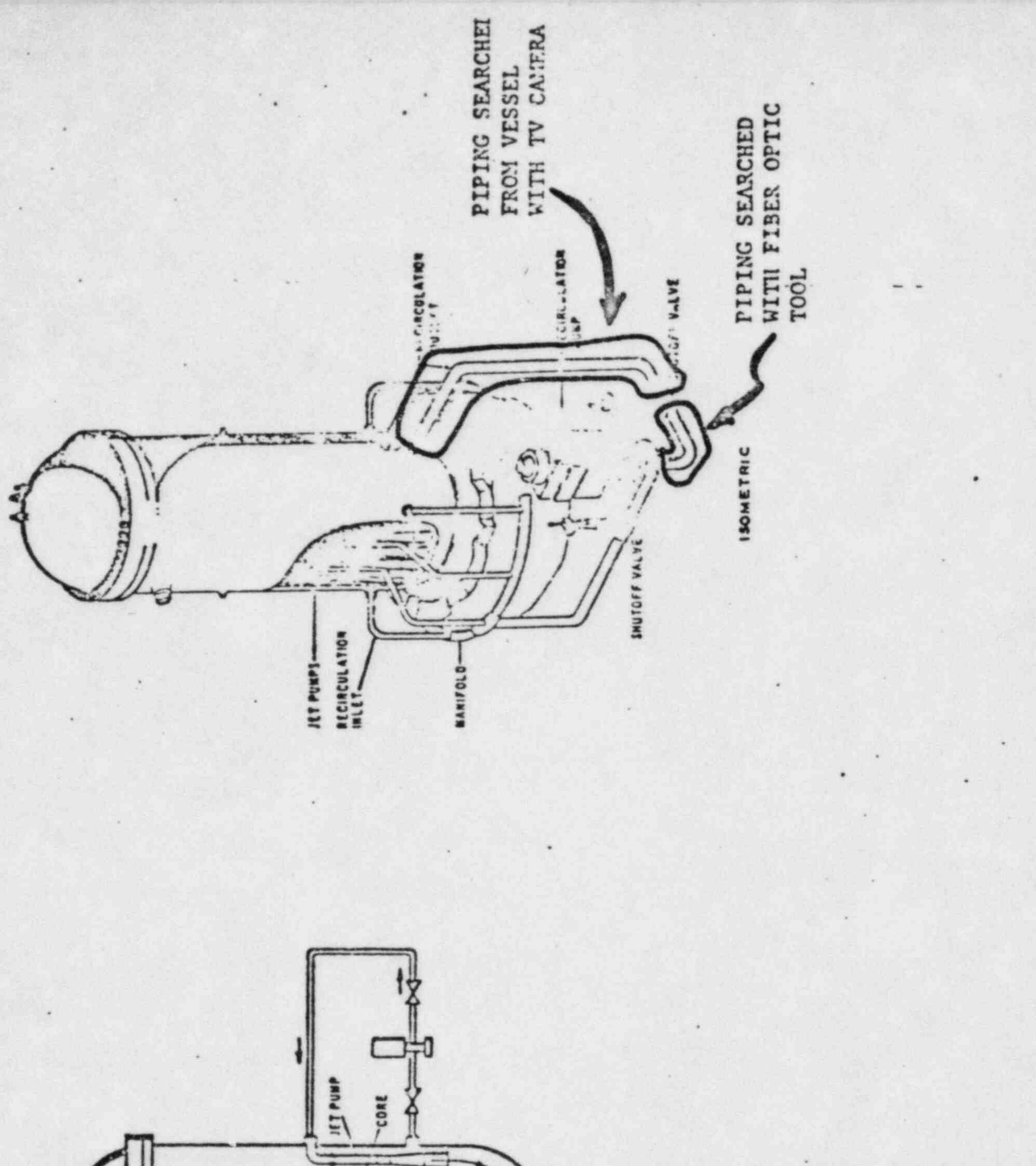
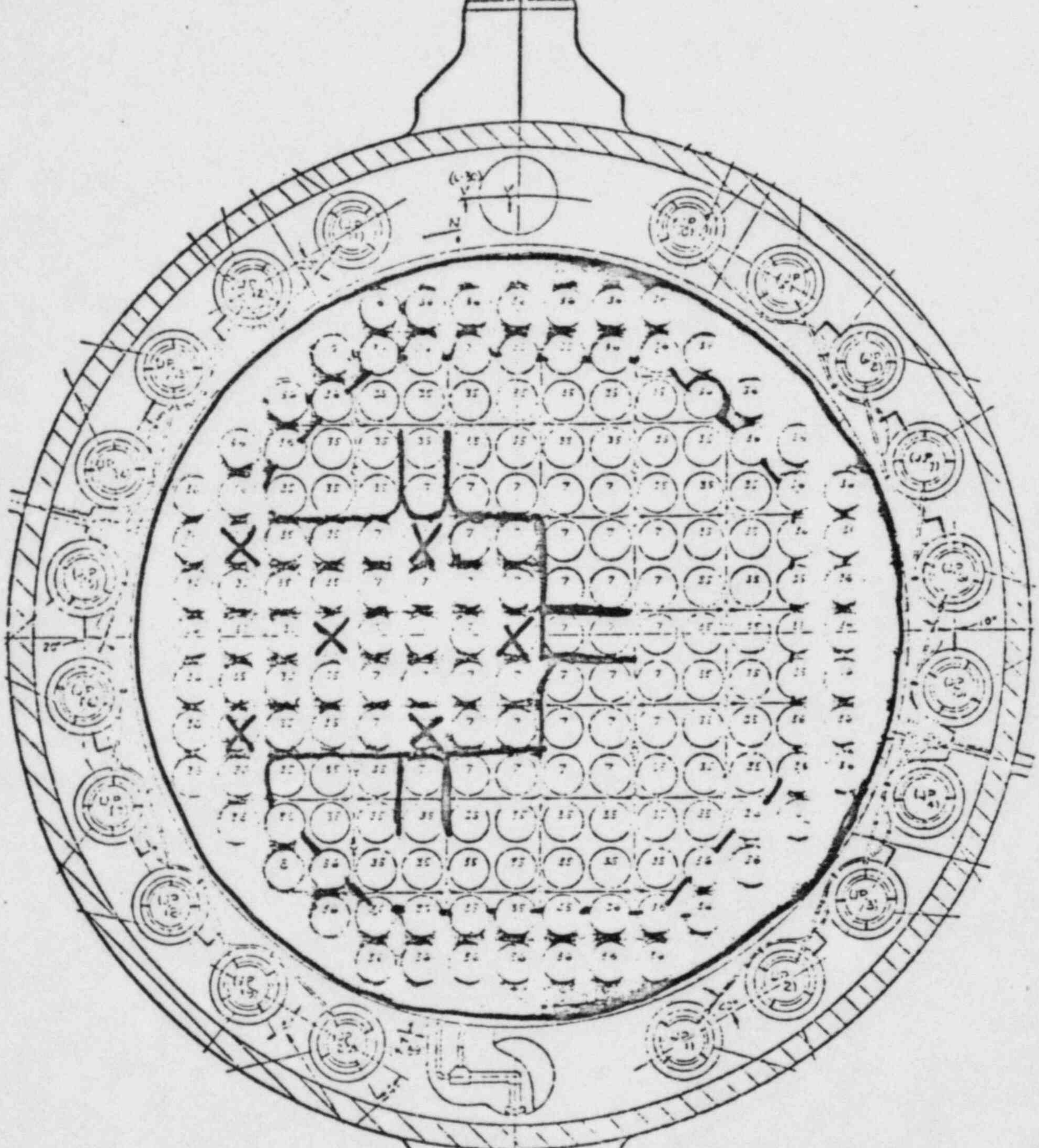



FIGURE 2




BROWNS FERRY NUCLEAR PLANT
FINAL SAFETY ANALYSIS REPORT



X - CONTROL ROD GUIDE
TUBES REMOVED

FIGURE 4

Attachment 2

GENERAL ELECTRIC

INSTALLATION AND SERVICE ENGINEERING DEPARTMENT

GENERAL ELECTRIC COMPANY . . . . . . 832 GEORGIA AVENUE
CHATTANOOGA, TENNESSEE 37402. Phone (615) 894-2550

G-ER-7-166

cc: J.G. Dewease
H.J. Green
D.R. Patterson

December 22, 1977

Mr. L. M. Mills, Chief
Regulatory Branch
Tennessee Valley Authority
303 Power Building
Chattanooga, TN 37401

SUBJECT: LOST PIECE ANALYSIS FOR BROWNS FERRY UNIT 1

Dear Mr. Mills:

This transmits our report "Safety Analysis - Lost Rubber Shoe Cover in the Browns Ferry Unit 1 Vessel," which incorporates TVA's comments.

A back-up copy of this report has been telecopied to your office.

Please call us if you have any questions.

Very truly yours,

for A. L. Vast
Service Manager - Nuclear

ALV:VGK:law

Enclosure

DEC 1977

## SAFETY ANALYSIS

## LOST RUBBER SHOE COVER IN THE

## BROWNS FERRY UNIT 1 VESSEL

### 1.0 BACKGROUND

During the 1977 refueling outage of the Browns Ferry Unit 1 Plant, a rubber shoe cover was inadvertently dropped into the RPV in the jet pump region. Repeated recovery attempts have failed to retrieve the shoe cover. Since the specific gravity of the shoe cover is only slightly higher than that of water, there is a significant probability that the circulation flow which is maintained during a refueling outage has carried the shoe cover into the recirculation system. It can be further postulated that the cover then passed through an operating recirculation pump where it was probably torn into several pieces.

### 2.0 LOST PART DESCRIPTION

The lost shoe covering was made by Tingley Rubber Co., South Plainfield, New Jersey.

The shoe covers tested were a composite of several materials including approximately: equal parts natural rubber and carbon black with 2% sulfur added for vulcanization and crosslinking.

### 3.0 CHEMICAL AND BEHAVIOR ANALYSIS

The natural rubber which is a major component of the shoe cover, has the molecular formula of $C_5H_8$ and is basically polymerized isoprene with a structure of $[-CH_2\ C\ (CH_3) = CHCH_2-]_x$ and a molecular weight of $\sim 10^6$, that is crosslinked by sulfur between chains (vulcanized). About 1-3% sulfur is used to give soft rubber--etc., properties, 22-35% sulfur is used to make hard rubber--rubbers vulcanized with intermediate amounts of sulfur are intractable and of no value. (Reference 1) Destructive distillation of natural rubber yields isoprine and other compounds. An analysis of the covering revealed 0% fluorine, 1.23% chlorine, and 2.39% sulfur.

a. Corrosion and Other Chemical Action

The addition of 1-2 grams of Chlorine to the reactor water will have an insignificant effect on reactor water chemistry. Under reactor operating conditions, the shoe cover should eventually decompose, probably into isoprene, methane, isopentane, (with radiolytic $H_2$) or similar compounds. The products of decomposition appear to be relatively innocuous and should have an insignificant effect on Reactor Water Chemistry. The small physical amount of material present (168 grams, 6 oz.) and the lack of fluorides or significant amount of chlorides tend to reinforce the conclusion that no significant effect on reactor water chemistry will result from the shoe cover in its initial state or the decomposition products.

b. Autoclave Testing

Samples from a rubber shoe cover were exposed in an autoclave at 500°F for 24, 26.5, 38 and 64.5 hours. These samples removed from the autoclave at about 200°F were chewy but had no tensile strength. The small tensile test specimens and strips had broken off their holders and had fallen to the bottom of the autoclave. These broken samples could not be removed until cooled to room temperature due to lack of tensile strength. The whole shoe samples had broken apart considerably.

Initially, samples were autoclaved at 550°F for various times up to 65 hours. These samples were also removed at 200°F and exhibited the same properties as those autoclaved at 500°F.

c. Radiation Resistance

A literature survey (references 2, 3, 4) indicates that of the elastomers, natural rubber is amongst the most radiation resistant and butyl rubber the least. Figures 1 and 2 show relative mechanical properties of these materials vs. exposure levels (rads). Radiation exposure is effective in increasing the hardness and lowering the ductility of this type of material.

Blending of two elastomeric materials generally results in a radiation resistance slightly higher than what would be expected from the weighted average of the two materials. Addition of carbon black will also improve radiation resistance. No information was found on the effects of adding calcium carbonate or zinc oxide to clastomers. Based on the limited information available on this material, the literature would predict radiation resistance similar to or slightly better than that encountered with natural rubber.

Two pieces from a rubber shoe cover have been exposed in the gamma pit at Vallecitos Nuclear Center (VNC). One piece was previously autoclaved at 550°F for 3 days. The second piece was as received. These pieces have now received 6.3X10$^8$ rads. The sample which was previously autoclaved has undergone virtually no change. The as-received sample has become substantially more brittle, harder and less-elastic, but the swelling noted due to exposure to 550°F water is absent.

In summary, exposure to high temperature water appears to be far more effective than exposure to radiation in degrading the properties of this material. Both conditions cause cross linking to occur.

d. Flow Tests

The purpose of these tests was to observe the effect of flow on a rubber shoe cover in a reactor fuel assembly with inlet orifice and lower tie plate. Five tests were run and will be discussed sequentially. A schematic of the test facility is shown in Figures 3 and 4.

Test #1 employed a whole shoe cover autoclaved for 64 hours at 550°F. It was placed upstream of the inlet orifice with 60°F water and flow was increased to 90 gpm. The pressure differential between the inlet pipe and the fuel channel was about 4 psi. After 70 minutes of testing, the sole and heel had not broken up to go through the lower tie plate. After 2.75 hours about 3 pieces of rubber of less than 1 inch diameter were found at the simulated core inlet plenum; about 55 pieces (largest piece 1.6" x 1") were found inside the fuel support casting. The approximate weight of the recoverable leftovers was 46.4 grams.

Test #2 used a whole shoe cover autoclaved for 38 hours at 500°F. The test was run at cooled down conditions (60°F). While coming up to the desired flow rate of 65 gpm, the pressure differential surged from 1.7 to 25 psi. Five minutes later, the pressure differential was 3.2 psi; at 27 minutes, it was down to 3.09 psi. The test was stopped at 55 minutes. The shoe had broken into pieces which had been plastered against the lower tie plate. About 90% of the total flow area of the lower tie plate was plugged.

Test #3 left the test #2 samples plastered on the lower tie plate. More 38-hour 500°F autoclaved samples were added to completely cover the grid of the lower tie plate in a shingle overlapping manner. This amounted to a total of about 1½ shoe covers on the lower tie plate. Volumetric flow rate vs. pressure differential curves are plotted for the plugged and unplugged conditions in Figure 5. About 70% of the flow could reach the fuel channel even if the lower tie plate was completely covered with pieces of autoclaved rubber at cold (60°F) conditions.

Test #4 was run at hot (176°-192°F) conditions, since it was observed that an autoclaved shoe was weaker at 200°F than 60°F. A 26.5 hour 500°F autoclaved sample was tested and the flow rate and pressure differentials are shown on Figure 6. Flow was increased gradually at flow rates equal to or lower than reactor flows, i.e., 30 minutes at 2 pi and 30 minutes at 4 psi. The volumetric flow rate versus pressure differential characteristic curves, with and without the shoe, intercept at 4 psi, as shown on Figure 6. The intercept indicates the point at which the shoe cover was for all practical purposes disintegrated.

Test #5 used a 24 hour 500°F autoclaved sample cooled to 180°F. The maximum flow rate was 100 gpm and the sample was removed after 2 hours. The shoe was completely broken up and only about 4 grams of material was observed on the lower tie plate. After 2 hours there was no measurable effect on flow or pressure differential due to the presence of the shoe, as shown on Figure 7.

The results of all the tests indicate that a shoe that has been exposed to 500°F water for over 24 hours will be broken up into small pieces at temperature greater than 170°F and flows and pressure drops similar to those experienced in the Browns Ferry-1 reactor.

## 4.0 POSSIBLE INTERFERENCE WITH CONTROL ROD OPERATION

In the event that the shoe cover has fallen into the core region, it could have landed on a fuel assembly, the top guide, into an empty fuel assembly position or on a control blade located between channels from where it may have subsequently fallen onto the core plate. If the shoe cover is located on the top surface of a fuel assembly, top guide or core plate, it would not be an immediate concern with respect to control rod operation. If an adjacent fuel support casting were removed, the shoe cover could fall into the control rod guide tube and possibly lodge between the velocity limiter and the guide tube. If the shoe cover dropped into an empty fuel assembly location, it is possible that it could have dropped through the gaps between the control blade and the support casting and passed into and became lodged in the guide tube. Increased friction may be observed susequently during control rod movement. However, the scram force is much greater than any postulated increased resistance from shoe friction; and the scram function of the rod would not be affected.

## 5.0 POTENTIAL FOR EQUIPMENT DAMAGE OR MALFUNCTION

No potential for damage to either the reactor internals or recirc loop components other than that discussed in Section 6, is postulated due to the pliable nature of the shoe cover prior to carbonization. Subsequent to carbonization of the shoe cover, no potential for such damage exits due to the frangible nature of the part.

## 6.0 POTENTIAL FOR FLOW BLOCKAGE

The concern associated with the lost piece is that associated with the potential for fuel bundle flow blockage and subsequent fuel damage. A detailed study of flow blockage in a BWR has been made in a GE report (References 5 and 6). Based on the results of tests and analysis given in Reference 5, the effect of flow blockage on bundle flow is determined. Using those results, the following statements can be made:

a. It was estimated that it would take more than an approximately 80% inlet area blockage at 100% power to cause a Minimum Critical Power Ratio (MCPR)* less than 1.0; therefore, no fuel rod damage would occur unless more than an 80% blockage occurs.

b. If the blockage were more than 80%, clad melt and fuel crumbling could occur. This would lead to high radiation sensed by the main steam line radiation monitors, which would scram and isolate the reactor. Off-site doses remain less than 10CFR20 limits (Ref. 5).

Based on the information concerning the size of the lost piece, the following conclusions are drawn:

(1) If the piece found its way intact into the lower plenum, the fluid velocities could be high enough to sweep it up toward the fuel bundles.

(2) If the intact piece were swept up toward the fuel bundles (central orifice diameter = 2.211 inch, peripheral orifice diameter = 1.469 inch), it could block the orifice sufficiently (i.e. more than 80%) to cause a boiling transition to occur in that bundle.

(3) If the blockage were more than 80%, clad melt and fuel crumbling could occur. This would lead to high radiation sensed by the main steam line radiation monitors, which would scram and isolate the reactor. Off-site doses remain less than 10CFR20 limits.

(4) No damage would occur to any bundle adjacent to the bundle with the flow blocked.

Therefore, it can be concluded that steps should be taken to insure that the shoe will be disintegrated prior to high power operation. If these steps are taken, the shoe will not pose a safety problem.

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* Reference 5 presented the results in terms of Minimum Critical Heat Flux Ratio (MCHFR) and determined it would take more than 90% inlet area blockage to cause a MCHFR <1.0.

Until the lost rubber shoe cover has disintegrated, the bundle power limit will be 0.6 Mwt. This low bundle power, approximately 10% of the limiting bundle power during normal operation, will insure that boiling transition will be avoided and saturated flow conditions maintained in the unlikely event of a complete flow blockage. As discussed in the flow blockage licensing topical report (Reference 6), the most severe potential event is the complete flow blockage at either the fuel support piece orifice or at the fuel assembly lower tie plate grid. Even during the almost incredible event of a complete flow blockage at the lower tie plate grid, at least $3 \times 10^3$ lbm/Hr of coolant flow will be available through the channel lower tie plate interface. An additional small amount of coolant will "overflow" from the plenum above the core. As can be seen in Figures 3-27, 28 of the GETAB licensing topical report, NEDE-10958-PA, at a minimum flow of $3 \times 10^3$ lbm/Hr ($G \sim .028 \times 10^6$/Hr-ft$^2$), boiling transition is not expected to occur for bundle powers less than 0.85 MWt. If no credit is taken for counter current flow, saturated flow conditions will always be maintained for bundle powers less than 0.6 MWt. Note that in the unlikely event of a complete flow blockage, bundle power will further be decreased due to loss of neutron moderation. The 0.6 MWt bundle power limit therefore conservatively insures that no fuel damage will result from operation with the rubber shoe cover lost in the reactor vessel.

## 7.0 CONCLUSIONS

No deleterious effects on water chemistry or any other chemical property are expected from the presence of the shoe. Any possible interference with control rod motion could be identified with control rod drive friction tests. Possible flow blockage will not pose a safety problem if it has disintegrated.

In order to insure that the shoe has been broken into small pieces, it will be necessary to bring the reactor up to operating temperature for at least 24 hours at flows exceeding those used in the flow tests described in these analyses. A 100 gpm flow rate in the test facility is equivalent to about 50% core flow in the reactor. Before this condition has been achieved, precautions should be taken to prevent boiling transition that could result from possible flow blockage.

In order to prevent boiling transition from flow blockage during the time it takes to disintegrate the shoe, the Browns Ferry 1 reactor should be operated with a maximum bundle power no higher than 0.6 MWt.

Therefore, if the precautions given supra are taken, the presence of the shoe in the reactor vessel will not compromise safe reactor operation.

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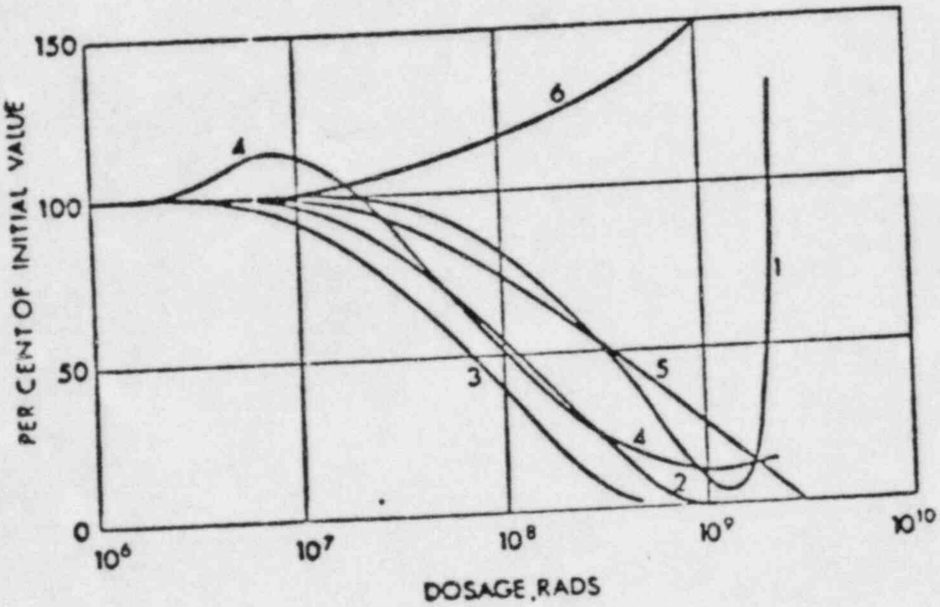
5. NEDO-10174, "Consequences of a Postulated Flow Blockage Incident in a Boiling Water Reactor", G. J. Scatena, May 1970.

6. NEDO-10174, Revision 1, "Consequences of a Postulated Flow Blockage Incident in a Boiling Water Reactor", October 1977.

Natural Elastomer

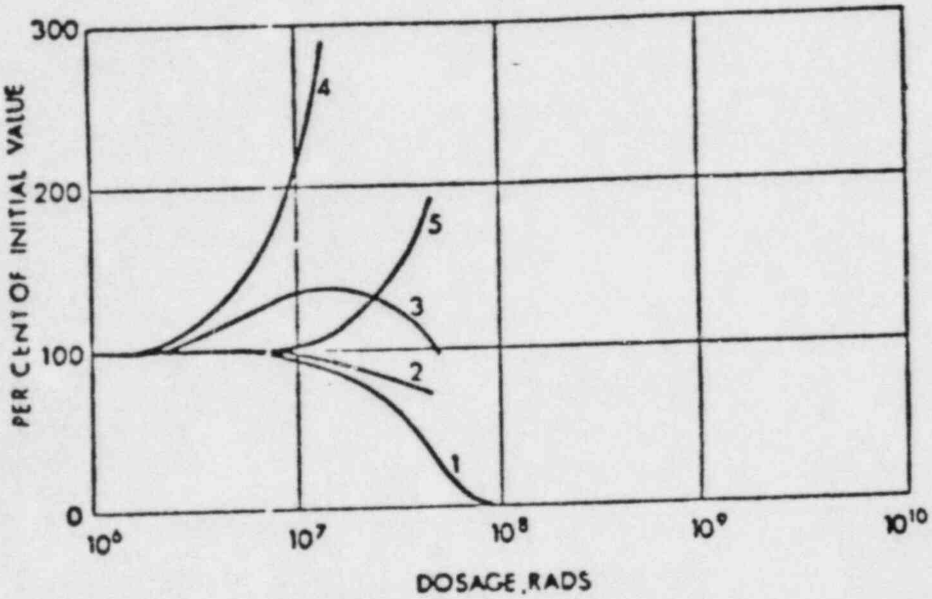



| PROPERTY | INITIAL VALUE |
|---|---|
| 1 TENSILE STRENGTH | $182 kg/cm^2$ |
| 2 ELONGATION | 420% |
| 3 SET AT BREAK | 32% |
| 4 COMPRESSION SET | 13% |
| 5 STRAIN AT $28 kg/cm^2$ | 30% |
| 6 DUROMETER HARDNESS | 60 |

NATURAL RUBBER – "POLYISOPRENE"

Fig. 1

Butyl Elastomer




| PROPERTY | INITIAL VALUE |
|---|---|
| 1 TENSILE STRENGTH | 77 $kg/cm^2$ |
| 2 ELONGATION | 525% |
| 3 SET AT BREAK | 35% |
| 4 COMPRESSION SET | 72% |
| 5 STRAIN AT 28 $kg/cm^2$ | 31% |

GR-150-"ISOBUTYLENE - DIENE COPOLYMER"

Fig. 2

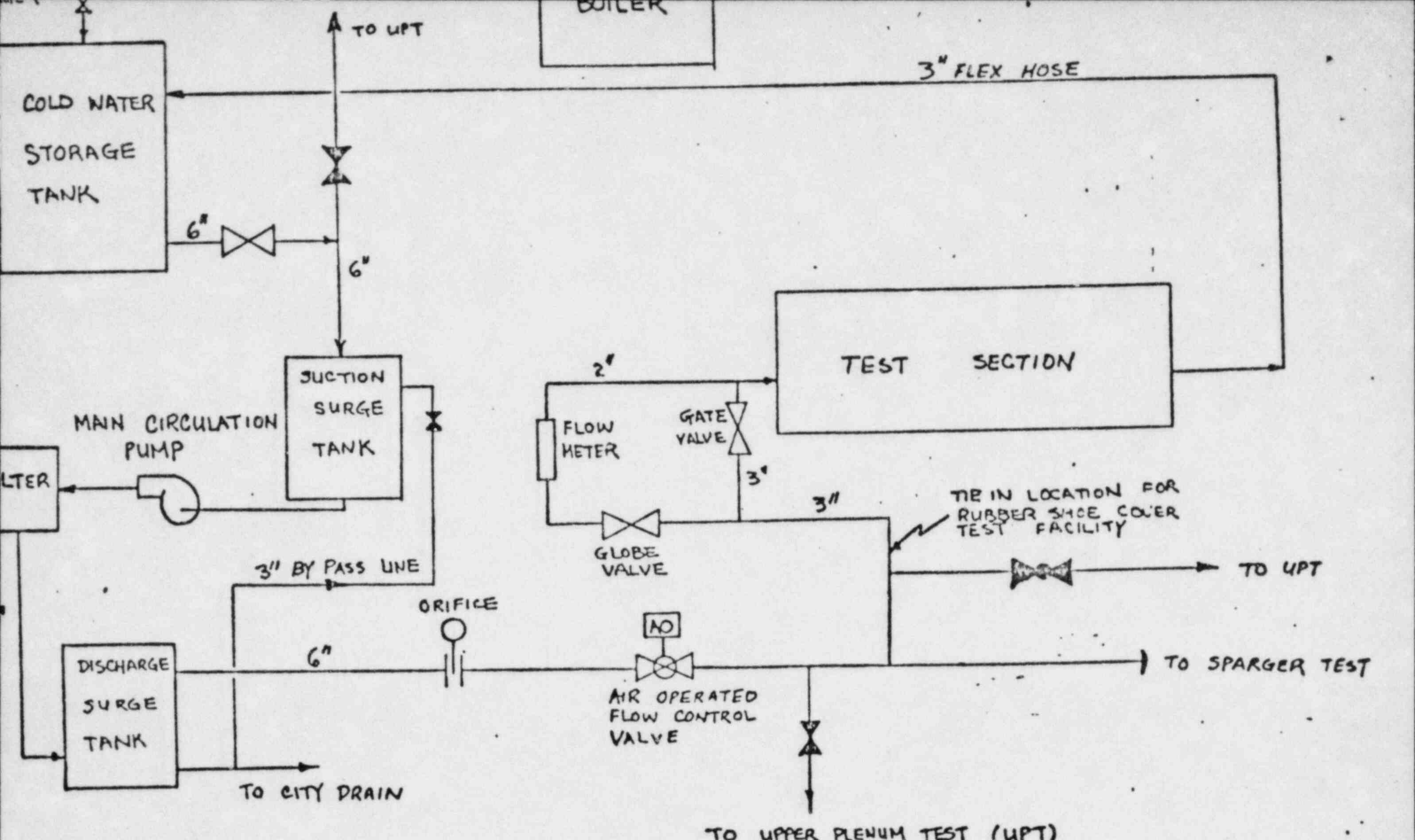
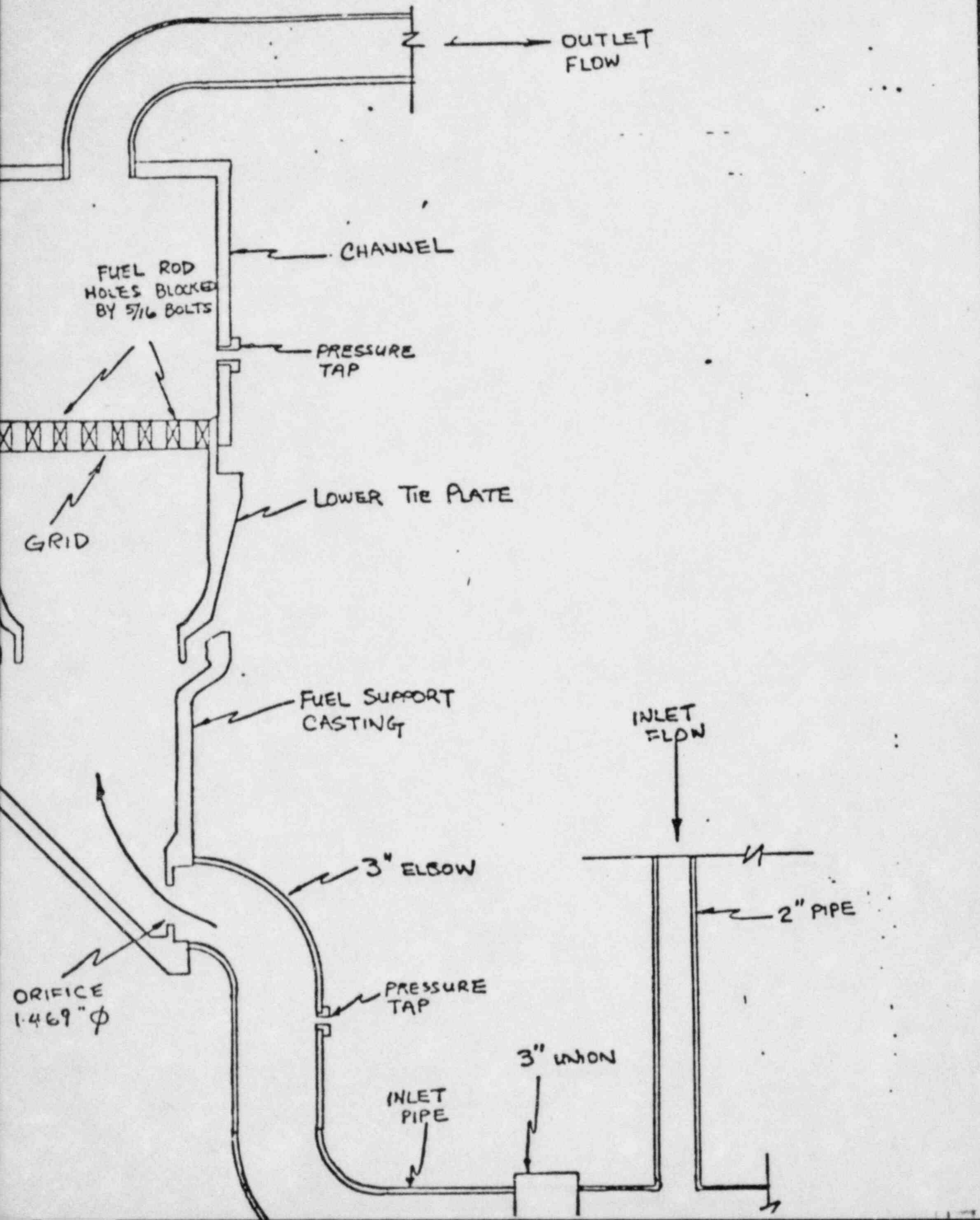



FIG. 3 SCHEMATIC OF TEST FACILITY

FIG. 4 SCHEMATIC OF TEST SECTION



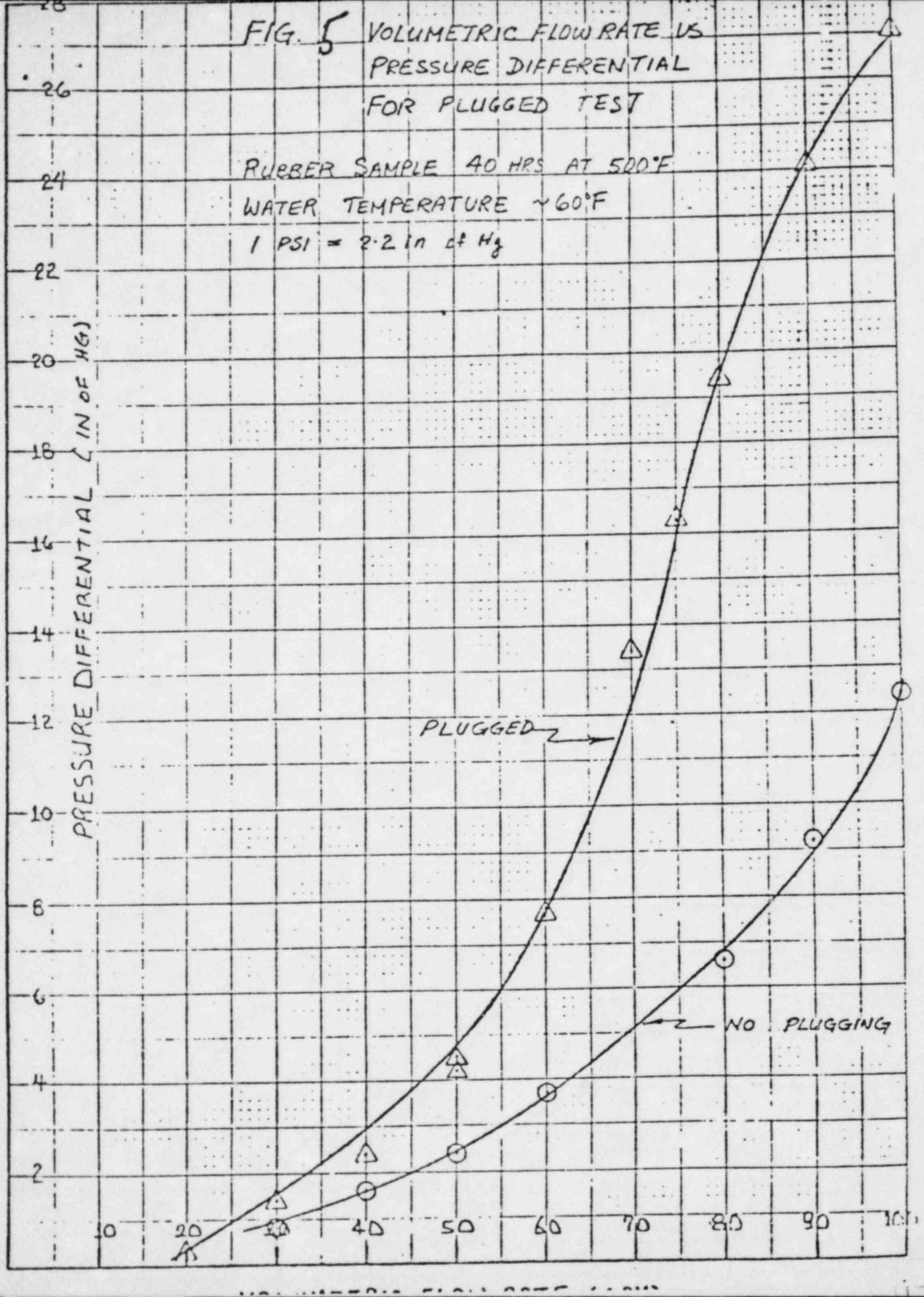


FIG. 5 VOLUMETRIC FLOW RATE VS PRESSURE DIFFERENTIAL FOR PLUGGED TEST
RUBBER SAMPLE 40 HRS AT 500°F
WATER TEMPERATURE ~60°F
1 PSI = 2.2 in of Hg
PRESSURE DIFFERENTIAL (IN OF HG)
PLUGGED
NO PLUGGING
26
24
22
20
18
16
14
12
10
8
6
4
2
10
20
40
50
60
70
80
90

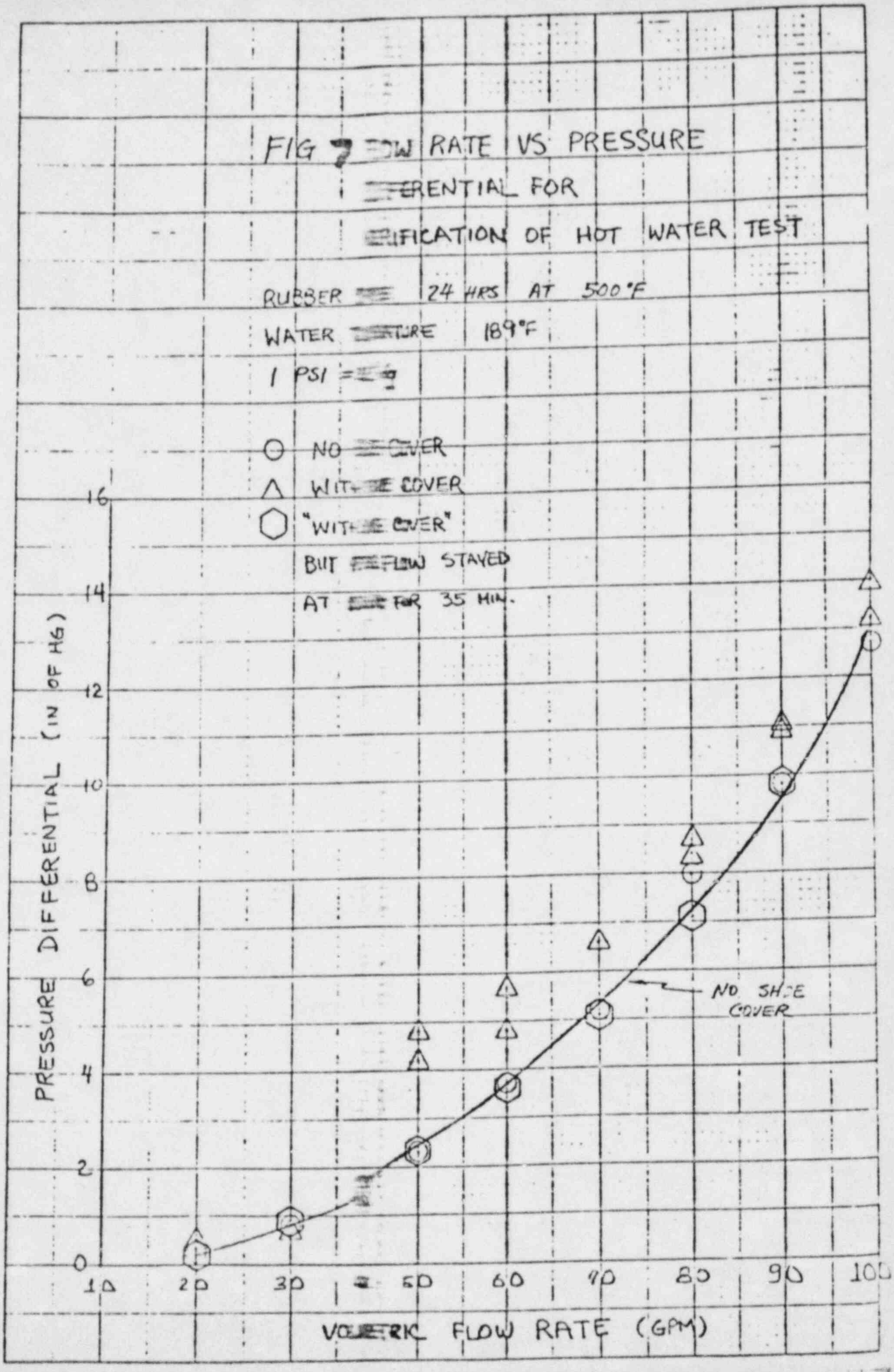


FIG 7 W RATE VS PRESSURE
ERENTIAL FOR
IFICATION OF HOT WATER TEST
RUBBER 24 HRS AT 500°F
WATER 189°F
1 PSI =
NO COVER
WITH COVER
"WITH COVER"
BUT FLOW STAYED
AT FOR 35 MIN.
NO SH E COVER
PRESSURE DIFFERENTIAL (IN OF HG)
0
2
4
6
8
10
12
14
16
10
20
30
50
60
70
80
90
100
FLOW RATE (GPM)

# ATTACHMENT 3

Question No. 1--Discuss the similarity between the test loop conditions and actual reactor conditions (especially pressure).

Answer No. 1--The test loop did not provide for parallel flow paths. Complete blockage at the orifice or the tie plate could have resulted in a $\Delta P$ equal to the shutoff head of the test pump. However, the maximum $\Delta P$ across the test setup was administratively controlled during the test. During the flow testing of both the 24-hour and 26.5-hour shoe samples and during the blockage tests, flow was increased very slowly from 0 in increments of 10 gpm or less. At no time did the $\Delta P$ increase beyond $\Delta P$'s achievable in the plant. There was at no time any evidence of complete blockage in either the orifice or tie plate. If complete blockage did occur, this blockage was cleared without any significant rise in $\Delta P$. For the 26.5-hour sample, a review of figure 6 of GE's safety analysis report (included in this package as an earlier attachment) implies that the sample was forced through the orifice at about 20 gpm with a $\Delta P$ of about .25 psi. For the 24-hour sample (figure 7 of same report), about 50 gpm was required for a $\Delta P$ of about 2 psi.

Question No. 2--Correlate the 0.6 MWt bundle power limit to a gross percent core power level.

Answer No. 2--A boundary peaking factor analysis was performed by GE using their standard methods, assumptions, and conservatisms as used in safety analysis calculations, such as rod drops. The most limiting peaking factor was calculated for the Browns Ferry unit 1 control rod withdrawal sequence. The most limiting peaking factor for the sequence was then assumed to occur at the highest power level. This analysis indicates that if gross core power does not exceed 5 percent of rated thermal power, the maximum bundle power will not exceed 0.6 MWt.

Question No. 3--If TVA does not plan to cool down to 200° F after the soak period at 500° F, quote an expert, text, or provide assurance that operation at 500° F is conservative.

Answer No. 3--TVA intuitively feels that continued operation at 500° F without a cooldown period is conservative. Further, the technical staff of the Goodyear Tire and Rubber Company has stated that the rubber shoe cover material disintegrates when it is extended beyond its curing state (about 400° F). Their opinion is that it will disintegrate more completely or at least as rapidly at 500° F than it would if cooled back down to 200° F.

TDK:MCB
1/3/78