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ENCLOSURE

An Evaluation of the Post-LOCA Boric Acid Concentration Control System for Oconee Reactors.....(1 cy encl rec'd)

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WILLIAM O. PARKER, JR.
VICE PRESIDENT
STEAM PRODUCTION

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August 6, 1976

Regulatory Docket File

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Mr. B. C. Rusche
Director of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. A. Schwencer

Re: Oconee Nuclear Station
Docket Nos. 50-269, -270, -287

Dear Mr. Rusche:

In my letter of December 18, 1975 a description of a proposed method for assuring that sufficient core circulation exists to avoid boron concentration buildup that might adversely affect long-term cooling capability was presented. In your letter of February 17, 1976 it was stated that review of our proposal indicated that the boron concentration buildup would be limited to an acceptable value. It was further stated, however, that the reactor operator must be provided positive indication of flow through the affected lines. If this positive flow indication could not be provided prior to Oconee 1, Cycle 3 operation, your letter also stated that a preoperational test should be conducted to demonstrate sufficient flow through these lines under post-LOCA conditions.

In our response dated March 4, 1976 a commitment was made to test the boron dilution drain lines prior to resuming operation. This functional test has now been satisfactorily performed on both Oconee 1 and Oconee 2, verifying the design of the system. With regard to the future installation of flow indication equipment, it was stated that this matter is being pursued with the intention of installing an acceptable system prior to Cycle 4 operation. As the result of our continued study of this matter, the attached "Evaluation of the Post-LOCA Boric Acid Concentration Control System for Oconee Reactors" has been prepared. This evaluation provides a description of the boron dilution system and an evaluation of the need for flow instrumentation and an assessment of the functional performance of the system. It is our conclusion that flow indication is not necessary, and in fact, may not be prudent.

8329

The boron dilution system will be installed on Oconee 3 during the impending refueling outage. This system will be functionally tested in a manner similar to that performed on Oconee 1 and 2. We believe that your review of the attached report will confirm our conclusion that a positive flow indication system is not required. It is requested that you provide your concurrence with this approach by January 1, 1977 in order that planning for the Oconee 1, Cycle 4 refueling outage may be completed.

Very truly yours,

William O. Parker, Jr.

MST:vr
Attachment

AN EVALUATION OF THE POST-LOCA BORIC ACID CONCENTRATION CONTROL SYSTEM FOR OCONEE REACTORS

1. INTRODUCTION

One of the criteria regarding the long-term cooling capability of a reactor during post-LOCA conditions is that the boric acid concentration in the core be kept within acceptable levels. In the absence of adequate core coolant circulation (either natural or forced circulation) the boric acid concentration in the core region might gradually increase with time. The Oconee units are designed to maintain a natural circulation flow path through the core during post-LOCA conditions, and this flow will prevent significant increase in the boric acid concentration in the core region. However, to provide positive assurance that the boric acid concentration will not occur, provisions have been made for Oconee reactors to incorporate a boron dilution system. This report describes the design of the system, evaluates the performance of the system for all postulated primary system pipe breaks, and describes the specific operator actions necessary to initiate the boron dilution and to verify the functional performance of the systems.

The system consists of redundant drain lines installed onto one of the reactor coolant hot leg nozzles, isolation valves, and associated instrumentation for control and position indication of the isolation valves. The drain lines provide a gravity flow path for the coolant to flow from the top of the core to the reactor building sump. The calculation of flow rates, taking into consideration the minimum available static driving head and all possible head losses, shows that these drain lines are capable of providing a minimum core flow in excess of 40 gpm in the post-LOCA long-term cooling environment. The predicted flow rates have been verified by measurement of the flow rates through these lines under simulated post-LOCA conditions of the reactor coolant system. Based on the analysis of the reactor system circulation and the time-varying boric acid concentration behavior during the long-term cooling phase, a core flow of 40 gpm will limit the boric acid concentration buildup to C/Co = 11, appreciably below the solubility limit (1).

A failure mode and effects analysis has been performed, and this analysis indicates that no single failure, including passive failures, can defeat the function of the system.

The post-LOCA course of the coolant flow within the reactor vessel is examined for the full spectrum of pipe breaks to demonstrate the effectiveness of the boron dilution system.

The matter of whether or not flow instrumentation would be required to assure the functional performance of the boron dilution system has been examined, and it is concluded that because of the passive nature and redundancy of the system such a flow instrumentation would be unnecessary. Furthermore, the operators can indeed determine the functional performance of the system with existing instrumentation by verifying the isolation valve position and the ECCS flow.

In summary, the boron dilution system for the Oconee units is an inherently simple, passive, reliable system that requires minimal operator action and is independent of, but complements, the normal ECCS system to provide long-term core cooling during a postulated LOCA.

2. DESCRIPTION OF THE BORON DILUTION SYSTEM

The Boron Dilution System, consisting of two drain lines installed onto the decay heat line, is a passive system which assists coolant flow through the core in a post-LOCA environment. The drain lines incorporate redundant electric motor-operated isolation valves to prevent inadvertent opening of the drain lines. These two drain lines are designed to provide flow rates through each line in excess of the minimum required core flow so that at least one line can permit the necessary flow in the event of a flow failure in the other line. The electrical power supplies for the isolation valves in each of the two flow paths are arranged such that a single electrical failure cannot affect both dilution paths.

Because of the difference in the decay heat line routing for Unit 1 from that for Units 2 and 3, the physical arrangement of the drain lines for Unit 1 is slightly different from that for Units 2 and 3.

For Unit 1, the decay heat line begins from the bottom of the hot leg nozzle at elevation 808' and continues downward to isolation valves LP-1 and LP-2, located in the horizontal run of the pipe at elevation 798' 6". A 3" pipe with isolation valves LP-103 and LP-104, installed onto the decay heat line at elevation 804' 6", serves as one of the drain lines (designated as drain line A). The other drain line (designated as drain line B) is an 8" pipe installed onto the decay heat line at elevation 798' 6" past LP-2. This 8" line is routed to the RB sump through isolation valve LP-105. When the isolation valves are opened, the reactor coolant will flow by the force of gravity from the hot leg to the RB sump through the decay heat line nozzle, the 3" piping, LP-103, and LP-104 for flow path A and through the decay heat line nozzle, LP-1, LP-2, and the 8" line through LP-105 for flow path B. The drain flow will be sustained as long as the water level within the reactor vessel is maintained above the bottom of the hot leg nozzle. Figure 1 shows a schematic drawing of the two drain lines for Unit 1.

Also for Units 2 and 3 drain line A, installed onto the decay heat line above LP-1, consists of a 3" line and two isolation valves (LP-103 and LP-104). Drain line B, however, is the existing decay heat line which allows gravity flow from the hot leg to the RB sump (or to the LPI pump suction) through the valves LP-1, LP-2, LP-3, LP-4 (Unit 2 only), and LP-19. Figure 2 shows a schematic drawing of the two drain lines applicable for Units 2 and 3.

The only equipment associated with the boron dilution system is the isolation valves. The valve operators and associated electrical cables are positioned above the post-LOCA water level in the containment, and are qualified for the post-LOCA environment. The controls of the isolation valves, including their position indications, are located in the applicable control rooms.

3. CALCULATION OF MINIMUM AVAILABLE FLOW RATE THROUGH THE DRAIN LINES

The magnitude of the flow rates that may be realized through the drain lines in a post-LOCA environment depends on the water level in the reactor core. The water level in the core, in turn, is determined by the type (location and size) of the break.

For a cold leg break, as far as the reactor vessel water level is concerned, the limiting break is the double-ended break at the cold leg nozzle on the reactor vessel side. The ECCS analysis (2) of this break has demonstrated that the entire core is quenched at less than 300 seconds and that the cladding temperature has decreased to T_{sat} at approximately 350 seconds. The LPI system maintains a constant downcomer water level corresponding to the bottom of the cold leg nozzles, and this provides a driving head to force core flow circulation. In the meantime, steam in the upper plenum is vented by the vent valves, equalizing the pressure in the upper plenum with that in the downcomer and allowing the fluid level in the core to rise to the level corresponding to the bottom of the cold leg nozzles, (i.e., 4" above the bottom of the hot leg nozzles). Any steam that remains in the core or upper plenum will be vented to the containment (or quenched by the water in the containment) as soon as the drain lines are open, thereby allowing the core water level to equalize with that in the downcomer. When the water from the top of the core begins to drain out through the drain lines, the core water level will be depleted and the drain flow decreased unless the downcomer water level is maintained; however, the LPI system has enough capacity to maintain the downcomer water level. Therefore, for a double-ended break at a cold leg nozzle on the reactor vessel side, the minimum water level in the core is 4" above the bottom of the hot legs (i.e., at elevation 808' 4"). For any other type of cold leg break, the post-LOCA water level in the core will be above elevation 808' 4". Since the core flooding nozzles are located above the hot leg and cold leg nozzles, in the event of a core flooding nozzle break, the post-LOCA water level in the core will be above the elevation 808' 4".

Similarly, for a hot leg break above the elbow on the reactor vessel side, it can be seen that the post-LOCA water level in the core will be above the elevation 808' 4". In the case of a double-ended break on the hot leg nozzle, the post-LOCA water level could be as low as 808', but for a hot leg break, no drain flow is required since the ECCS injection water flows through the core removing the sensible heat in the core and exiting through the break - thus acting as a forced circulation flow path. Because of the forced circulation nature of the system flow and the fact that abundant ECCS flow is available, the boric acid concentration buildup will not occur for any hot leg breaks. Therefore, for drain flow calculation, the limiting post-LOCA water level in the core is at elevation 808' 4".

The flow rate through each of the drain lines may be calculated from the equation:

$$Q = 19.65\ d^2\sqrt{\frac{h}{K}},$$

where Q(gpm) is the flow rate, d(in) is the diameter of the drain pipe, h(ft) is the static head (i.e., elevation difference between the water level in the hot leg and the discharge point of the drain line), and K is the total head loss coefficient for the flow path. Using as-installed dimensions and characteristics of the piping and values, the flow rate through drain line A is calculated to be approximately 100 gpm.

The static head for drain line B is the elevation difference between the water level with the hot leg (808' 4") and the post-LOCA water level in the containment (795' 9-5/8"). Because of this larger static head and the larger size of the piping in this line, a flow rate in excess of 500 gpm can be realized through this flow path.

4. EXPERIMENTAL VERIFICATION OF MINIMAL DRAIN FLOW THROUGH THE LINES

In an effort to demonstrate the adequacy of the design of the boron dilution system to permit the necessary drain flow, the drain flow through the limiting flow path (drain line A) has been measured under simulated post-LOCA conditions of the reactor coolant system. Specific measurements were not taken for the larger drain line B since this line is used for normal cooldown of the reactor coolant system and flow through this line is verified during such operations. The measurements were taken during the second refueling outage of Oconee Unit 1 and the first refueling outage of Oconee 2. The core heat generation rates at the times of the measurements were typical of that which would be expected during the post-LOCA long-term cooling phase, and the reactor water level was maintained at approximately a post-LOCA level. The flow rate through drain line A was then measured by collecting the flow out through this line for a fixed time period. A sufficient number of measurements were obtained to assure confidence in the measurement. The measured flow rates agreed with the predicted values within the tolerance of the measurement. This experimental verification provides added assurance of the adequacy of the system's design.

5. FAILURE MODE AND EFFECTS ANALYSIS

The only components of the boron dilution system are the piping and the isolation valves associated with the two drain lines. The failure of a drain line would consist of either a rupture of the piping (passive failure) or the failure of the isolation valve to open (active failure). Since the drain lines are intended to provide gravity drainage of the relatively concentrated water from the top of the core into the reactor building, a break in the drain line would not adversely affect the function of the system since the drain flow path is still maintained; and therefore, a passive failure in the boron dilution system would have no adverse effect on the function and capability of the system. In the event of an isolation valve failure, the drain flow would be prevented in that particular line; however, the other line would be available to permit the necessary flow. From the standpoint of minimum drain flow, the worst single failure is that of an isolation valve in drain line B, which results in drain flow directed only through drain line A. Drain line A, however, is designed to permit a minimum flow in excess of 40 gpm, a sufficient capacity to limit the boric acid concentration buildup to $C/co = 11$. Therefore, no single active or passive failure in the boron dilution system can defeat the intended function of the system. Table 1 provides a summary of the failure mode and effects analysis.

6. ANALYSIS OF REACTOR COOLANT FLOW AND BORIC ACID CONCENTRATION BEHAVIOR FOR A SPECTRUM OF POSSIBLE PIPE BREAKS

6.1 Large Breaks

6.1.1 Cold Leg Piping Breaks

In the case of a large cold leg piping break, the hydraulic conditions within the core, upper plenum, and downcomer during the initial phase of the long-term cooling period are such that a natural circulation will exist in the reactor vessel through the path downcomer-core-upper plenum-vent valve-downcomer. Boric acid concentration in the core region will remain within acceptable levels provided adequate core circulation persists. However, the natural circulation flowrate will diminish with increasing fluid density in the core, and at some point in time the natural circulation may diminish to a point where it can no longer effectively control the increase in boric acid concentration. When the drain lines are opened, water of higher concentration will drain from the top of the core to the sump allowing ECCS water to enter the core and to promote core circulation. With the LPI system continuously injecting ECCS water into the downcomer and the drain lines allowing drainage of water from the top of the core, a sustained core flow will be established. The minimum core flow in this case will be equal to the drain flow, and as the heat generation rate in the core decreases with time, the core flow will become sufficient to keep the core subcooled, and eventually the core boric acid concentration will become dilute.

For a large break at the reactor inlet nozzle, the flow paths for long-term cooling are as shown in Figure 3. In this case the downcomer is filled with subcooled water which provides the driving head for natural circulation. Conservative calculation (1) of the boric acid concentration in the core shows that this natural circulation will limit the boric acid concentration to C/Co = 1.19 at 24 hours after the break. When the drain lines are opened (operator opens the isolation valves within 24 hours after the break), the diminishing natural circulation flow will be compensated by the core flow generated by the drain flow. If both drain lines are open or if just drain line B is open, the resulting core flow will be in excess of 500 gpm, which will limit the core boric acid concentration to C/Co = 2 or less. If only drain line A is available, a core flow of at least 40 gpm will exist, which will be sufficient to limit the maximum boric acid concentration buildup to C/Co = 11. Eventually, with decreasing decay heat generation in the core and constant core flow, the boric acid concentration in the core region will become dilute with time approaching that of the ECCS water.

For a large break assumed to occur at the pump suction, the reactor coolant system flow paths for long-term cooling are as shown in Figure 4. The flow paths in this case are essentially the same as those for a break at the reactor vessel inlet nozzle, except that the downcomer water level will be higher because the break flow has to pass through a higher elevation relative to the reactor vessel hot leg and cold leg nozzles. The increased downcomer driving head generates increased core flow during the natural circulation phase and the drain flow phase. Consequently, the increase in core boric acid concentration in the event of a large break at the pump suction will be less than that for a large break at the reactor inlet nozzle.

Similarly, for a large break of the cold leg piping at any other location, it can be seen that the increase in core boric acid concentration will be less than that for a large break at the reactor inlet nozzle.

6.1.2 Hot Leg Piping Breaks

The hot leg breaks allow sufficient ECCS injection flow to pass through the core, and therefore significant increase in the boric acid concentration will not occur even if the drain lines were not available.

The reactor system flow paths for a double-ended break at the hot leg nozzle are as shown in Figure 5. In this case, the entire ECCS injection flow passed through the core and out through the break. The minimum core flow with one LPI pump operating is 3000 gpm, which will be sufficient to prevent boiling and concentration increase within 1.5 hours after the LOCA. The maximum concentration under these circumstances will be less than 1.19. The drain lines will have no effect on core flow and boric concentration behavior; and, in fact, no flow may be realized through these lines in the case of a double-ended break between the decay heat drop line and the outlet nozzle.

The reactor system flow paths in the case of a large break at the highest point of the hot leg piping (180° bend) are as shown in Figure 6. Initially, the ECCS injection flow will split approximately 50/50 between the core and steam generators until the steam generator stored heat is removed (approximately one day). After the steam generator stored heat has been removed, the steam generator fluid acts as a seal, forcing all injection flow through the core. The minimum core flow in this condition is 146 lb/sec, which will be sufficient to prevent boiling and concentration increase within two days after the LOCA. When the drain lines are opened, the core flow will increase significantly if both drain lines are fully open. In this case, the core will attain subcooled condition, and the core boric acid concentration will begin to decrease immediately after initiation of dilution flow. If only drain line A is available, the core flow and boric acid concentration behavior do not change significantly with the drain flow.

6.2 Small Breaks

Small breaks are generally categorized as those with break areas less than 0.5 ft^2.

In the case of small breaks, the reactor coolant system is depressurized in a slow and sometimes controllable manner. During the gradual depressurization of the reactor coolant system the combined and sequential injection flow delivered by the HPI system, the core flood tanks, and the LPI system will force natural circulation throughout the system. This natural circulation alone would prevent excessive buildup of boric acid concentration in the core region. However, to preclude any possibility of undesirable boric acid concentration buildup, the operator will initiate boron dilution flow at approximately 24 hours after the break (after the complete depressurization of the reactor coolant system).

For a small break in the cold leg piping, the reactor system's flow paths during the long-term cooling phase are similar to those of either Figure 3 or Figure 4. If the break flow rate is less than the injection flow rate, the downcomer water level will be above the elevation 808' 4". This added driving head will provide increased natural circulation flow and drain flow, resulting in lesser evaporation from the core and reduced boric acid concentration compared to the limiting break (double-ended break in the cold leg nozzle).

For a small break in the hot leg piping, the reactor system's flow paths during the long-term cooling phase are similar to those of either Figures 5 or 6. The hot leg break will permit the injection flow to pass through the core and remove decay heat without evaporation within one hour after the break, and concentration increase is expected to terminate after this time. The core flow and boric acid dilution will be augmented by the drain flow.

6.3 Intermediate Breaks

In the case of intermediate breaks, the reactor coolant system will be depressurized within a few minutes. Once the reactor coolant system is depressurized, the core flow and boric acid concentration behavior are similar to those of a large break. Here again, the operator will open the dilution flow paths at approximately 24 hours after the break. The maximum boric acid concentration buildup will be bounded by that obtained in the event of a large break.

7. EVALUATION OF THE NEED FOR FLOW INSTRUMENTATION AND ASSESSMENT OF THE FUNCTIONAL PERFORMANCE OF BORON DILUTION SYSTEM

The role of the boron dilution system in the unlikely event of a loss of coolant accident is to provide a gravity flowpath leading from the top of the core to the reactor building sump, thereby allowing drainage of water of higher concentration from the top of the core to the reactor building sump. The physical layout of the drain lines are such that a gravity flow of the coolant from the top of the core to the RB sump will always exist through these drain lines during all postulated primary system pipe breaks, with the exception of a double-ended break at the RV hot leg nozzle, for which no additional flowpath is required. The feasibility of gravity flow through these drain lines has been demonstrated by testing. The only mechanism by which the drain flow in these lines may be prevented is the failure of an isolation valve; but since redundant flowpaths are provided, the reliability of the system is assured. It should be pointed out that the existence of a "no flow" condition in these lines would not necessarily suggest failure of the system since in the case of a double-ended break on the hot leg between the reactor vessel and the decay heat line nozzle water from the top of the core is discharged directly into RB sump through the break, and no flow can be realized through the drain lines. At the same time, the existence of flow in these lines does not imply that the break is not on the hot leg between the RV and the decay heat drop line since a small break or a split break at this location will allow flow through these drain lines. Therefore, installing instrumentation to indicate flow specifically through these lines will not provide any useful information. In face, the installation of flowmeters in the drain lines will create additional head losses, which will impede the drain flow. In addition, it should be noted that full flow may not exist through the drain lines, especially in drain line B, when both drain lines are open; and therefore, while fully adequate flow may exist flow indication at times may be confusing. These considerations suggest that it is unnecessary, and, in fact, it is not prudent to install flow instrumentation in these drain lines.

Since the drain flow through the lines is the result of the elevational driving head created by the LPI system flow into the downcomer and the existence of the gravity flow paths leading from the hot leg to the RB sump, the functional performance of the boron dilution system is determined by the LPI system flowrates into the downcomer and the status of the drain lines. The control room operators receive continuous readouts of the LPI flow through each of the two LPI strings leading to the downcomer, and the status of the drain lines is indicated in the control room by the position indications (red and green lights) from limit switches installed on the isolation valves. Therefore, the operator can assess the functional performance of the boron dilution system at all times when it is used by monitoring the ECCS flowrate and the valve positions of the isolation values in the drain lines.

8. OPERATOR ACTIONS TO INITIATE DILUTION FLOW AND TO VERIFY FUNCTIONAL PERFORMANCE OF THE SYSTEM

Considerable time exists after a loss of coolant accident before operator action is required to prevent excessive buildup of boric acid concentration. However, to provide the greatest assurance that the boric acid concentration is minimized, the operator is required to initiate boron dilution flow at approximately 24 hours after the accident. (At this time the ECCS is operating in the recirculation mode.) The operator is expected to perform the following actions to initiate boron dilution flow and to verify the performance of the system:

For Unit 1

a. Assure that the reactor coolant system is depressurized.

b. Open both drain lines by opening LP-1, LP-2, LP-103, LP-104, and LP-105.

c. Assure that at least one drain line is open by verifying the positions of the isolation valves in that line.

d. Monitor the ECCS flow and ensure that at least one-half of full capacity flow is available through each LPI string.

For Units 2 and 3

a. Assure that the reactor coolant system is depressurized.

b. Assure that the ECCS is operating in the recirculation mode.

c. Open both drain lines by opening LP-1, LP-2, LP-3, LP-19, LP-103, and LP-104.

d. Assure that at least one drain line is open by verifying the positions of the isolation valves in that line.

e. Monitor the ECCS flow and assure that at least one-half of the full capacity flow is available through each LPI string.

Following initial assessment that at least one drain line is open and that at least one-half of the full capacity flow is available through each LPI string, the operator must monitor the status of the system periodically.

After the isolation valves, the only active component of the boron dilution system, are opened, the system becomes passive; and, therefore, no maintenance work will be required to assure continued operation of the system. However, maintenance of the Emergency Core Cooling System conponents may be required during the long-term cooling period; but since the boron dilution system is independent of the ECCS components, any required maintenance on an ECCS component can be performed without interfering with the dilution flow paths.

9. CONCLUSIONS

Based on the foregoing evaluation, it can be concluded that:

1. The boron dilution system provided for the Oconee reactors meets the necessary redundancy and reliability requirements and is capable of effectively preventing the boric acid concentration buildup in the core region in the event of a LOCA.
2. The design of the system and the hydraulic conditions existing in the core are such that a core flow in excess of the minimum required to limit the core boric acid concentration buildup will exist for all types of primary system pipe breaks.
3. Experimental verification of drain flow through the flow paths confirms the design predictions of the system.
4. Only limited operator action is required to initiate boron dilution and to assess the system's functional performance.
5. The boron dilution system will augment the normal emergency core cooling system in providing long-term core cooling, thereby minimizing the consequences of a LOCA.
6. Isolation valve position indication and the LPI system flow indication together provide the means to assess the overall performance of the system and eliminate the need for incorporating flow indications in the drain lines.
7. Flow indication is unnecessary and has the potential for providing misleading information to the operator.

References

1) R. C. Jones, et al., ECCS Analysis of B&W's 177-FA Lowered-Loop NSS, BAW-10103, Babcock & Wilcox, June 1975.

2) B. M. Dunn, et al., Supplementary and Supporting Documentation of B&W's ECCS Evaluation Model Report with Specific Application to 177-FA Class Plants with Lowered Loop Arrangement, BAW-10091, Suppl. 1, Babcock & Wilcox, December 1974.

Table 1. Failure Mode and Effects Analysis

Component	Failure Mode	System Effect of Failure
Piping	Rupture	Reactor coolant drains through the break. No adverse effect on functional performance of the system.
1 2 LP-103 3 or 1 2 LP-104	Fails to open	Prevents flow through this particular line; however, the other line permits adequate flow. Will not cause failure of the system.
1 2 LP-1 3 or 1 2 LP-2 3 or 1 LP-105 or 2 LP-3 3	Fails to open	Prevents flow through this particular line; however, the other line permits adequate flow. Will not cause failure of the system.
2 LP-19 3	Fails to open	Prevents flow to the RB sump through this line; however, flow through this line can be maintained by operating LPI pumps 'A' or 'C'. Failure of this valve will have no effect on flow through the other line.

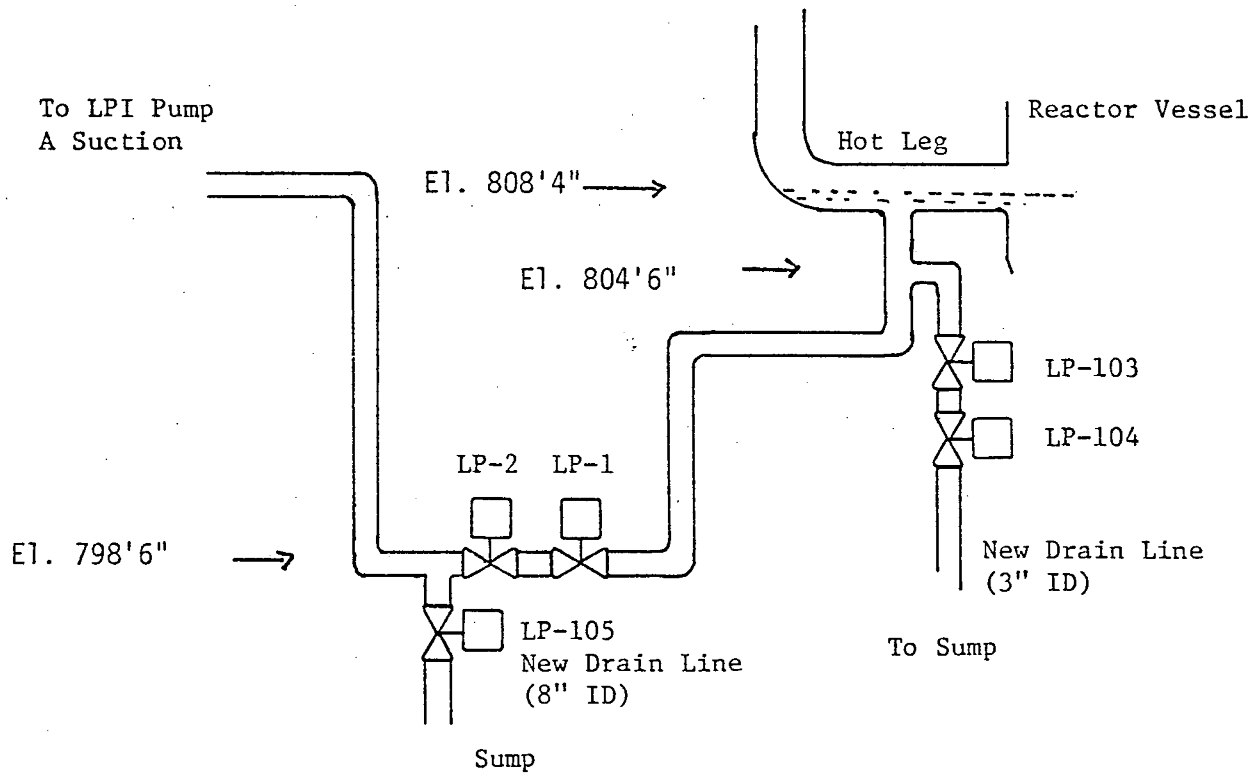

Figure 1. Schematic Diagram of Oconee 1 Post-LOCA Reactor Coolant System Drain Lines

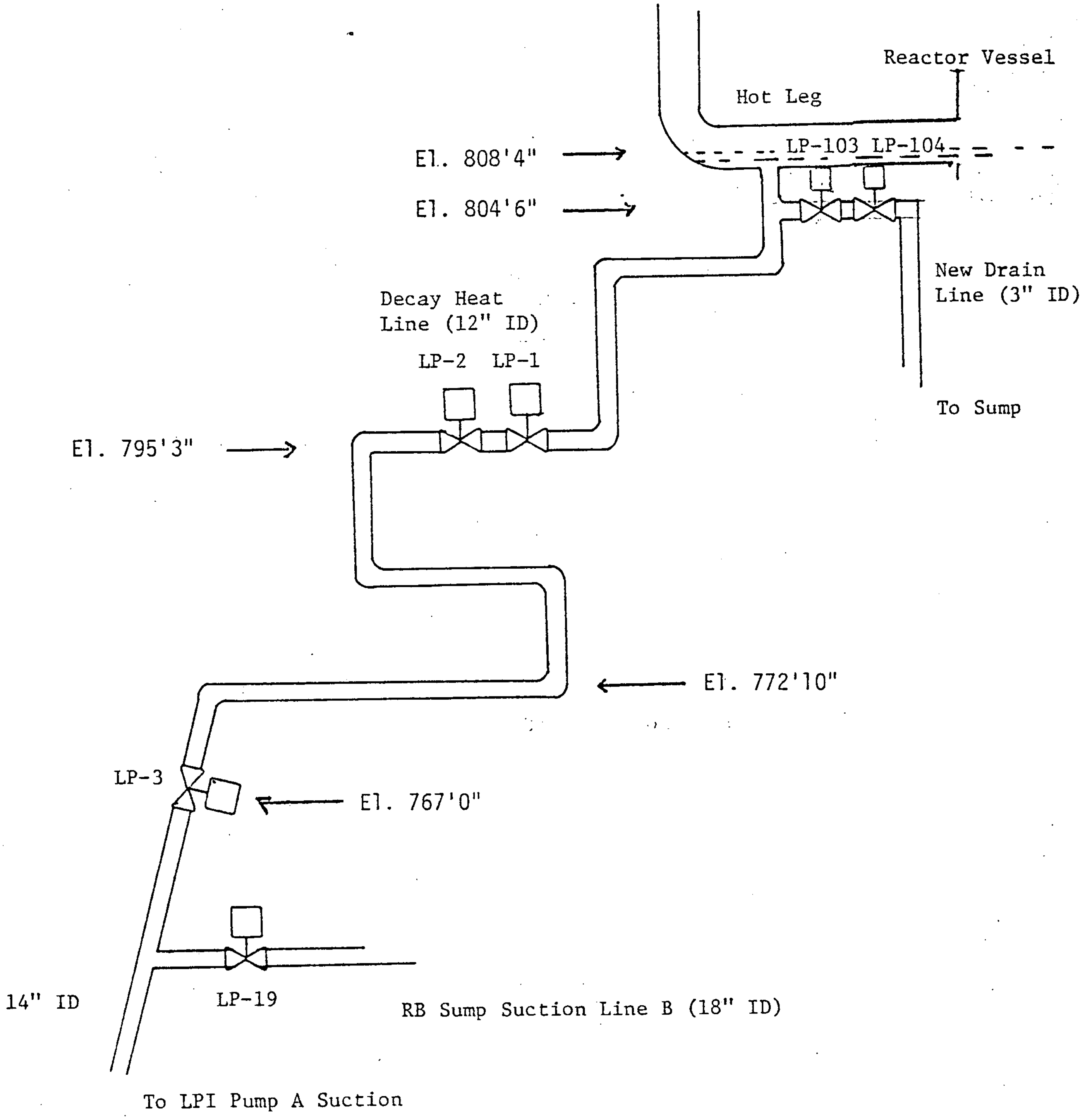

Figure 2. Schematic Diagram of the Oconee 2 and 3 Post-LOCA Reactor Coolant System Drain Lines

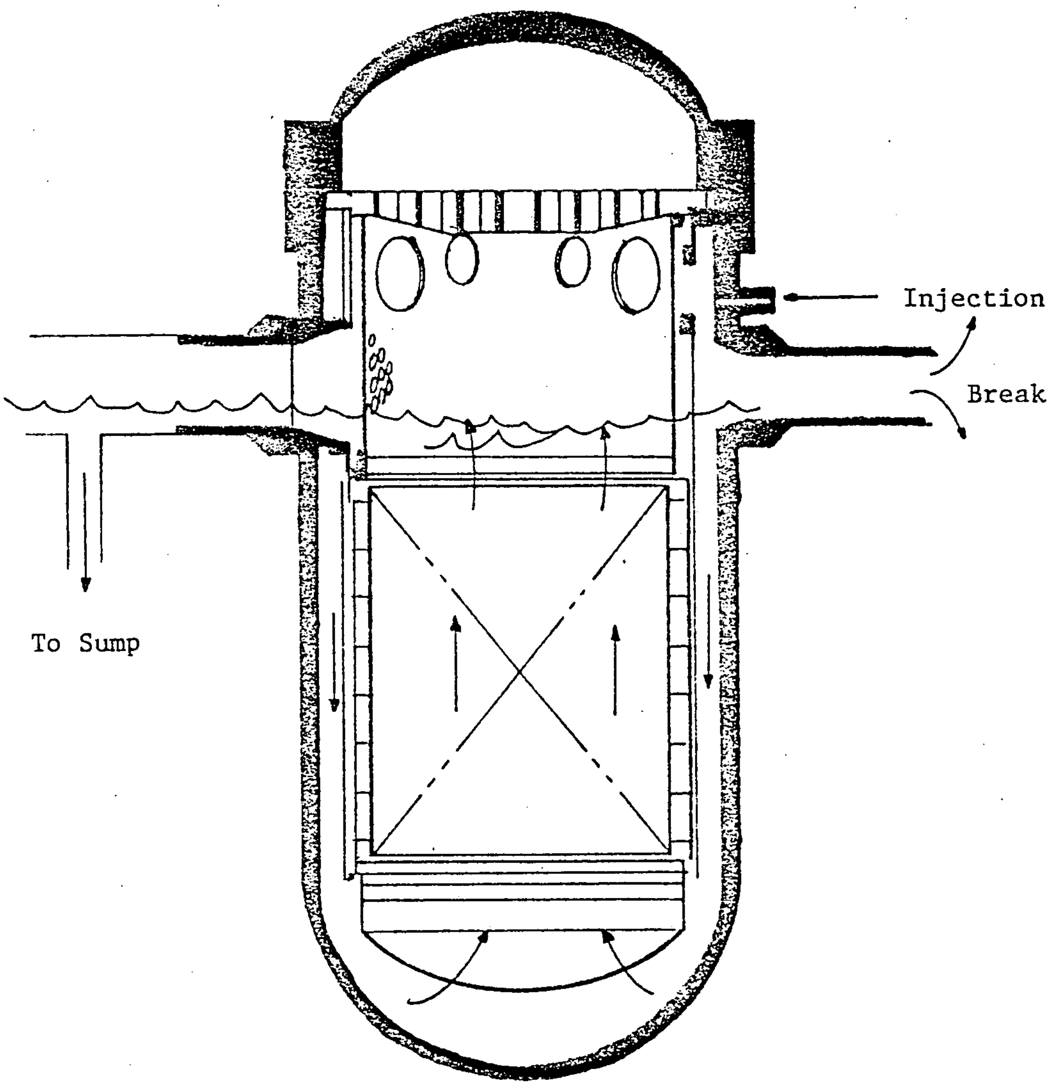

Figure 3. Long-Term Cooling Flow Paths, Large Break at Reactor Vessel Inlet

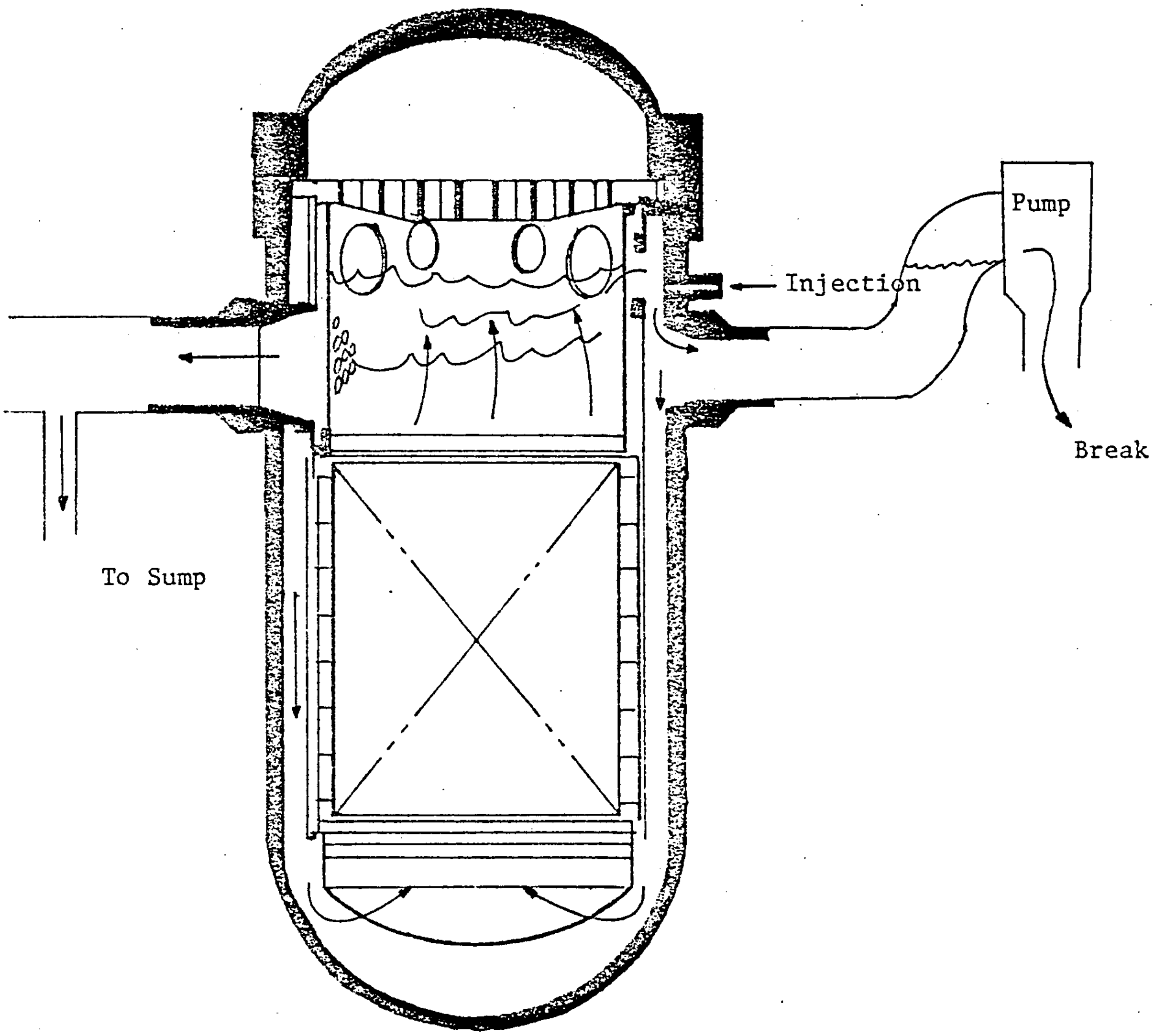

Figure 4. Long-Term Cooling Flow Paths, Large Break at Pump Suction

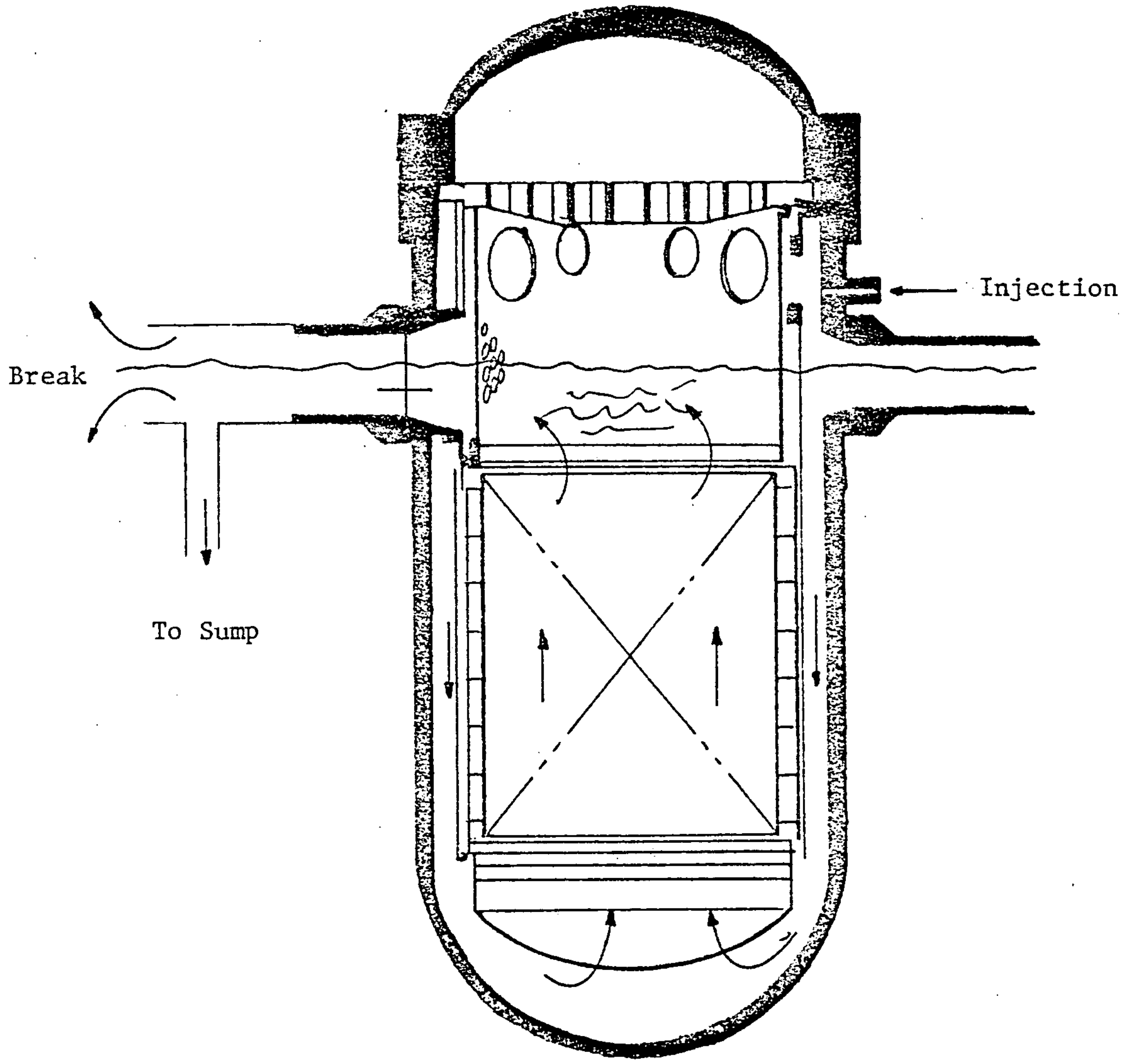

Figure 5. Long-Term Cooling Flow Paths, Large Break at Reactor Vessel Outlet

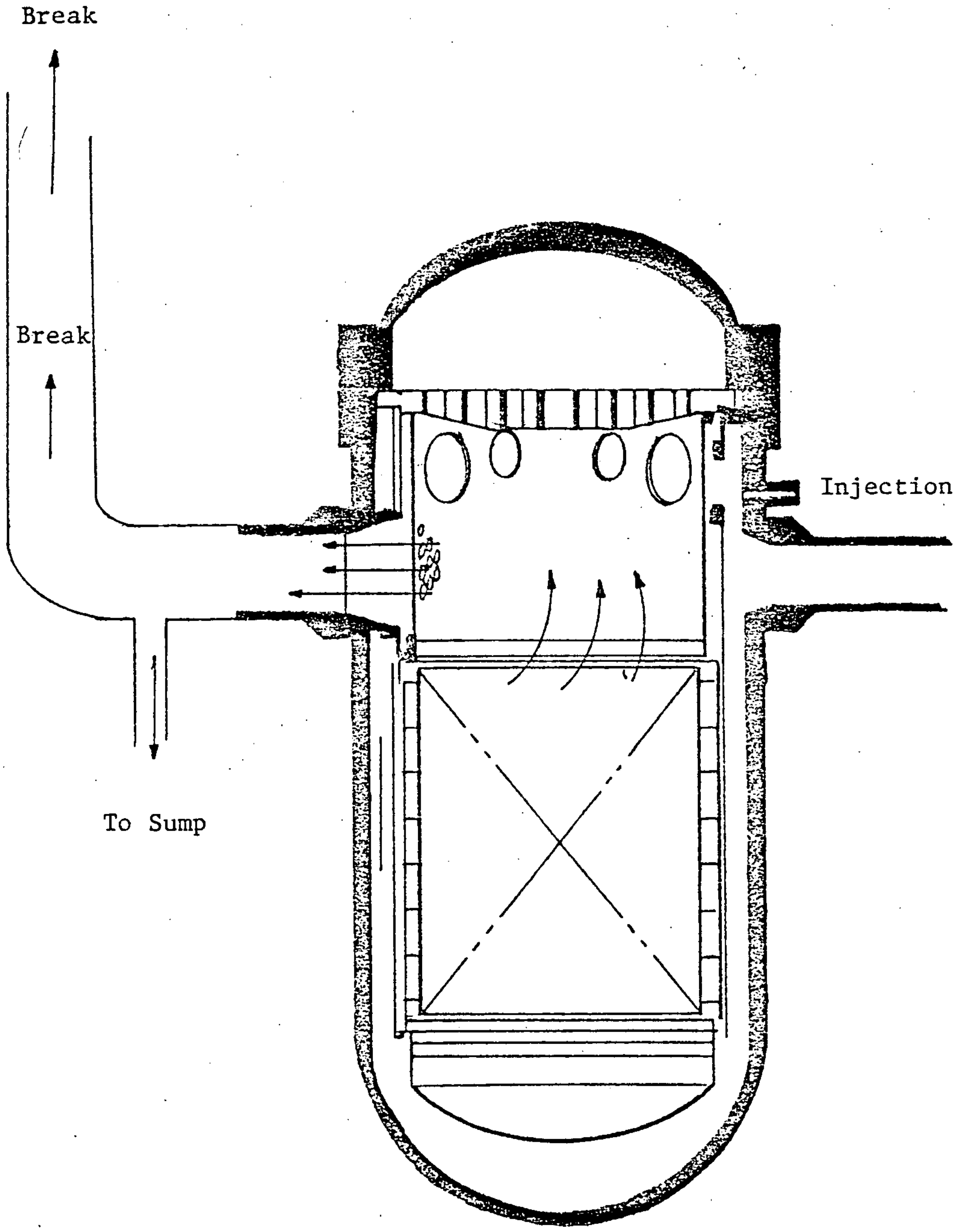

Figure 6. Long-Term Cooling Flow Paths, Large Hot Leg Break Top of 180° Bend