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DESCRIPTION:

Ltr re our 3-14-75 ltr....trans the following:

PLANT NAME: Oconee 1, 2, & 3

ENCLOSURES:

Possibilites of significant changes in chmeical concentrations during LOCA.....

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A. C. THIES
SENIOR VICE PRESIDENT
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P. O. Box 2178

April 16, 1975

Mr. Angelo Giambusso, Director
Division of Reactor Licensing
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

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

Dear Mr. Giambusso:

In response to a March 14, 1975 letter from Mr. R. A. Purple, a review of the system capabilities and operating procedures of the Oconee Nuclear Station has been performed to evaluate the possibility of significant changes in chemical concentrations, during the long term, after a postulated loss of coolant accident (LOCA). This review has considered all aspects of station design, including component qualification in the LOCA environment, in addition to a detailed review of operating procedures.

On August 5, 1974, the Babcock and Wilcox Company submitted Topical Report BAW-10091 to the Commission. This report describes the B&W ECCS evaluation model for conformance to Appendix K of 10 CFR 50 along with specific application to 177-FA Class plants with lowered-loop arrangement. Duke Power Company adopted this topical report and submitted and implemented proposed technical specifications to bring the operation of the Oconee units into conformance with the LOCA limits contained in BAW-10091. Subsequent to this submittal, the Commission staff raised several questions with B&W concerning the report. Supplement 1 to BAW-10091 was submitted on January 15, 1975 which responded to these questions. Several of these questions and responses pertained to boron precipitation during long-term cooling and are discussed below.

The response to Question 117 (pp. 3-85 through 3-87) described operator actions which are required to initiate and maintain long-term cooling. The response to Question 120 (pp. 3-88 through 3-99) described the analysis which demonstrates that boron precipitation will not occur during long-term cooling due to the leakage gaps between the outlet nozzles and the core support shield opening during the cooldown period following a LOCA. It is believed that these gaps will open and, therefore, no additional operator action will be required to prevent boron precipitation.

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The attached evaluation, however, describes three modes of operation which could be utilized to assure that boron precipitation would not compromise long-term core cooling capability following a LOCA if it is assumed that the above described gaps are not available. The three modes of operation are described in Section III with the associated operating procedures described in Section V of the evaluation. Existing systems are considered adequate for implementing Modes 1 and 2; however, dose calculations have not been completed to determine the feasibility of operation of manual valves in the Auxiliary Building in the post-LOCA environment. The described operating procedures for Modes 1 and 2 could be implemented if the expected dose is within acceptable values. If the dose rate is not acceptable, a number of manual valves in the Auxiliary Building could be replaced with electric motor operated (EMO) valves; however, the procurement and installation time required could be approximately two to two and one-half years.

Mode 3 would be required to provide additional assurance that a single failure of a motor operated valve used in Modes 1 or 2 would not prevent recirculation. Implementation of this mode would require the installation of two motor operators on valves in the Reactor Building. Procurement and installation time required for this modification could also be approximately two to two and one-half years.

A review of the dose calculations described above and of longer initiation times for implementation of the long-term cooling mode following a postulated LOCA is being performed to determine the necessity for additional modifications. The results of this review will be submitted by June 1, 1975. It is re-emphasized, however, that it is considered that the methods described in BAW-10091, Supplement 1 are adequate to prevent boron precipitation and that the steps described in the attached are unnecessary.

Very truly yours,

A. C. Thies

A. C. Thies

ACT:vr
Attachment

AN EVALUATION OF BORON PRECIPITATION

DURING LONG-TERM COOLING

FOLLOWING A POSTULATED LOSS OF COOLANT ACCIDENT

I. Introduction

Reactor system circulation and boron concentration in the post-LOCA, long-term cooling environment have been analyzed for the potential of unacceptably high boric acid concentrations in the core region. Both large and small breaks of the reactor inlet and outlet pipes are considered and the large break of a reactor vessel inlet pipe is shown to be the most limiting case.

The analysis indicates that natural circulation within the reactor vessel, where the flow path is downcomer-core-upper head-vent valves downcomer-, provides adequate circulation to prevent rapid increases in solute concentrations, including the limiting case. The resulting slow concentration buildup indicates that a time period in excess of 30 days is available for alignment and operation of alternate flow paths. If both Low Pressure Injection (LPI) strings are operable, then the procedure, one day after the postulated LOCA, is to establish suction on the reactor vessel outlet pipe (hot leg) through the decay heat line with one LPI string. This will force flow from the LPI string through the core. This procedure, (Mode 1), will limit concentration buildup to a factor of two or less.

In the event the decay heat line is not available, the procedure (Mode 3) is to open the auxiliary spray to the pressurizer. This will act as hot leg injection by routing dilute injection to the area above the core. The flow path will be through the auxiliary spray line into the pressurizer, out of the pressurizer through the surge line, into the hot leg and then into the reactor vessel. This flow path will act first as a dilutant for core water and then, reversing the direction of core flow, providing long-term sensible heat removal. The concentration buildup rate decreases as auxiliary pressurizer spray becomes effective and the concentration gradually decreases as sensible heat removal proceeds. The minimum auxiliary spray capacity is 40 gpm. This auxiliary spray rate, if required, will limit concentration buildup to $C/Co=11$.

The decay heat line may not permit circulation of saturated water because the line routing takes it above the hot leg pipe. This decay heat line is, however, capable of being aligned (Mode 2) such that a connection from the LPI pump discharge to the decay heat line will route flow backwards through this line into the hot leg. This will route dilute injection into the area above the core. The analysis description that follows describes hot leg injection by way of the auxiliary pressurizer spray. However, the hot leg injection results presented are independent of source, e.g., auxiliary pressurizer spray or reverse flow through the decay heat line.

II. Discussion of Analysis

A. Reactor Inlet - Large Break

The reactor vessel internal natural circulation flow paths are shown in Figure 1. In this circulation mode, the driving head for the core flow is provided by downcomer fluid. The downcomer head is sufficient to promote significant core flow and to provide an adequate pressure differential to open the vent valves.

The core flow rate as a function of time is shown in Figure 2. This flow rate from the core and through the vent valves is assumed to mix with the injection flow (3000 gpm) and exit from the vessel through the inlet break. For concentration calculations, however, the concentration entering the core is conservatively assumed to be equal to that leaving the core at a given time step. (In effect, no boron is assumed to leave the vessel through the break.) The resulting concentration ratio of boron as a function of time is shown in Figure 3. The resultant natural circulation flow is such that very low quality mixture is produced which produces relatively low concentrating rates. The rate of concentration is such that alignment of an alternate flow path is not required for a time period in excess of one month.

However, in order to provide measurable assurance that boron concentration is minimized, alignment of the decay heat line is performed within one day after the postulated LOCA. The flow path in the reactor vessel in this flow mode called "forced circulation," is shown in Figure 4. The minimum core flow in this "forced circulation" mode, assuming no density gradient in the core is approximately 118 lb/sec, which is more than adequate to provide decay heat removal without evaporation within five days. Figure 5 shows the boron concentration change and peak value following alignment of the decay heat line after one day of natural circuation operation.

In the event that the decay heat line is not operational (failure of isolation valve to open), the alternate system to promote low boron concentration and to dilute the boron concentration is alignment of the auxiliary pressurizer spray. The flow paths for this mode of operation (defined as "hot leg injection") are shown in Figure 6.

Hot leg injection has little effect on circulation and concentration until the steaming rate, assuming evaporation only from the core, is equal to or less than the hot leg injection rate. As the injection rate approaches the steaming rate the hot leg injection acts to reduce the rate of core boron concentration by adding non-concentrated water. As the decay heat rate decreases with time, the hot leg injection becomes adequate to remove decay heat by sensible heat removal. The core flow direction reverses, and the concentration of boron in the core becomes dilute with time. The concentration with time for "hot leg injection" is shown in Figure 5, for an injection rate of 40 gpm.

Figure 7 shows the model used for calculating the concentration after the decay heat letdown is opened or after the pressurizer spray injection is initiated. The concentration, C, is given by

$$C = \frac{\text{Mass Solute}}{\text{Mass Solvent}}$$

$$C = \frac{McCi + \int_{t1}^{t} W_{in} C_{in} dt - \int_{t1}^{t} W_{out} C dt}{M_c}$$

$$\text{or } C/C_o = \frac{Ci}{C_o} + \int_{t1}^{t} \frac{W_{in}}{M_c} \frac{C_{in}}{C_o} dt - \int_{t1}^{t} \frac{W_{out}}{M_c} \frac{C}{C_o} dt \qquad (1)$$

where Ci is the concentration at t1
t1 is time of vent valve opening or spray initiation
Co is same reference concentration

Equation 1 is used to calculate the concentration ratio after the natural circulation phase of the transient is terminated.

The important assumptions used for this part of the transient are:

(1) Constant mixing mass, Mc = 30000 LBM

(2) 40 gpm flow rate from pressurizer sprays

(3) Constant LPI injection rate and concentration

(4) No density gradients in calculation of forced circulation

(5) 1000 BTU/LBM needed to produce steam

(6) Maximum flow out break for letdown line case

(7) K-factors based on full flow values

<u>Summary: Reactor Inlet - Large Break</u>

The results of the calculations are shown in Figure 5. They show that the maximum concentration ratio for the letdown line case is 1.19 at 1 day; the maximum concentration ratio for the hot leg injection case is 11 at 60 days. The solubility curves show that a concentration ratio of 35:1 is needed before precipitation will occur. Thus, it has been shown that the proposed method for controlling concentration buildup in the long-term cooling phase of a LOCA is credible. This is particularly true when the conservatisms inherent in the analysis are considered. These conservatisms include:

(1) No dilution of injection H_2O is considered
(2) Absorption of boric acid by concrete is neglected
(3) Volatility of boric acid was neglected

B. Pump Suction - Large Break

For large breaks postulated at or in the pump suction line, the flow paths are as shown on Figure 8. In this case the leak fluid must pass through the RC pump which is some 3½ feet above the centerline of cold leg nozzle. This condition provides increased downcomer driving head for core flow which results in more core flow and a lower outlet quality and boron concentration when operating with LPI injection, "Natural Circulation mode." In this case, the core flow versus time will be equal to or greater than that shown in Figure 3.

Operations in the forced circulation mode will produce flow patterns equivalent to that shown in Figure 9, with a near constant minimum flow rate of approximately 118 lb/sec, which is more than adequate to provide decay heat removal without evaporation within five days. Switch over to this mode will provide a concentration ratio equal to or less than that shown in Figure 5.

In the event the decay heat line is not operational, the alternate system, pressurizer spray, dilutes the boron concentration as described in Section II.A above. The hot leg injection flow paths are shown in Figure 10, and the concentration ratio versus time is equal to or less than that shown in Figure 5.

C. Reactor Outlet - Large Break

In the case of a postulated large break, the flow paths are as shown in Figure 11. Any parallel alignment such as opening the decay heat line, or hot leg injection, will produce little or no effect. This case corresponds to the forced circulation cold leg break with the decay heat line open, except that all injection water flows through the core. The minimum core flow with one LPI pump operating is expected to be 3000 gpm (416 lb/sec) which will prevent boiling and concentration within approximately 18 hours. The resulting concentration ratio, then will be significantly less than that shown in Figure 5.

D. Reactor Outlet - Top of 180° Bend - Large Break

In the case of a postulated large break at the top of the 180° bend, reactor outlet, the overall flow paths are as shown in Figure 12. With one LPI injection pump assumed operating, the injection flow will split approximately 50/50 between the core and steam generators until the steam generator stored heat is removed (approximately one day). During this period the flow paths within the vessel are approximately those of forced circulation. The corresponding core flow rates are equal to or greater than (approximately 200 lb/sec) those shown in Figure 2, because of increased driving head.

After steam generator stored heat has been removed, the flow paths within the vessel are also those of forced circulation, where the steam generator fluid acts as an extended downcomer, forcing all injection flow through the core. The minimum core flow in this condition is 416 lb/sec.

After one day with the decay heat line opened, the flow paths become those shown in Figure 11 with no change in core flow or concentrating effect.

If the decay heat line is not operational, and the alternate auxiliary pressurizer spray system is used, the flow paths remain as forced circulation. Core flow and concentrating effects do not change since the auxiliary spray flow is swept up the hot leg pipe by the reactor outlet flow.

E. Small Breaks

1. General

Generally, small breaks are categorized as those with break areas less than 0.5 ft^2. To avoid excessive concentration of boric acid, the operator would take the same actions as those specified for large breaks. For very small breaks where the system depressurization is slow and the system pressure remains at pressures over the design pressure of the decay heat removal system, the operator must wait until the pressure falls below this point or take action to depressurize the system by using normal cooldown procedures.

Prior to taking any action, the system is being depressurized by losing energy out of the break and the cooling provided by the high pressure injection system. The pressure will remain up until the loss of energy is greater than that being added from the core and that being released from the reactor coolant system metal. The core decay heat is by far the predominate contributor of heat during a slow depressurization. However, the reactor coolant system will not experience an indefinite time of pressures remaining at high levels for breaks even as small as that equivalent to a 1 inch diameter break (0.005454 ft^2). For this 1 inch break, the pressure has been calculated to be less than 400 psia in 2 hours and decreasing. At this pressure, the flow from one HPI pump delivers more than twice that being lost out the break. The injection flow from one HPI pump is greater than the leak flow when the pressure is 1200 psia. This will force natural circulation throughout the system and prevent concentration of boric acid. If both HPI pumps were operating, depressurization should occur faster initially but the pressure would tend to stabilize or even increase as the system again became filled with water. At this point, the operator could shut a pump off and go into a "normal" cooldown mode.

For a break four times larger (2" I.D.), the system pressure would be below 400 psia within 1 hour and 300 psia within 2 hours if no operator action were taken. Even for this size break, the injection flow from two HPI pumps is greater than the leak flow when the system pressure is 400 psia. This would result in the RCS eventually refilling and could occur before the borated water storage tank empties. Prior to the system refilling, the high pressure injection flow will generate sufficient driving head in the reactor vessel downcomer annulus and steam generators to cause natural circulation through the core and the internals vent valves. This by itself would prevent excessive buildup of boric acid concentrations.

After the reactor coolant system has depressurized to allow LPI system operation, the various flow paths and concentration effects are described as follows.

2. Small Breaks - Cold Leg

Assuming a small cold leg break equal to the LPI injection flow (3000 gpm), the flow patterns are the same as those shown in Figure 1, for injection flow only (i.e., the natural circulation mode). Switching to the decay heat line will produce flow patterns similar to that of Figure 4, and in the event hot leg injection is required, flow patterns will be produced similar to those of Figure 6. The corresponding concentration changes will be equal to or less than those of Figure 5.

Breaks smaller than the injection rate will permit the water to rise within the reactor coolant system, thereby providing additional driving head for the natural circulation path within the vessel, and reducing the concentration rate because less evaporation occurs.

3. Small Breaks - Hot Leg

Assuming a hot leg break with flow rate equivalent to the injection flow rate, the flow patterns will be similar to those of Figure 11. Hot leg breaks will permit the injection flow to pass through the core (417 lb/sec) and remove decay heat without evaporation within one hour after the break and concentration is expected to terminate after this time.

Hot leg breaks smaller than the injection rate will permit the water level to rise within the system with approximately the same flow patterns and concentrating effect.

III. Flow Paths

A. Mode 1 - Suction from Hot Leg with One LPI String

This flow path is identical for all three Oconee units. Suction is established from the reactor vessel outlet pipe (hot leg) through the decay heat line with one LPI string (see Figure 13). The flow is through existing valves LP-1, LP-2, LP-3, LP-4 (for Units 1 and 2), LP-9, LP-12, LP-17 and into the reactor vessel through the core flood nozzle.

B. Mode 2 - Hot Leg Injection Through the Decay Heat Line

This flow path uses a connection from the LPI pump discharge to the decay heat line to route flow backwards through the decay heat line and into the hot leg.

The flow path will be different for Oconee Units 1 and 2 and Unit 3. Oconee Units 1 and 2 have a cross connect (8" line) from LPI String B (upstream of the LPI cooler) to the decay heat line. Flow path is through the cross connect (valve LP-68) into the decay heat line and backwards in the decay heat line through valves LP-3, LP-2 and LP-1 to reach the hot leg. Oconee Unit 3 does not have this cross connect to the decay heat line. For Unit 3, cross connects to the letdown line of the HPI System will be used. The cross connect from LPI String B cooler outlet is a 2" line connecting the HPI System letdown line downstream of the letdown control valve and upstream of the demineralizers. A return cross connect leaves the HPI System letdown line downstream of the purification demineralizers but upstream of the letdown storage tank and connects into the LPI System downstream of the valve LP-4 in the decay heat line. The normal functio nof these cross connects to the HPI System is to obtain purification flow during cold shutdown after the HPI System is shut down. When using this path during long-term cooling, the filters and demineralizers in the HPI System would be bypassed. Units 1 and 2 will be able to achieve, as a minimum, several hundred GPM into the hot leg with only one LPI pump operational and a large majority of the pump flow split between the two LPI lines. Unit 3 will be able to achieve a flow rate greater than the 40 GPM minimum into the hot leg.

C. Mode 3 - Open Auxiliary Spray Line to Pressurizer

This flow path uses an HPI pump taking suction from an operating LPI string through cross connect valves LP-15 or LP-16. The flow path to the hot leg will be through the auxiliary pressurizer spray line which is through valves HP-355, HP-340 and LP-45. Changes are required to make this a workable flow path as there are manually operated valves inside the reactor building which must be opened and closed during the long-term cooling period to establish this flow path. Changes required are shown on Figure 3 and are: (1) change valve LP-45 to locked open, (2) add on an electric motor operator (EMO) to valve HP-340, and (3) add on EMO to valve HP-356. Valve HP-356 must remain open during normal operation to provide a continuous minimum makeup line flow to minimize thermal transients on the RC pipe nozzle. This valve (HP-356) must be closed for Mode 3 to prevent the flow from diverting to the HPI line. Valve HP-340 must remain closed during normal operation to prevent the continuous minimum makeup line flow from diverting to the pressurizer. The flow rate for this path to the hot leg is controlled and limited to 40 GPM by the block orifice downstream of valve HP-340.

IV. Single Failure Analysis

The three modes listed above are necessary to satisfy the single failure criteria. Operations must be designed for a single failure in either the short-term or long-term cooling period but not a single failure in the short term and then another single failure in the long-term period. Since the operator may not be able to determine the location of the break, Mode 1 is attempted first (if both LPI strings are operable) to determine if the normal decay heat removal path can be established. It can be established if the break location is high enough in elevation so that the decay heat suction nozzle on the hot leg is sufficiently flooded to prevent gas or steam entrainment at the LPI pump flow rate. Even if there is no single failure during the attempt, success is not assured because of the possibility of gas or steam entrainment in the decay heat suction nozzle. If Mode 1 fails because LPI pump flow is erratic or loses prime, then Mode 2 is attempted. Success or failure of Mode 2 will be indicated by flow indicators. On Oconee Units 1 and 2, opening of the last valve to establish reverse flow in the decay heat line will cause the LPI string flow to decrease. On Oconee Unit 3, a flow indicator in the letdown line of the HPI System will indicate the reverse flow rate in the decay heat line. If Mode 2 fails due to single failure, then Mode 3 is performed. The above was for a single failure in the long term. The single failure could occur in the short term with the single failure being such that only one LPI string is operable. Mode 1 then cannot be attempted because prime could be lost on the only LPI pump operating. So, Mode 2 would then be performed.

All valves located within the reactor building, that must be operated in any of the three modes will be electric motor operated and located outside the secondary shield wall. All of the existing valve EMO's are qualified for the LOCA environment and all EMO's to be added will be qualified EMO's. If power is not available to any of the EMO's required to implement any of the three modes, electrical jumper cables will be used to connect power to the EMO controller.

V. Operating Procedures for Long-Term Cooling

The three operating modes which have been described for long-term cooling cannot presently be fully effected. The existing equipment is adequate to provide the necessary flow paths for Modes 1 and 2; however, dose calculations are not completed for areas of the Auxiliary Building in which manual valves must be operated. Operating Mode 3 cannot be implemented until electric motor operators are added to valves HP-340 and HP-356 which are located in the Reactor Building and valve LP-45 is modified to be locked open.

The ECCS systems will be placed in one of the following three modes of operation (Mode 3 will only be possible after modifications) within one day of the accident. Injection flow to the RC System should be maintained through two paths while attempting to place the system in one of the three operating modes. The two injection flow paths can be either the two LP injection lines or one LP injection line combined with one HPI string (LPI pump acting as a booster pump for the HPI pump).

Mode 1 - Attempt to Establish Suction from Hot Leg With One LPI String

a. This mode is to be attempted only if both LPI strings are operable. If successful, it is indicative that the RC System is filled to above the hot leg elevation. LPI String A must be used for the attempt.

b. Open decay heat line EMO valves LP-1 and LP-2.

c. Ensure that cross connect valves between LPI Strings A and B are closed (EMO valves LP-9 or 10 and LP-6 or 7).

d. Place LPI String B in series with one HPI string to ensure injection flow through two paths. Control valve HP-26 or 27 used to control HPI flow to 500 GPM and LPI control valve LP-14 used to control LPI pump flow to 3000 GPM. LPI pump flow is the sum of LPI Line B flow rate and the HPI string flow rate.

e. Place LPI String A in operation taking suction on the decay heat line. Shut off LPI pump in String A and the associated building spray pump. Open manual valve LP-4 (for Units 1 and 2 only) and EMO valve LP-3 in decay heat line. Close EMO sump outlet valve and control valve LP-12.

   Start LPI pump in String A and slowly increase flow. Observe pump flow indication and pump noise for symptoms of cavitation and entrainment of vapor or gas. LPI pump in String A is now taking suction from the hot leg only.

f. The HPI pump taking suction from LPI String B may now be shut off. LPI String A is now taking suction from hot leg and pumping to reactor vessel and LPI String B is taking suction from RB sump and pumping to reactor vessel.

g. An additional step may be taken, when convenient, to determine if the break location is high enough in elevation to operate only one LPI string with the suction being from the hot leg. Slowly decrease the flow rate in LPI String B and then shut off the LPI pump in String B; continuously observe LPI string A indicated flow rate for erratic behavior. Coolant from the sump is not being pumped to the reactor vessel now, i.e., not providing an overflow out the break. If suction to the LPI pump A is not lost, it is indicative that: (1) the RC System is filled to above the hot leg elevation, (2) the break in the RC System is above this elevation, and (3) the LPI String A injection line is intact. LPI String B may now be placed back in operation (taking suction from sump) or operated periodically to make up for volume contraction as LPI String A reduces the reactor coolant temperature.

Mode 2 - Route Flow Backwards Through the Decay Heat Line Into the Hot Leg

Oconee Units 1 and 2

a. If Mode 1 is not successful, maintain injection flow to reactor vessel through two injection flow paths by any of the following:

   (1) Two LPI strings

   (2) One LPI pump operating with LPI pump discharge header open (valves LP-9 and LP-10 open) and the flow split between the two injection lines by the control valves.

   (3) One LPI string in series with one HPI string.

b. Decay heat line EMO valve LP-1, LP-2, and LP-3 are open. Close manual valve LP-4.

c. Open manual valve LP-68 in cross connect from LPI String B to decay heat line.

   (1) If two LPI pumps are operable, use String A to inject through LPI line to reactor vessel. Use String B's full flow through the cross connect (valve LP-68) to decay heat line and into the hot leg. Close String B LPI line EMO valves LP-18 and LP-14.

   (2) If only one LPI pump is operable, split the flow between one LPI line to the reactor vessel and the cross connect path to the hot leg. The flow split is accomplished by throttling the LPI line EMO control valve (LP-18) and manual valve LP-68 in the cross connect. Flow split indication is confirmed by LPI pump discharge pressure indication remaining the same (same as for 3000 GPM LPI line injection flow rate) and the LPI line flow rate indicator at approximately 1500 GPM.

d. If Mode 2 is successful, injection flow to the reactor vessel is through two injection flow paths and dilute injection is reaching the area above the core (if the break is a cold leg break).

Oconee Unit 3

a. Step a, for Oconee Units 1, 2 above, is applicable.

b. Decay heat line EMO valves LP-1 and LP-2 are open. EMO valve LP-3 in decay heat line is closed.

c. Line up cross connect (valve LP-96) flow path from LPI String B to HPI System letdown line. Complete the flow path up to the return cross connect (valve HP-363) to the LPI System. In the HPI System letdown line, isolate the filters and demineralizers and open the bypasses around them. Close the inlet valve to the letdown storage tank.

d. LPI pump P1A must not be operating and its suction EMO valves LP-5 and LP-6 must be closed. The building spray pump associated with LPI String A must be shut off and the sump EMO outlet valve LP-19 must be closed. Open manual valve HP-363 in return cross connect to LPI System. Open EMO valve LP-3 in decay heat drop line.

e. The flow path is now complete. The flow rate indicator in the HPI System letdown line indicates the flow rate in this path from LPI String B to HPI System letdown line to LPI String A suction to decay heat line and backwards through this line to the hot leg.

Mode 3 - Open Auxiliary Spray Line to Pressurizer

a. This operating mode will be used if Mode 2 is not successful.

b. Close main pressurizer spray line EMO valve RC-1 or RC-3 or both.

c. Open auxiliary spray line EMO valve HP-340. Open manual valve HP-355 in Auxiliary Building. Close EMO valve HP-356 to force flow to the auxiliary spray line.

d. Start any one of the three HPI pumps taking suction from an operating LPI string through the cross connect.

e. HP injection can be stopped by closing injection valves HP-26, HP-27, and HP-120 or HP injection flow can be maintained in parallel with the auxiliary spray flow by controlling valve HP-26 or HP-120. Injection flow to the reactor vessel should be maintained through two paths per Item a of Mode 2. Auxiliary spray line flow rate is indicated by the flow measurement upstream of manual valve HP-355 (normal makeup line flow indication).

VI. Summary of Results

The recommended operating procedures for Oconee 1, 2, and 3 to minimize boron concentration following a LOCA are, in order of preference:

A. Always maintain a minimum of 3000 GPM LPI injection into the downcomer. This provides for a natural circulation flow path within the reactor vessel and the maximum concentration buildup is C/Co = 1.19 for the first 24 hours after a LOCA. (Co is initial concentration - 2200 ppm boron solution.)

B. Align decay heat line in a low flow mode within 24 hours after the LOCA (see Step e of Mode 1 in Section V) which provides a minimum core flow of 500 gpm. This is called a force circulation mode and if successful will provide a maximum concentration ratio of 1.3 as shown in Figure 5.

   In addition, if this operating mode is successful and operation proceeds to the normal decay heat system flow rate, the forced core flow is 3000 gpm minimum resulting in even lower concentration ratios ($\leq$ 1.19) as shown in Figure 5.

C. Should Step B not be successful, the decay heat line is aligned for a reverse flow of 40 gpm minimum within 24 hours after the LOCA. This is called hot leg injection and limits the concentration ratio to 11.0 at 60 days (Figure 5). If larger reverse flow rates are available through the decay heat line, the concentration ratio will be held to a smaller value 1.9 at 7 days (140 gpm hot leg injection Figure 5).

D. In the event that the decay heat line is not operational (single failure), the auxiliary pressurizer spray flow is aligned to provide 40 gpm minimum flow within 24 hours after the LOCA. This mode is also called hot leg injection and produces the same results as discussed in C above. (C/Co=11.0 60 days)

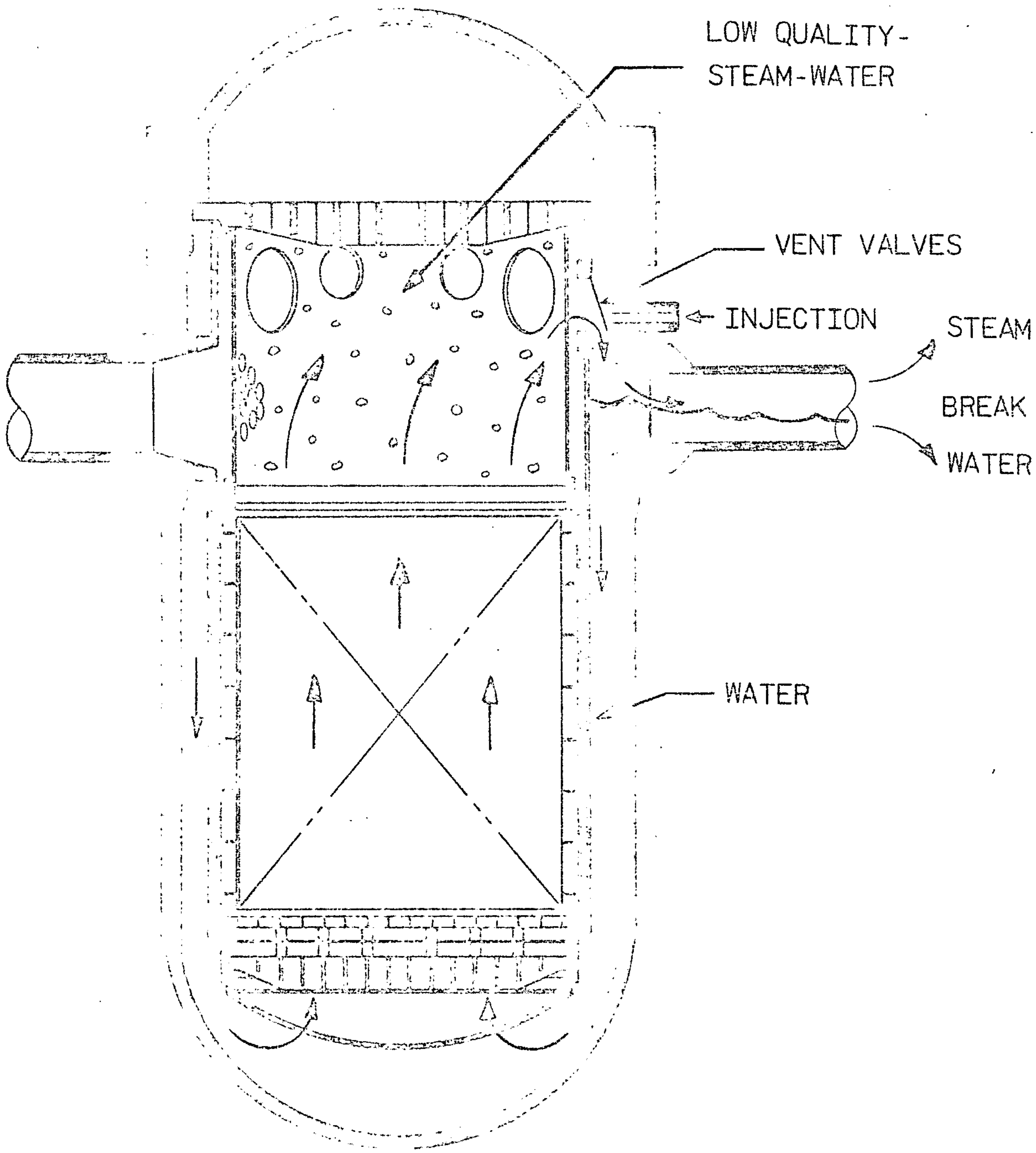


FIGURE 1

FLOW PATHS-REACTOR INLET-LARGE BREAK

"NATURAL CIRCULATION"

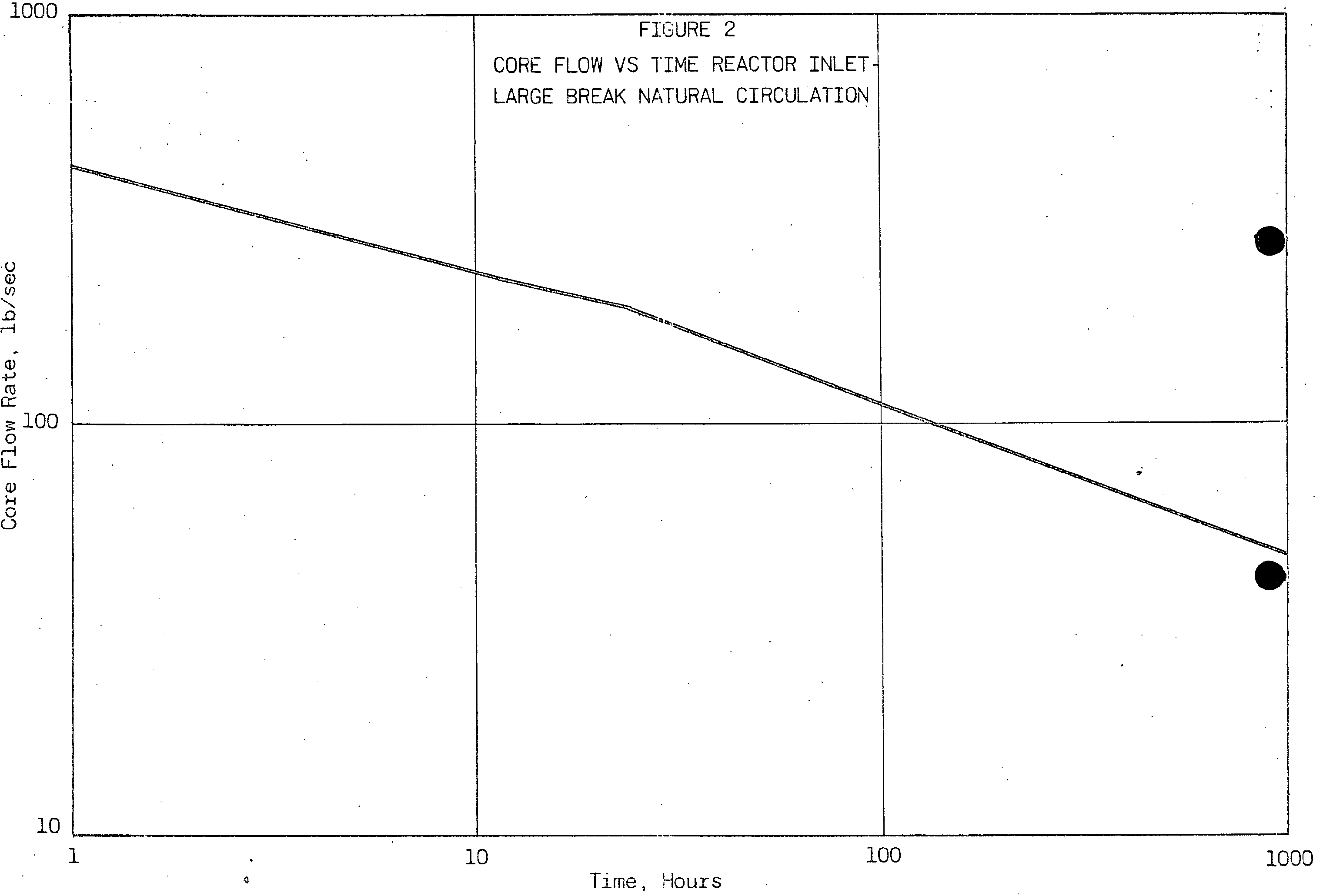


FIGURE 2
CORE FLOW VS TIME REACTOR INLET-
LARGE BREAK NATURAL CIRCULATION
1000
100
10
Core Flow Rate, lb/sec
1
10
100
1000
Time, Hours

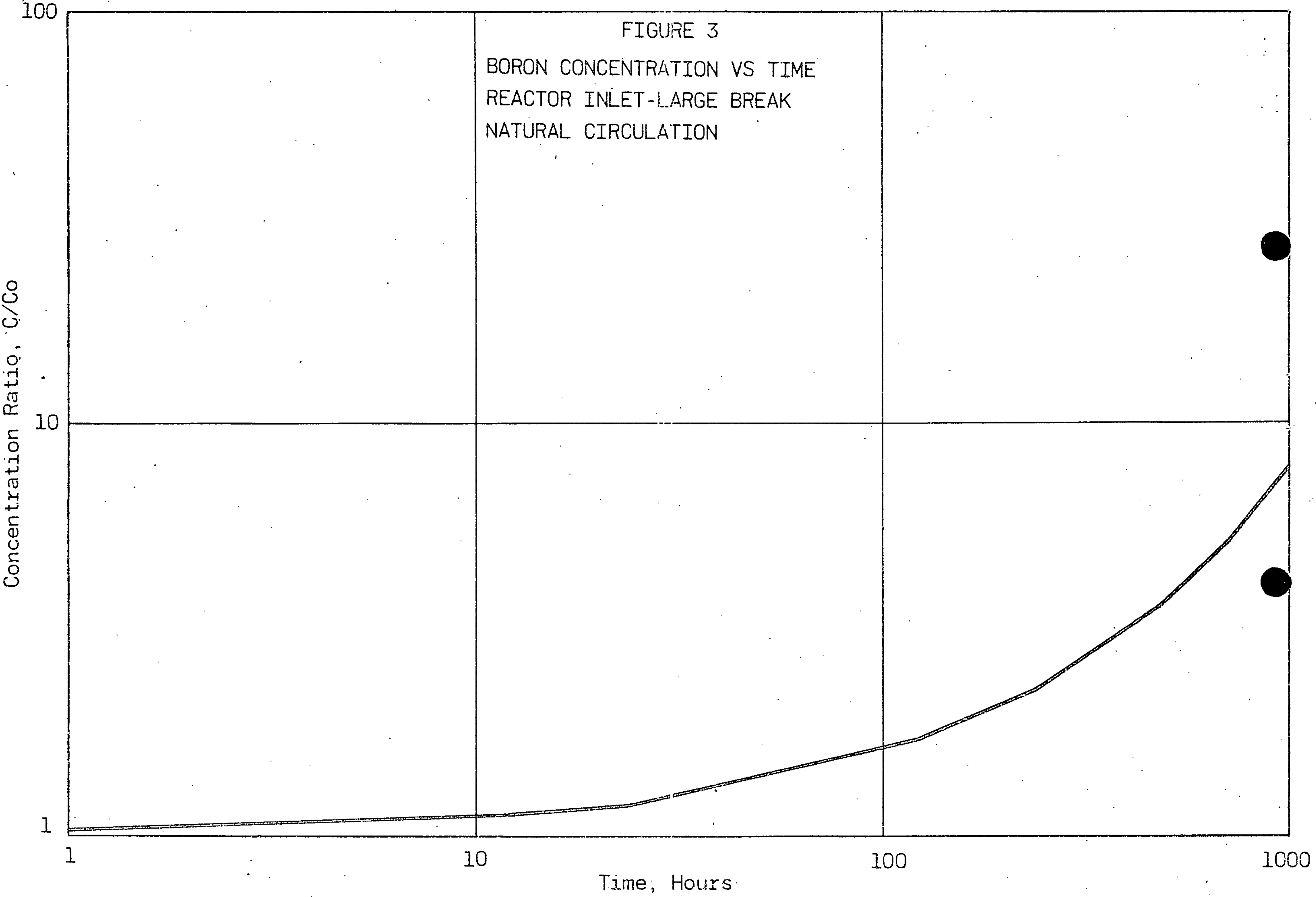


FIGURE 3
BORON CONCENTRATION VS TIME
REACTOR INLET-LARGE BREAK
NATURAL CIRCULATION
Concentration Ratio, C/Co
100
10
1
1
10
100
1000
Time, Hours

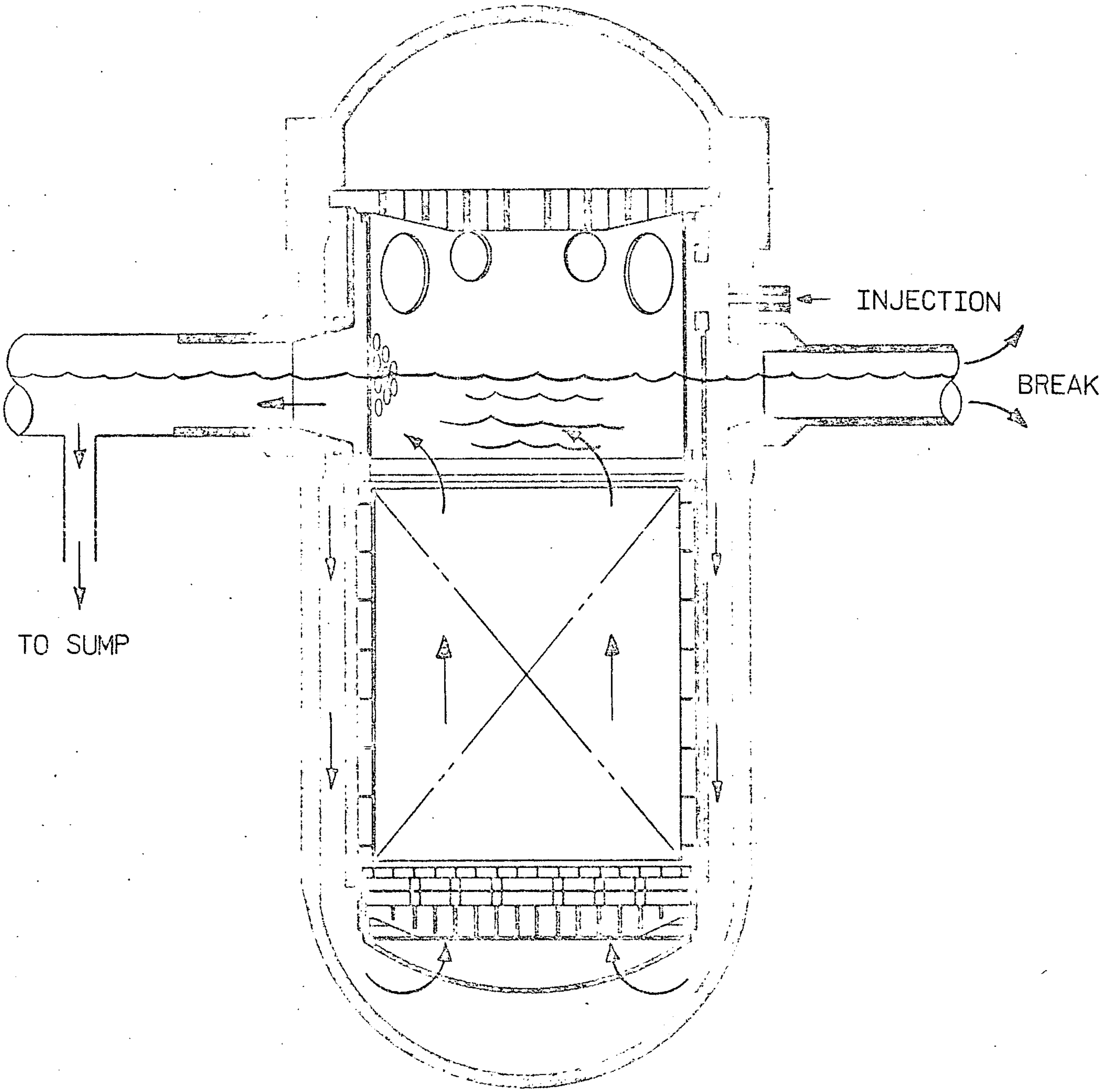
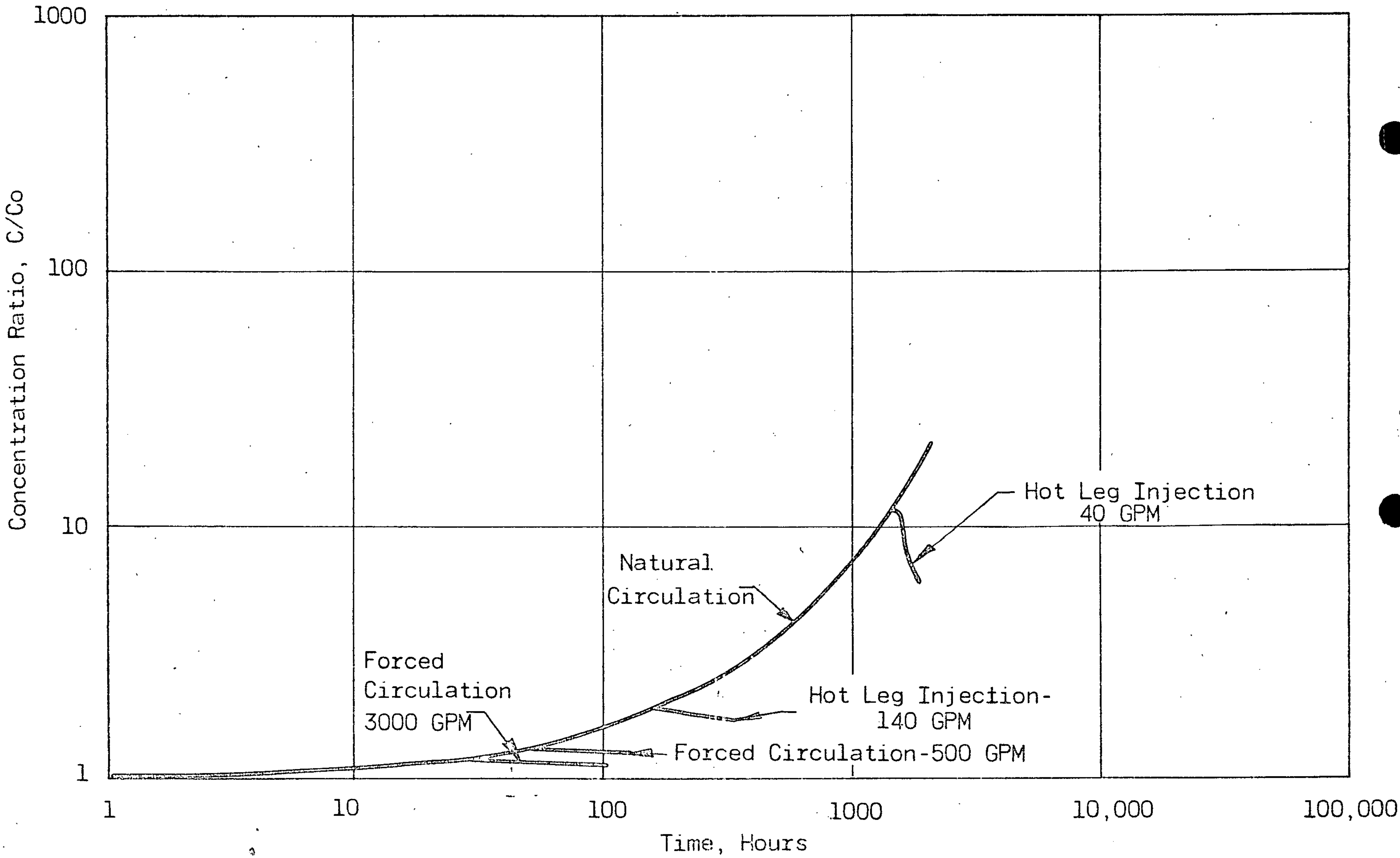


FIGURE 4

FLOW PATHS-REACTOR INLET-LARGE BREAK
"FORCED CIRCULATION"

FIGURE 5

BORON CONCENTRATION VS TIME



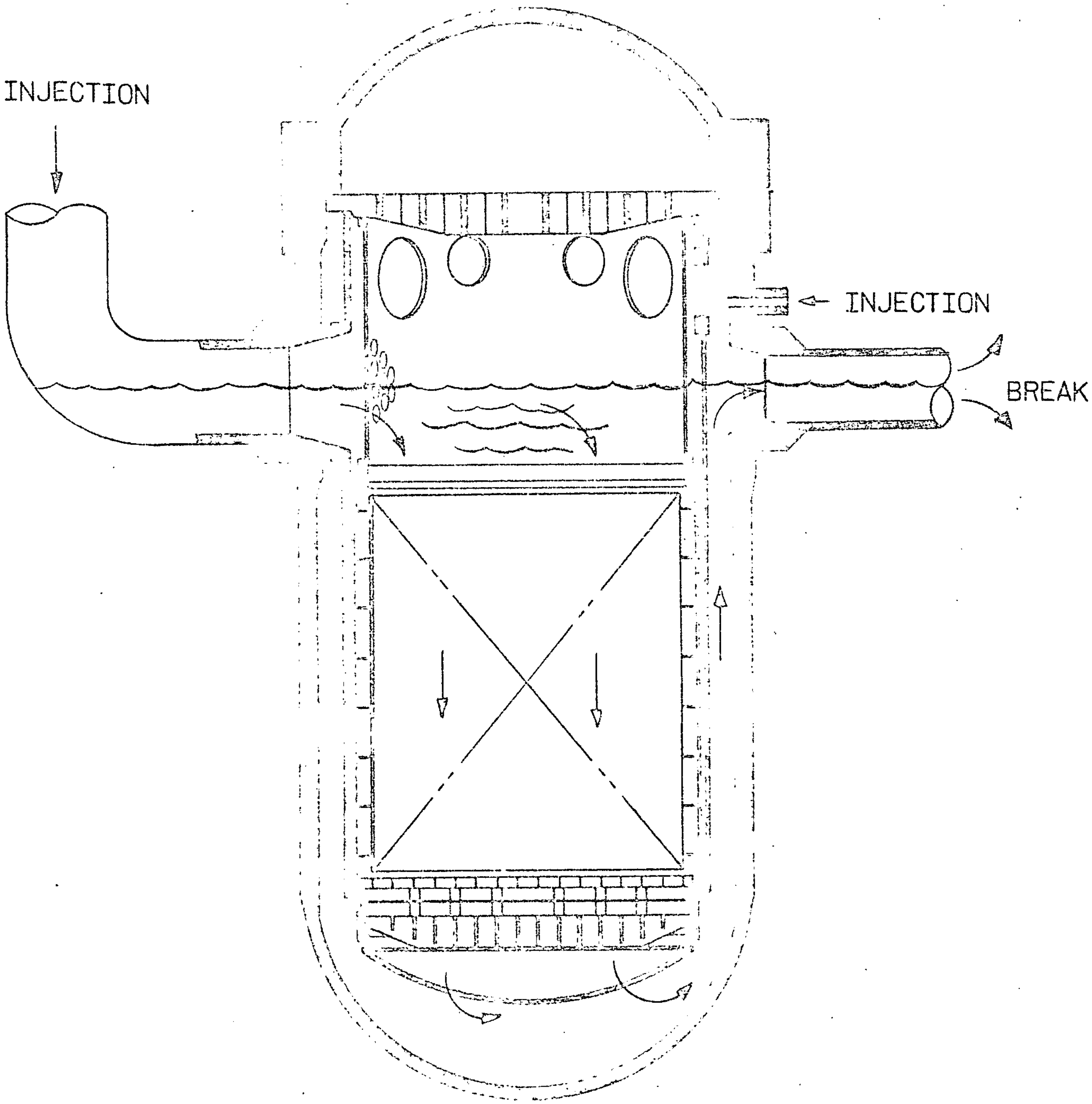
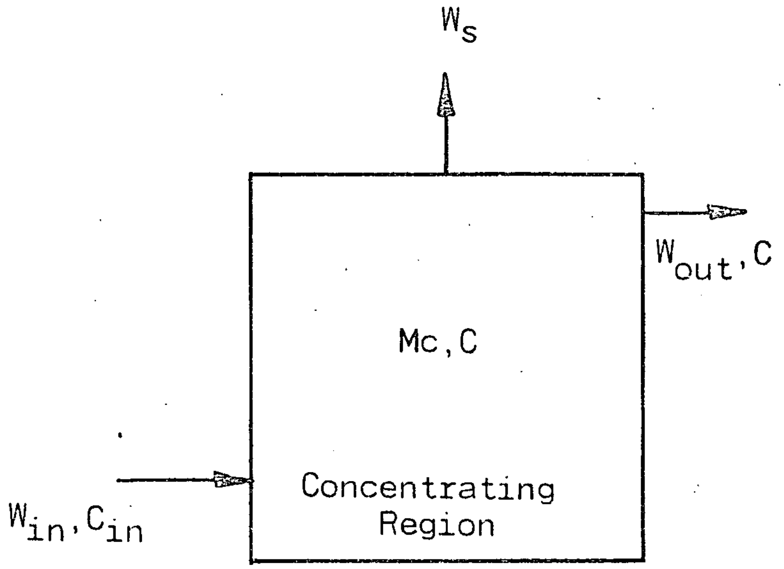


FIGURE 6

FLOW PATHS-REACTOR INLET-LARGE BREAK
"HOT LEG INJECTION"

FIGURE 7 MODEL USED FOR CALCULATING CONCENTRATION AFTER NATURAL CIRCULATION PHASE



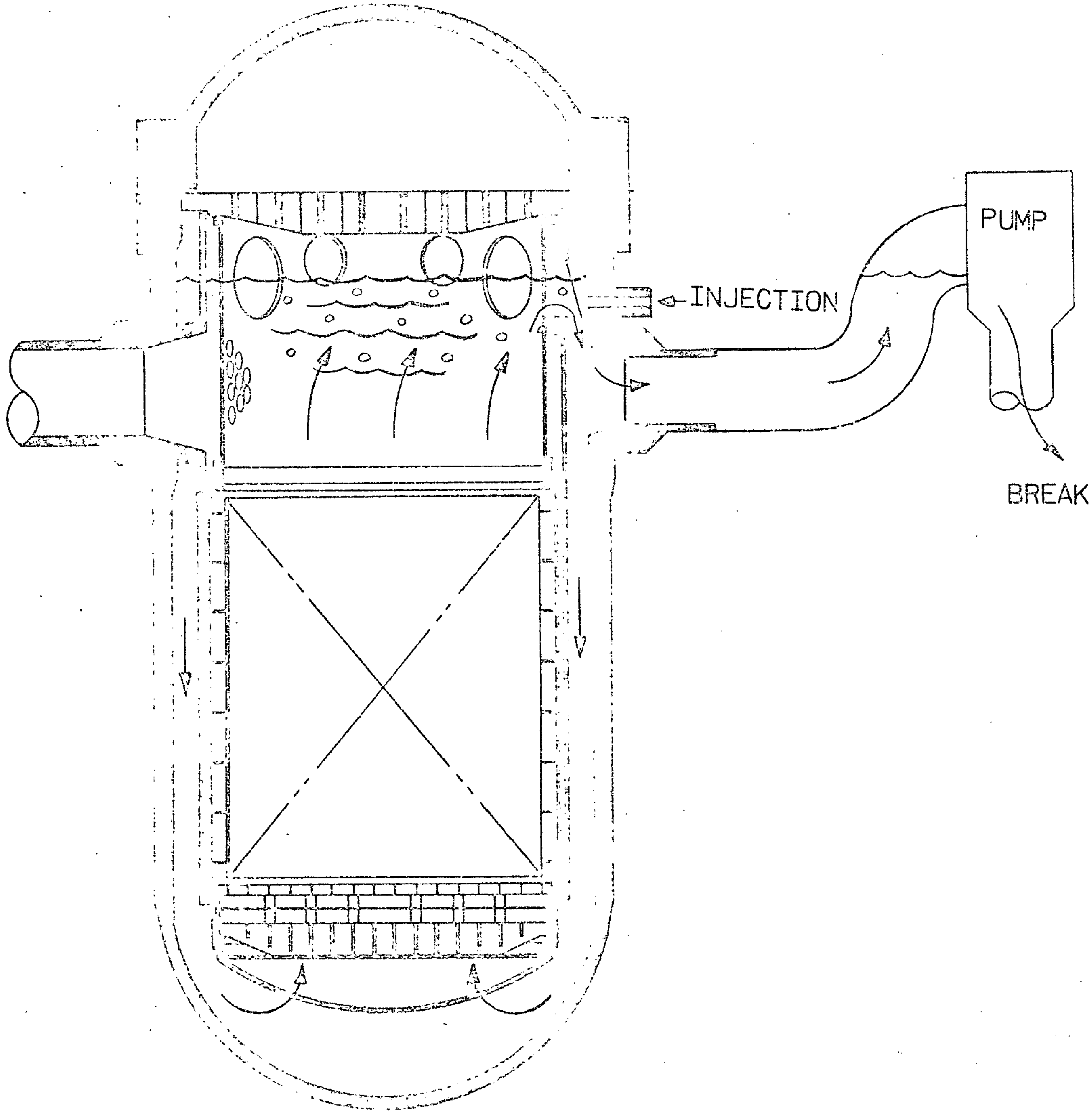


FIGURE 8
FLOW PATHS-PUMP SUCTION-LARGE BREAK
"NATURAL CIRCULATION"

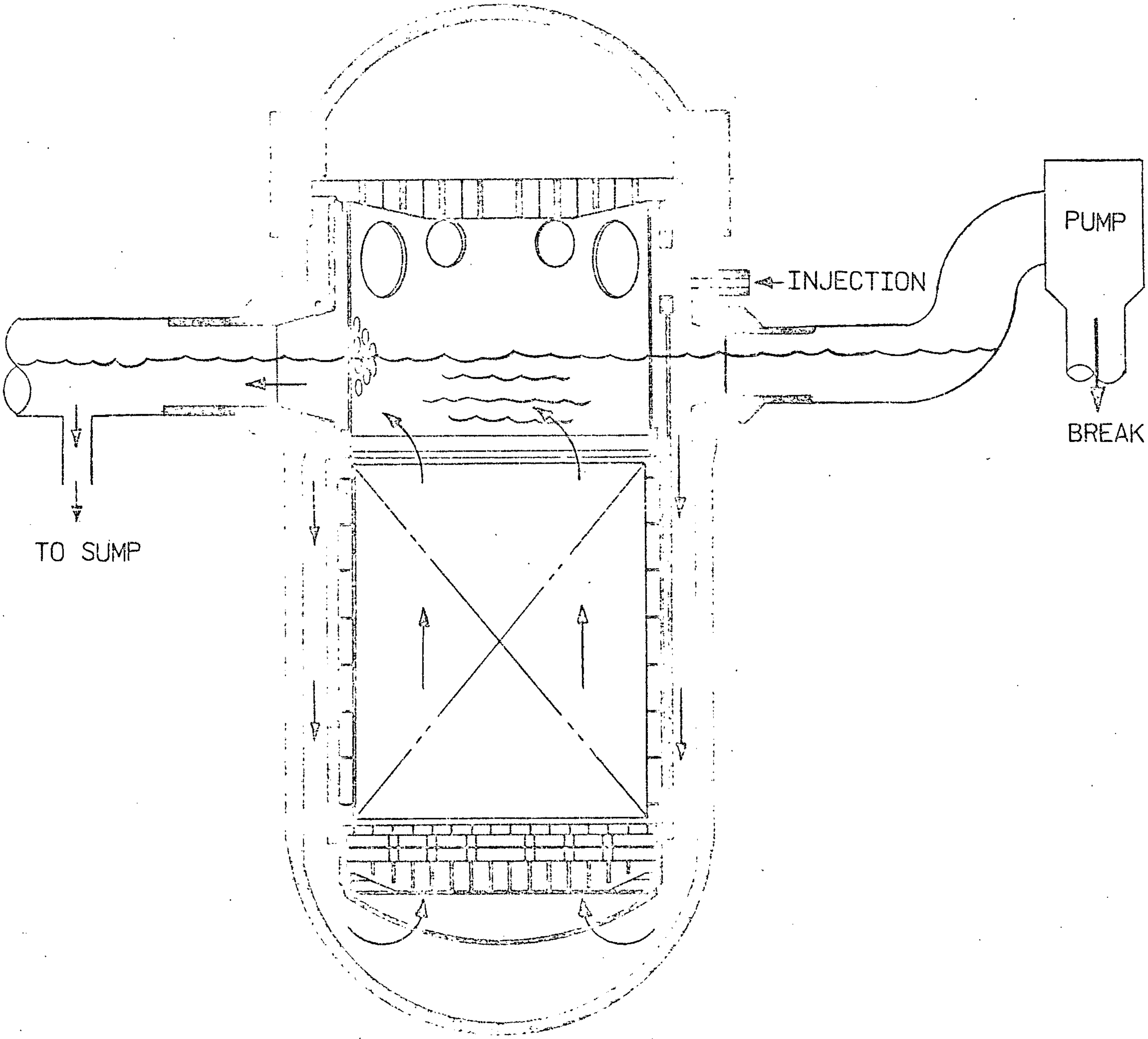


FIGURE 9

FLOW PATHS-PUMP SUCTION-LARGE BREAK
"FORCED CIRCULATION"

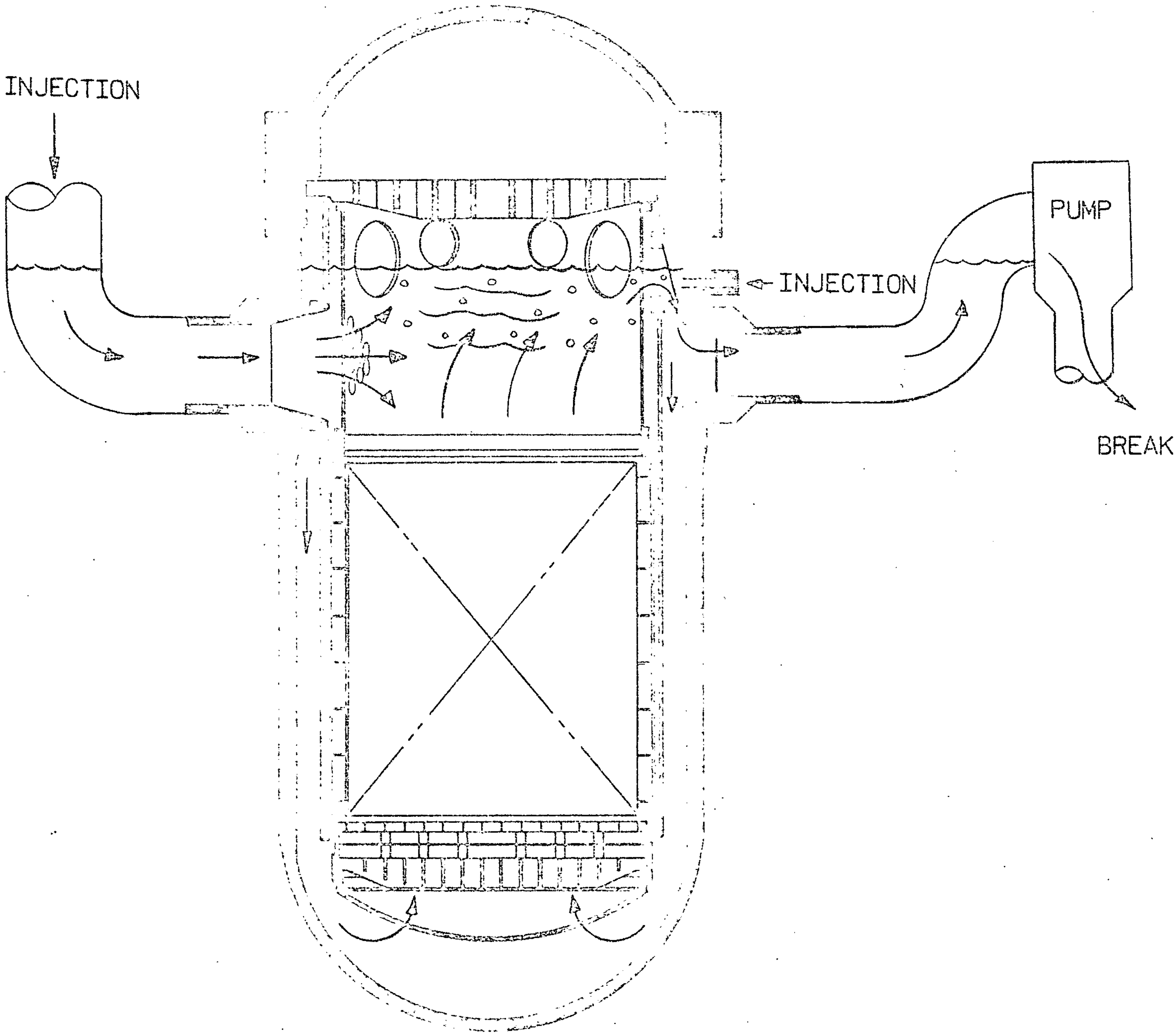


FIGURE 10

FLOW PATHS-PUMP SUCTION-LARGE BREAK

"HOT LEG INJECTION"

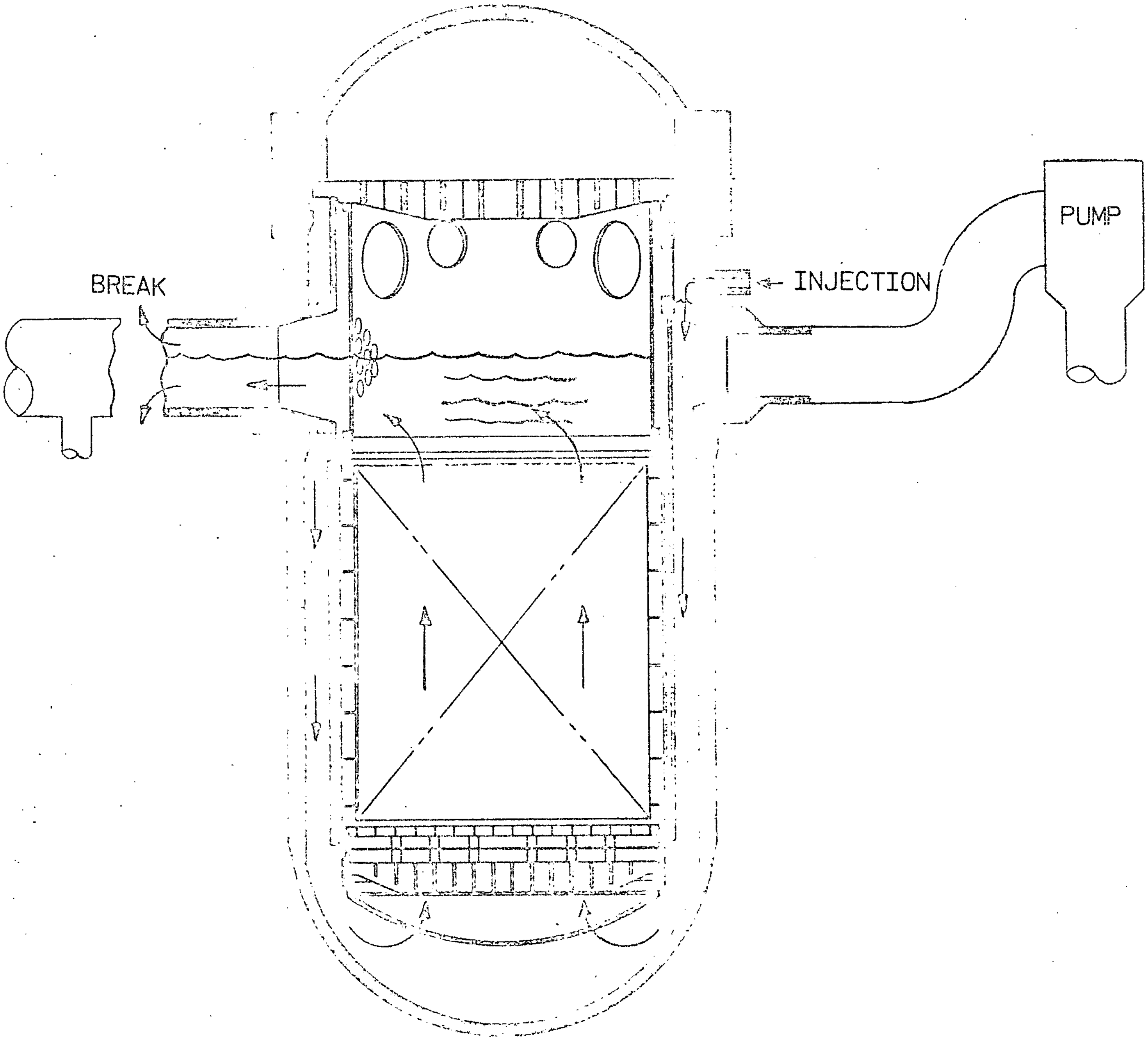


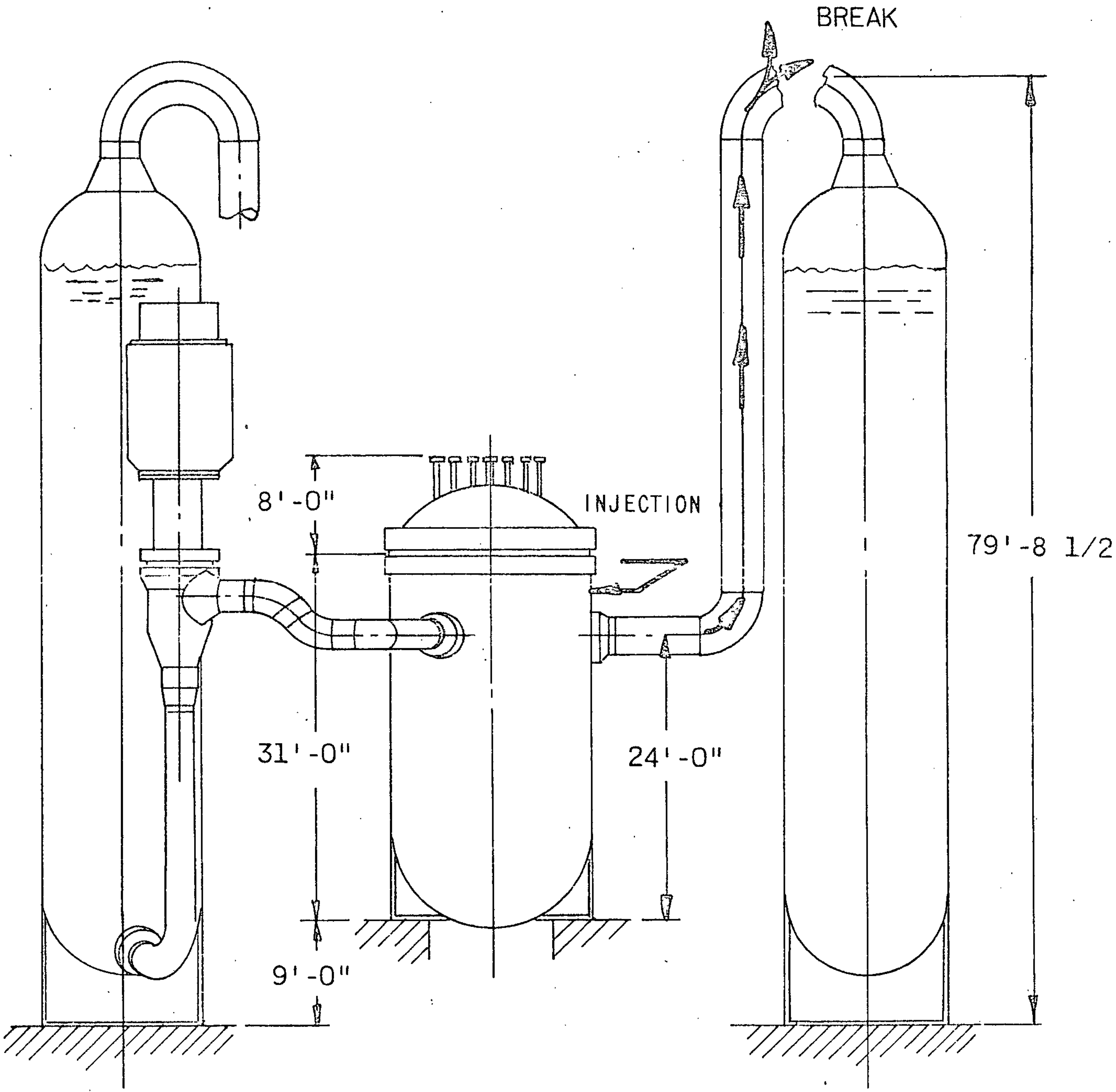
FIGURE 11

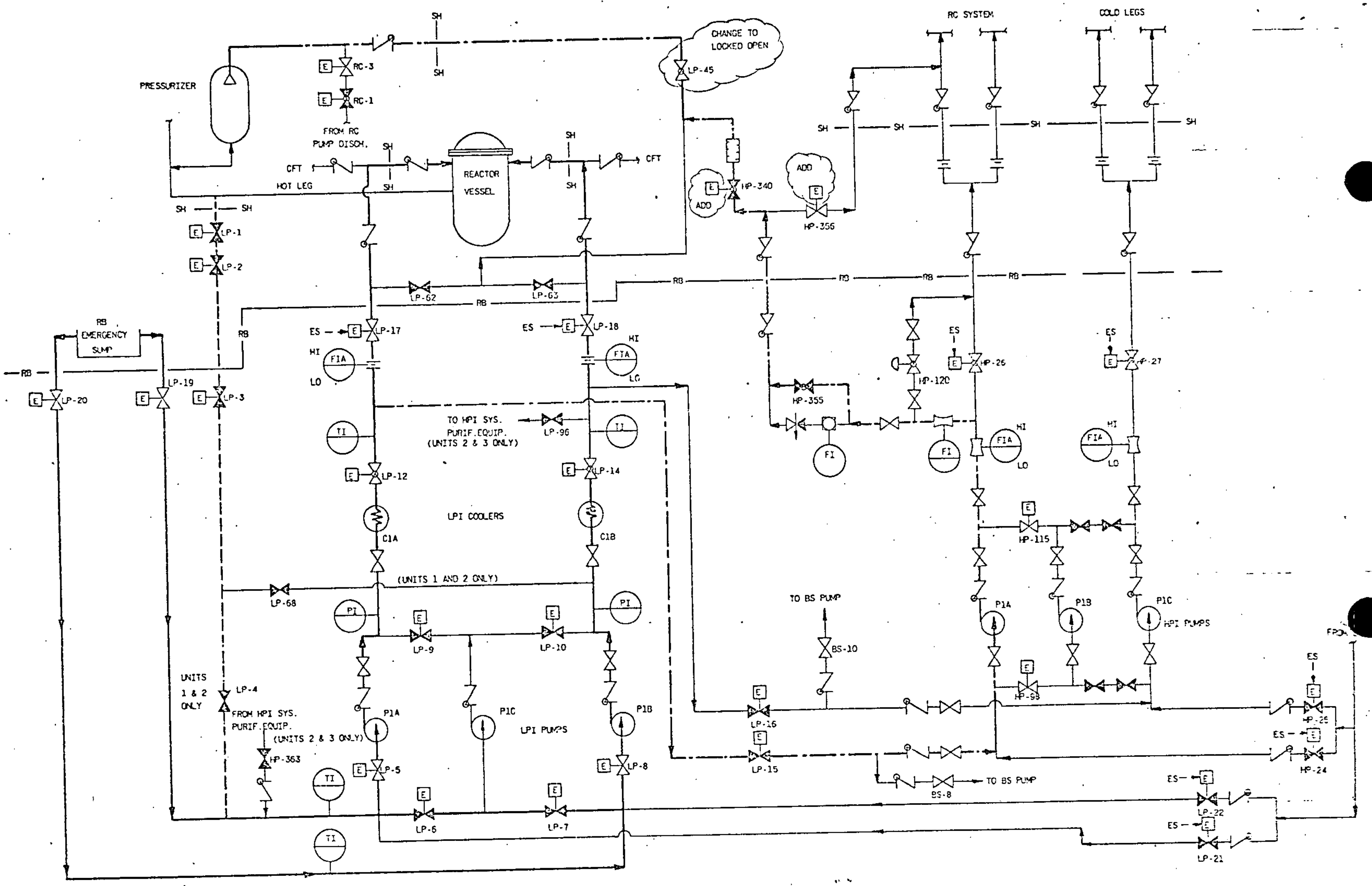
FLOW PATHS - REACTOR OUTLET - LARGE BREAK

"FORCED CIRCULATION"

FIGURE 12

HOT LEG BREAK TOP OF 180° BEND





ECCS SCHEMATIC DIAGRAM FOR OCONEE LONG TERM COOLING

Figure 13

Normal Injection
Decay Heat Line
Auxiliary Spray