JAERI-M
83-097

LOSS-OF-LOAD TRANSIENT CALCULATIONS FOR THE ROSA-IV LSTF AND THE REFERENCE PWR WITH RELAP5/MOD1 (CYCLE 1)

June 1983

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編集兼発行　日本原子力研究所
印　　刷　㈱高野高速印刷

Loss-of-Load Transient Calculations for the ROSA-IV LSTF and the Reference PWR with RELAP5/MOD1(Cycle 1)

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(Received June 3, 1983)

The response of LSTF and the reference PWR to two loss-of-load transients was analyzed with the RELAP5/MOD1, Cycle 1, computer program. The transients analyzed included a loss-of-load only (base case) and a loss-of-load without scram. These calculations were the first attempt to analyze the response of LSTF to a loss-of-load transient and, therefore, are not a final assessment of the system's capability to represent the PWR response.

Comparison of the results showed that LSTF has the capability to simulate the basic PWR response to a loss-of-load. For both transients calculated, the final state of LSTF and the PWR were the same, in that the primary systems had stabilized and were maintained in that condition by the same type of secondary system operation. Because of differences in initial core power and primary flow rate, however, the details of the thermal-hydraulic response (such as the system pressure and temperature) were different. Further study and analysis of the problem areas are recommended in order to find ways to improve the LSTF response relative to the PWR.

Keywords: ROSA-IV, LSTF, PWR, Loss-of-Load, Operational Transient, RELAP5, Computer Analysis, Comparative Evaluation.

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* USNRC sponsored delegate to the ROSA-IV Program.

ROSA－IV　LSTFおよびPWRの負荷喪失過渡のRELAP5／MOD1（Cycle　1）コードによる解析

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（1983年6月3日受理）

LSTFとPWRの2ケースの負荷喪失過渡に対する挙動をRELAP5／MOD1（Cycle　1）コードで解析した。解析したのは負荷喪失のみの場合（基準ケース）とスクラムしない負荷喪失の2ケースである。これらの解析はLSTFの負荷喪失の最初のものであり，LSTFがPWRの挙動をどれだけよく模擬しているかの最終評価ではない。

解析結果からLSTFがPWRの負荷喪失過渡の基準ケースをよく模擬しうることが分った。2ケースの過渡両方にたいしLSTF，PWRともに同様の最終状態におちついた。そして一次系は二次係の同じ様な操作により安定し，同じ状態に維持された。しかし初期炉心出力および流量に差があるため系圧力・温度等の詳細な熱水力挙動は異なっている。これらの点に関してはさらに解析を行い，LSTFの模擬性を向上する方法をみいだすことが望まれる。

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* 米国原子力規制委員会の出資によりROSA－IV計画に米国から派遣されている研究員

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1. INTRODUCTION

The Japan Atomic Energy Research Institute has initiated the Rig of Safety Assessment, Number 4 (ROSA-IV) program to study the thermal-hydraulics and plant parameters which affect the behavior of a pressurized water reactor (PWR) during a small break loss-of-coolant accident (SBLOCA) or an operational transient. The ROSA-IV program was initiated in response to the accident at Three Mile Island (TMI) which showed the need for more detailed study of these types of accidents and transients. The ROSA-IV program will operate two test facilities. The Two-Phase Test Facility (TPTF)[1] will be used to obtain fundamental two-phase data from separate effects tests in PWR components -- core, horizontal pipe and steam generator. The Large Scale Test Facility (LSTF)[2] will be used to conduct system and integral effects tests. Computer analyses of LSTF used to help in designing the facility and in planning the test matrix are described in this report.

As mentioned above, one of the areas to be investigated with LSTF is PWR behavior during an operational transient. Previous analyses of LSTF and the reference PWR have investigated the SBLOCA[3,4,5] and the loss-of-feedwater transient[6]. Therefore, there was an interest in analyzing the response of LSTF and the reference PWR to a loss-of-load transient to evaluate the capability of LSTF to simulate the PWR response. This evaluation was particularly important because LSTF will not be able to simulate full-scaled core power and flow. Because of these limitations, at steadystate LSTF will (1) operate at the maximum core power available, 10 MW (14% of full-scaled core power), (2) maintain the primary loop temperature distribution of the PWR in LSTF by using an initial flow rate which is 14% of full-scaled flow and (3) increase the steam generator secondary pressure to limit steadystate heat transfer to 10 MW. With these differences in initial conditions, method of operation and system capability there was the potential that the LSTF and PWR response to a loss-of-load transient would be significantly different. To make an initial evaluation of LSTF, the response of LSTF and the reference PWR to two loss-of-load transients was analyzed with the RELAP5/MOD1[7], Cycle 1, computer program. The first transient (Case 1) assumed all systems worked as designed during a loss-of-load. The second transient (Case 2) was the same except the transient was assumed to occur without scram. The results of these initial analyses are described in this report. These analyses are not a final assessment of the capability of LSTF to represent the PWR response to a loss-of-load transient but should be viewed as a starting point for further study and analysis.

Section 2 of this report briefly describes the LSTF design philosophy and ROSA-IV program objectives. Section 3 describes the analysis models used to perform the calculations, the results of the analyses are contained in Section 4 and Section 5 presents the main conclusions of the study.

2. OBJECTIVES AND DESIGN PHILOSOPHY OF ROSA-IV LSTF

2.1 Objectives

The purpose of tests to be performed at LSTF is to provide test data from a large-scale test facility on the transient performance of PWRs under small break loss-of-coolant accident and transient conditions and on the effectiveness of emergency safeguard systems and procedures under such conditions. The tests will also provide experimental data on two-phase fluid flow in PWRs. Specifically, LSTF will be used to:

(1) Study the effectiveness of the ECCS under SBLOCA and plant transient conditions. Both standard and potential, alternate ECCS will be evaluated.

(2) Study the effectiveness of secondary side cooling via the steam generators under SBLOCA and plant transient conditions.

(3) Examine the nature of forced and natural circulation cooling in PWRs in various flow regimes and cooling modes and in transition from one flow regime or mode of cooling to another.

(4) Examine the effect of break size and location on system behavior.

(5) Study the effects of non-condensible gases on system behavior during a SBLOCA or plant transient.

(6) Investigate alternate system designs and/or procedures which are being considered to improve system performance during a SBLOCA and/or plant transient.

(7) Provide test data with which to develop/verify the SBLOCA analytical model to be developed in connection with the ROSA-IV Program.

2.2 Design Philosophy

LSTF is an experimental test facility designed to model the full height primary system of a PWR. LSTF will use two equal volume loops to represent the four loops of the reference PWR. Therefore each loop in LSTF represents two loops of the PWR. The reference PWR for LSTF is a 1100 MWe (3423 MWt) PWR with 50,952 fuel pins arranged in 17 x 17 square lattices. The overall scale factor for LSTF is 1/48. LSTF is scaled as follows:

a. Elevations are preserved, i.e., the scaling ratio is 1/1. Preserving correct elevations is important in LSTF, since gravity strongly influences PWR long-term transient behavior, for instance, natural circulation.

b. Volumes are scaled by the facility scale factor of 1/48.

C. Flow Areas in the pressure vessel and steam generators are scaled by the facility scale factors of 1/48 and 1/24, respectively. But the flow area of the primary loop, i.e., the hot-leg and cold-leg, is determined to maintain both volume scaling and the Strouhal number so that flow regime transition could be simulated.

d. Core Power is scaled by the facility scale factor of 1/48 so that the power input per unit volume in the core region is the same as for the reference PWR. Note, for full power operation, the scaled power of the core would be 71 MW. However, heater rod power supply is limited to 10 MW. Hence, proper core power scaling can only be attained for a simulated core power starting at about 14% of full power.

e. Fuel Assembly dimensions, i.e., fuel rod diameter, pitch and length, guide thimble diameter, pitch and length, and the ratio of the number of fuel rods to the number of guide thimbles, are the same as for the 17 x 17 fuel assembly of the reference PWR in order to preserve the heat transfer characteristics of the core. The total number of rods is scaled by the facility scale factor and is 1060 heated and 104 unheated rods.

f. Design Pressures for the LSTF fluid systems will be at least the same as those for their counterparts in the reference PWR.

g. Fluid Flow ΔPs of major components, e.g., pumps, pressure vessel and steam generators will be the same as in the reference PWR.

h. Flow Capacities for LSTF systems are scaled by the power scale factor (1/342) to preserve the enthalpy distribution.

The major characteristics of LSTF are shown in Tables 2.1 and 2.2, a flow diagram is shown in Fig. 2.1 and a plan view of the primary loop is shown in Fig. 2.2.

Table 2.1 Major Characteristics of Large Scale Test Facility (LSTF) as of January 1983.

COMPONENT		PWR	LSTF	SCALE
PRESSURE VESSEL				
VESSEL INSIDE DIAMETER	(mm)	4394	640	1/6.87
VESSEL THICKNESS	(mm)	220	61	1/3.61
CORE BARREL OUTSIDE DIAMETER	(mm)	3874	534	1/7.25
DOWNCOMER LENGTH	(mm)	6147	6658	1/0.923
DOWNCOMER GAP	(mm)	260	53	1/4.91
DOWNCOMER FLOW AREA	(m^2)	3.38	0.0977	1/34.6
LOWER PLENUM FLUID VOLUME	(m^3)	29.6	0.617	1/48
UPPER PLENUM FLUID VOLUME (NOT INCLUDE UPPER HEAD VOLUME)	(m^3)	28.4	0.490	1/58.0
UPPER HEAD FLUID VOLUME	(m^3)	24.6	0.513	1/48
FUEL (HEATER ROD) ASSEMBLY				
NUMBER OF BUNDLES		193	24	
ROD ARRAY		17 x 17	7 x 7	
ROD HEATED LENGTH	(mm)	3660	3660	1/1
ROD PITCH	(mm)	12.6	12.6	1/1
FUEL ROD OUTSIDE DIAMETER	(mm)	9.5	9.5	1/1
THIMBLE TUBE DIAMETER	(mm)	12.24	12.24	1/1
INSTRUMENT TUBE DIAMETER	(mm)	12.24	12.24	1/1
NUMBER OF HEATER RODS		50952	1060	1/48.1
NUMBER OF NON-HEATING RODS		4825	104	1/46.4
CORE FLOW AREA (WITHOUT SPACER LOCATION)	(m^2)	4.75	0.120	1/39.6
CORE FLOW AREA (WITH SPACER LOCATION)	(m^2)	3.70		
CORE FLUID VOLUME	(m^3)	17.5	0.440	1/39.8
PRIMARY LOOP (SAME 2 LOOPS)				
HOT LEG INSIDE DIAMETER	(mm)	736.6	207	
HOT LEG LENGTH	(mm)	6993	3687	L/$\sqrt{D}$ SIMULATED
CROSSOVER LEG				
INSIDE DIAMETER	(mm)	787.4	168	
LENGTH	(mm)	8346	9547	
COLD LEG INSIDE DIAMETER	(mm)	698.5	207	
COLD LEG LENGTH	(mm)	7207	3438	

Table 2.1 (CONTINUED)

COMPONENT	PWR	LSTF	SCALE
PERSSURIZER			
VESSEL INSIDE DIAMETER (mm)	2126	600	1/3.54
VESSEL HEIGHT (mm)	15500	4200	1/3.69
TOTAL VOLUME (m^3)	51	1.1	1/48
FLUID VOLUME (m^3)	31	0.65	1/48
ACCUMULATOR (COLD AND HOT)			
VESSEL INSIDE DIAMETR (mm)	3500	950	1/3.68
VESSEL HEIGHT (mm)	5280	6600	1/0.80
TOTAL VOLUME (m^3)	38.2	4.8	1/7.96
LIQUID VOLUME (m^3)	26.9	3.38	1/7.96
RHR HEAT EXCHANGER			
NUMBER OF TUBES/1PASS	568	24	1/23.7
TOTAL U TUBE LENGTH (mm)	8600	8600	1/1
TUBE OUTSIDE DIAMETER (mm)	19.0	19.0	
TUBE INSIDE DIAMETER (mm)	16.6	15.8	
TUBE WALL THICKNESS (mm)	1.2	1.6	
TUBE PITCH (mm)	28.5	28.5	1/1
TUBE ARRAY	Δ	Δ	
HEAT TRANSFER AREA (m^2) (OUTER SURFACE)	590	25	1/23.6
STEAM GENERATOR (SAME 2 S.G s)			
NUMBER OF TUBES	3382	141	1/24
TUBE LENGTH (AVERAGE) (m)	20.24	19.71	1/1.03
TUBE OUTSIDE DIAMETER (mm)	22.2	25.4	
TUBE INSIDE DIAMETER (mm)	19.6	19.6	1/1
TUBE WALL THICKNESS (mm)	1.3	2.9	
HEAT TRANSFER AREA (m^2) (OUTER SURFACE OF TUBE)	4780	221.6	1/21.6
INLET PLENUM VOLUME (m^3)	4.18	0.174	1/24
OUTLET PLENUM VOLUME (m^3)	4.18	0.174	1/24
PRIMARY SIDE VOLUME (m^3)	30.14	1.214	1/24.8
SECONDARY SIDE VOLUME (m^3)	163.12	6.80	1/24

Table 2.2 Elevation of Each Position

POSITION		PWR	LSTF	SCALE
BOTTOM OF HEATER BUNDLE	(mm)	0	0	
TOP OF HEATER BUNDLE	(mm)	3660	3660	1/1
TOP OF DOWNCOMER	(mm)	4889	5399	1/0.906
BOTTOM OF DOWNCOMER	(mm)	-1259	-1259	1/1
CENTER OF COLD LEG	(mm)	5238	5503	1/0.952
TOP OF COLD LEG INSIDE DIAMETER	(mm)	5588	5606	1/0.997
CENTER OF LOOP SEAL LOWER END	(mm)	2095	1786	1/1.17
BOTTOM OF LOOP SEAL LOWER END	(mm)	1703	1703	1/1
CENTER OF HOT LEG	(mm)	5238	5503	1/0.952
TOP OF HOT LEG INSIDE DIAMETER	(mm)	5606	5606	1/1
BOTTOM OF UPPER CORE PLATE	(mm)	3968	3968	1/1
TOP OF LOWER CORE PLATE	(mm)	109		
BOTTOM OF TUBE SHEET OF STEAM GENERATOR	(mm)	7414	7642	1/0.970
PLENUM LOWER END OF STEAM GENERATOR	(mm)	5819	5819	1/1
TOP OF TUBES OF STEAM GENERATOR	(mm)	18584	18584	1/1

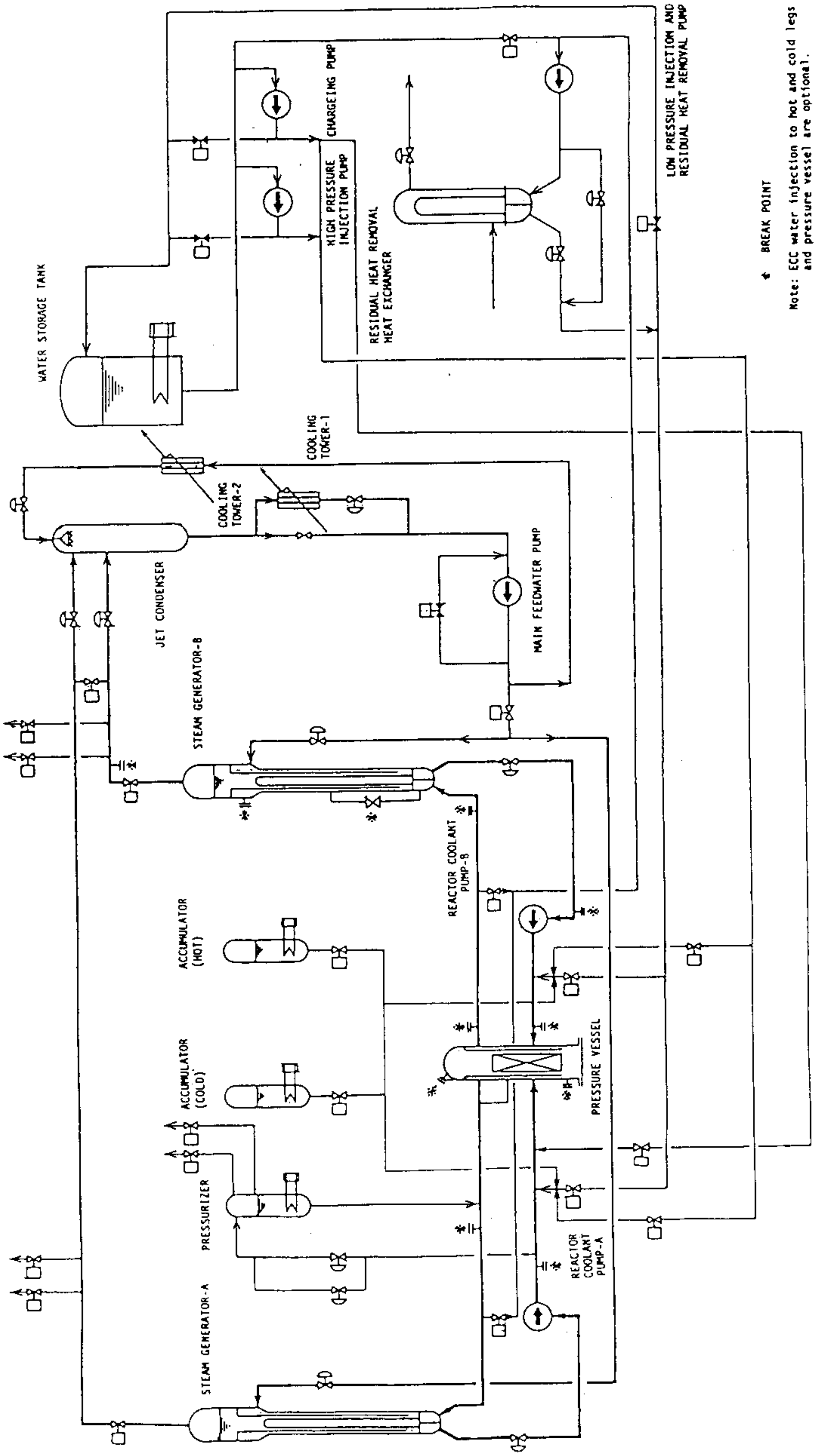

Fig. 2.1 Flow Diagram of LSTF

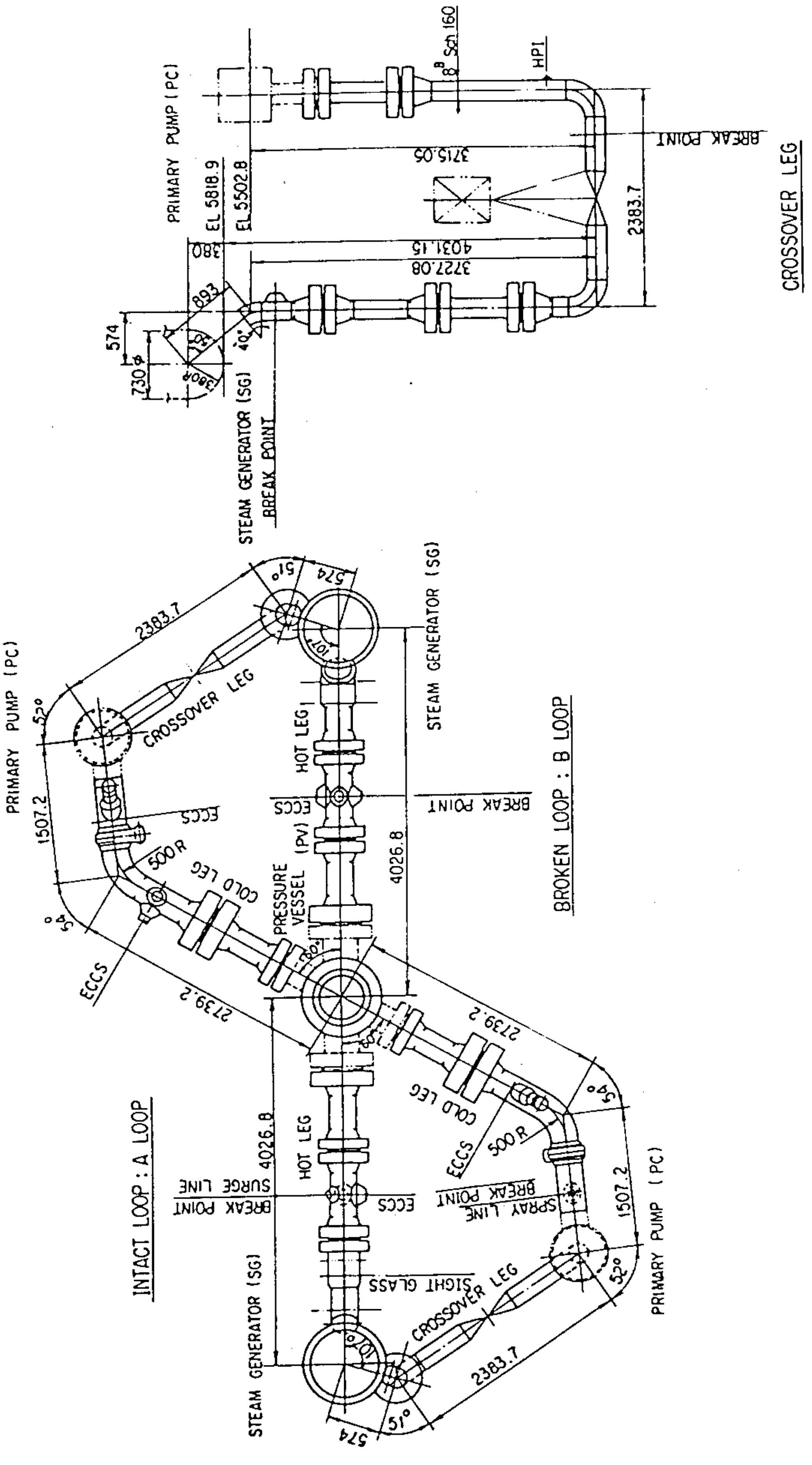

Fig. 2.2 Plan View of Primary Loop of LSTF

3. RELAP5 MODEL DESCRIPTIONS

The RELAP5 models used to make the calculations for LSTF and the reference PWR are described in Sections 3.1 and 3.2, respectively. The trip and control logic for the systems is described in Section 3.3.

3.1 LSTF RELAP5 Model

The RELAP5/MOD1, Cycle 1, model used to represent the LSTF system is shown in Figure 3.1. The model included 190 volumes and 198 junctions. Heat transfer from vessel structures and in the core and steam generators was modeled using 66 heat structures. Steam generator secondary systems, including the jet condenser, were modeled in detail. Since LSTF will have two symmetric loops, both loops in the model are the same except for the location of the pressurizer and the break (if needed).

The RELAP5 control system capability was used to model the control system for the LSTF jet condenser spray and the primary mean temperature control logic for the turbine bypass valve. This is described in detail in Section 3.3.

The initial conditions for the transient calculations were obtained from a RELAP5 steady-state calculation. The initial conditions for LSTF, in Table 3.1, were developed based on maintaining the same initial steam generator downcomer (SG) level as in the PWR calculations (approximately 44%). However, because of the smaller core power in LSTF and differences in the steam generator secondary void distribution the secondary mass needed to get a downcomer level of 44% in the LSTF model was greater than that obtained by scaling the secondary mass of the PWR broken loop steam generator by 2/48 (each LSTF steam generator represents two steam generators in the reference plant). This difference was about 520 kg (2150 kg/SG in LSTF versus 1630 kg/SG scaled from the PWR). There were small differences in the initial temperatures and pressures between the LSTF model and the PWR model, but these did not affect the transient calculations. There were larger differences in the initial primary flow rate, core power and secondary mass for the three models, and of these the differences in primary flow rate and core power did affect the transient calculations as discussed in Section 4.

3.2 PWR RELAP5 Model

The nodalization diagram for the RELAP5/MOD1, Cycle 1, model used to represent the reference PWR is shown in Figure 3.2. The model included 185 volumes and 192 junctions. Heat transfer in the system was modeled using 72 heat structures. Detailed modeling of the steam generator secondary systems was included out to the turbine throttle and turbine bypass valves. The intact loop represents three loops and the broken loop one loop in the PWR.

To facilitate comparison of the calculated results to those obtained with the LSTF model, as much as possible, the same modeling approach was applied in setting up the PWR model as the LSTF model. Differences in the models occur where a lack of detailed information was faced when modeling the PWR or where the design of the systems is clearly different, as is the case in the secondary systems downstream of the steam generator outlets. In general, however, the description of the LSTF model, above, applies to the PWR model as well.

The initial conditions for the PWR transient calculations were obtained from a RELAP5 steady-state calculation. The initial conditions are listed in Table 3.1 for comparison to the LSTF data.

3.3 Trip and Control Logic

The trip logic used in the LSTF and PWR calculations to control the steam generators and the plant protection systems (core trip and emergency core cooling system (ECCS)) was based on the trip logic of the reference plant. These trips are described in Table 3.2.

The turbine bypass valve (TBV) control logic based on the primary mean temperature was modeled in both the PWR and the LSTF calculations. This logic is designed to use the turbine bypass valve to maintain a primary mean temperature of 564.9 K after scram by opening or closing the valve depending on whether the mean temperature is above or below this setpoint. The same control system was applied to both systems in the calculations.

In the LSTF model, a control system was setup to control the jet condenser spray. In LSTF, the control system will be used to adjust the spray flow rate in order to maintain the jet condenser pressure at its initial value (about 7.07 MPa) during most experiments.

During a loss-of-load transient in the reference plant the main feedwater system will remain operational and will be controlled to maintain the zero load SG downcomer level of 33%. The feedwater valve control system will have three input variables - downcomer level, steam flow rate and feedwater flow rate. This control was modeled in the calculations by assuming the dominant factors during a loss-of-load would be the steam flow rate and the downcomer level. Because of the smaller than scaled core power in LSTF, the assumptions in setting up the models for the two transients analyzed were slightly different. In the analysis of the base case transient, since scram was assumed to occur, the main feedwater flow was set to be 6% of initial flow at the 33% level. Since the core power in LSTF will be correctly scaled below 14% of full power (i.e. after scram) the flow in the LSTF model was input as 2/48 the flow in the PWR model. This was ramped to zero flow at a downcomer level of 41% and 12% flow at a level of 25%. In the transient without scram, the main feedwater flow was set to be 100% of the initial flow at the 33% downcomer level. This was done because without scram occurring, the steam flow would remain near its initial value. Because of the smaller than scaled core power in LSTF, however, the flow used in the LSTF model was based on the initial LSTF flow (and the maximum core power of 10 MW) rather than the values scaled from the PWR. The flow was ramped to zero flow at the 41% level and 133% of initial flow at the 25% level (a maximum main feedwater flow rate of 133% of initial flow was assumed).

Table 3.1 LSTF and PWR Initial Conditions

	LSTF	PWR
System Pressure (MPa)	15.59	15.60
Cold Leg Temperature		
Intact Loop (K)	562.31	562.20
Broken Loop (K)	562.28	562.22
Hot Leg Temperature		
Intact Loop (K)	598.24	598.22
Broken Loop (K)	598.24	598.22
Core Temperature Difference (K)	35.93[a]	36.02[a]
Core Flow Rate (kg/s)	48.40[b]	16516.
Core Power (MW)	10.0[b]	3423.
Steam Generator Secondary		
Intact Loop		
Pressure (MPa)	7.12[c]	5.71
Mass (kg)	2151.4	117043.
Downcomer Level (%)	44.5	44.8
Broken Loop		
Pressure (MPa)	7.12[c]	5.71
Mass (kg)	2148.7	39068.
Downcomer Level (%)	44.4	45.0

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[a] Based on intact loop data.

[b] Both the initial flow rate and core power are 14% of the full-scaled values based on a system scale factor of 1/48.

[c] The initial SG secondary pressure is higher in LSTF than in the PWR to reduce the steady-state heat transfer to 10 MW.

Table 3.2 Trip Logic

Action	Setpoint
① PWR Scram, SG turbine throttle valve closes; turbine bypass valve opens[a]	On loss of load
② LSTF core power trip	1 + 7.1 s
③ Trip coolant pump and initiate HPI and safety injection	$P < 12.27$ MPa[b] or $P < 4.235$ MPa[c]
④ Main FW control	Control main Fw to maintain 33% level in SG downcomer[b]
⑤ Main steam isolation valve closes	$P < 4.235$ MPa[c]
⑥ Steam generator relief valve	
Open	8.03 MPa[c]
Close	7.72 MPa[c]
⑦ PORV	
Open	16.20 MPa[b]
Close	16.07 MPa[b]

---

[a] The turbine bypass valve opens if the primary mean temperature is above 564.9 K(plus a 2.78 K delay), otherwise it is closed.

[b] Pressurizer pressure

[c] Steam generator steam dome pressure.

[d] Main feedwater is controlled to maintain the collapsed liquid level in the upper SG downcomer at 33% of full-scale during a loss-of-load

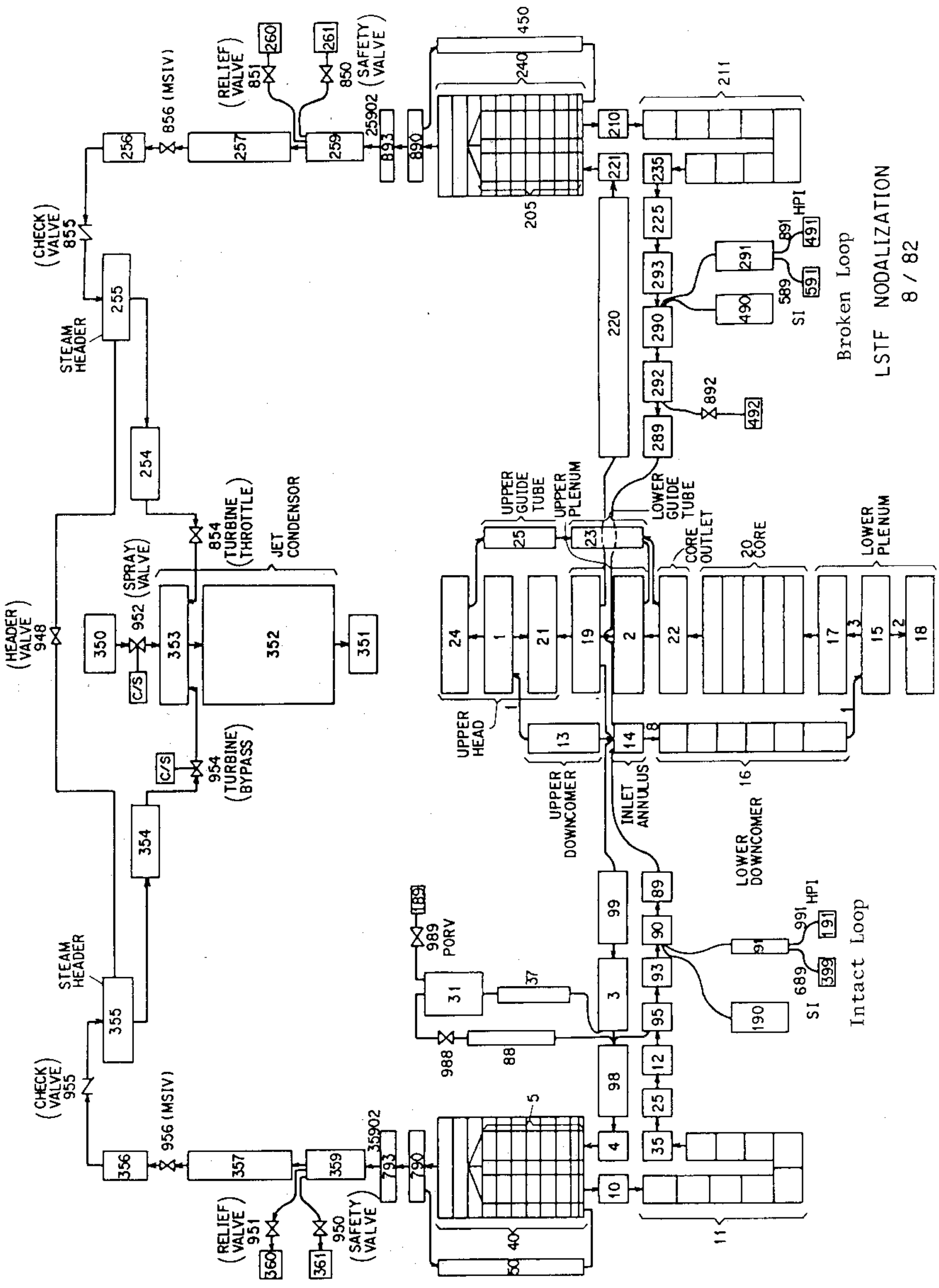

Fig. 3.1 Nodalization of LSTF

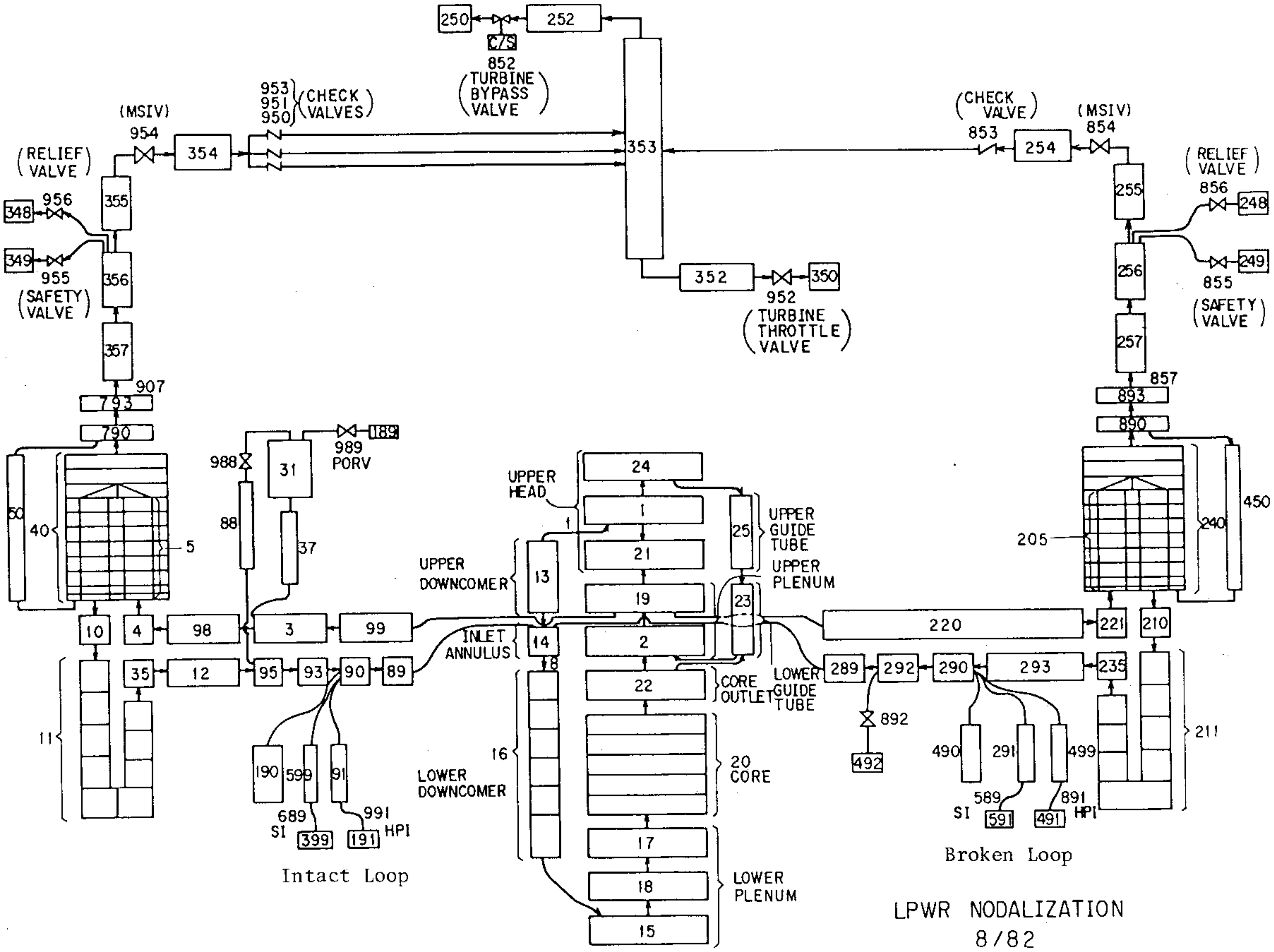

Fig. 3.2 Nodalization of PWR

4. Analyses of Calculated Results

The analyses of the loss-of-load calculations completed as part of this study are presented in this section. Section 4.1 presents the calculated results for the loss-of-load in which all systems worked as designed (Case 1). The results of the calculation in which scram was assumed not to occur (Case 2), are presented in Section 4.2.

4.1 Analysis of Case 1 - Loss-of-Load with all Systems Operational

In both the LSTF and PWR calculations, the loss-of-load was assumed to occur at t=0.0 (due to turbine failure) and is followed immediately by reactor scram. The secondary pressure response in the two calculations is shown in Figure 4.1. In the PWR run, the pressure increased at t=0.0 because, with the loss-of-load, the turbine throttle valve was closed. The pressure increased until 150 s when the primary mean temperature (PMT) exceeded the turbine bypass valve (TBV) set point and the TBV opened (see Figure 4.2 and 4.3). After this time, the secondary pressure remained constant as the TBV maintained the primary mean temperature.

The secondary pressure in the LSTF run did not increase as much at the beginning of the calculation because the turbine bypass valve opened (see Figure 4.3) while it was initially closed in the PWR calculation. This difference was due to the different primary mean temperature response early in the transient (see Figure 4.2) which was a result of the smaller than scaled flow during the transient in the LSTF analysis. In the PWR run, the primary mean temperature decreased rapidly at scram because, with the full core flow available, the hot leg temperature decreased rapidly and the PMT dropped below the TBV setpoint. In the LSTF run, however, because of the smaller than scaled primary flow, the hot leg temperature did not decrease as rapidly as in the PWR run. This resulted in a higher PMT which opened the turbine bypass valve. The changes in the LSTF secondary pressure from 0 to 500 s were probably due to changes in the overall secondary heat balance as the TBV setting changed and primary to secondary heat transfer fluctuated slightly. After 500 s the pressure was constant as the turbine bypass valve controlled the PMT.

The final secondary pressure in the two calculations was different because of the smaller than scaled primary flow in the LSTF calculation. At a given core power, the smaller flow in LSTF results in a larger core temperature difference. Therefore, since the final PMT was the same in both calculations (see Figure 4.2), the hot leg and cold leg temperatures in the LSTF run were higher and lower than the respective temperatures in the PWR run. In order to get the lower cold leg temperature in the LSTF calculation, the secondary pressure had to be lower.

The initial primary pressure decrease in the PWR calculation was more rapid than in the LSTF run again because of the difference in primary flowrate (see Figure 4.4). With the smaller than scaled flow in the LSTF run, the hot leg fluid cooled at a slower rate after scram than in the PWR run. Since the fluid cooled more slowly, the specific volume decreased more slowly and, therefore, the pressure decreased at a slower rate. The PWR pressure increased after the initial drop because primary to secondary heat transfer was less than the energy input by the core (see Figure 4.5). The primary pressure in both calculations stabilized after the turbine bypass valve began to maintain the PMT.

Both calculations showed the systems stabilized with the primary system in a hot standby condition. This condition was maintained by a secondary feed and bleed through the feedwater and turbine bypass valve systems.

4.2 Analysis of Case 2 - Loss-of-Load without Scram

In the analysis of the loss-of-load without scram, the information needed to model the reactor kinetics in the PWR was not available and, therefore, the affects of reactivity feedback due to changes in moderator density and fuel temperature are not included in the calculation. To simulate the loss-of-load without scram in the PWR calculation, the core power was held constant at its initial value throughout the run. The lack of information on the reactor kinetics in the reference PWR also precluded any attempt to model the reactivity feedback effects in the LSTF run as well, so the transient was run with the LSTF model by holding the core power constant at its initial value.

The loss-of-load was assumed to occur at t=0.0. With the loss-of-load, the turbine throttle valve closed and the turbine bypass valve opened in both calculations and remained open because the PMT was above the setpoint (see Figure 4.6 and 4.7). Because scram did not occur, the PMT increased after the loss-of-load because the heat transfer to the secondary dropped below the energy input by the core as shown in Figures

4.8 and 4.9. The increase was larger in the PWR calculation relative to the LSTF run because the core power in LSTF was only 14% of full-scaled core power.

The decrease in heat transfer to the secondary was a result of the change in the secondary flow path from the turbine throttle to the TBV. Since the turbine bypass valve only had the capacity to remove 70% of full core power at the initial steam generator secondary pressure, the secondary pressure increased at t=0.0 (see Figure 4.10), decreasing the primary to secondary temperature difference and, therefore, the heat transfer. In both calculations, the secondary pressure increased until the flow through the turbine bypass valve equaled the initial flow through the throttle valve and the energy balance between the primary and secondary was restored. There was a larger increase in the PWR secondary pressure when compared to the LSTF pressure because the core power in LSTF was only 14% of the full-scaled core power.

The primary system pressures in both runs also increased at the initiation of the transient (Figure 4.11) because the fluid heated up and expanded. The pressure increase in the PWR run was larger because of differences in core power. The pressure in the PWR calculation increased to the PORV setpoint and the PORV cycled several times before the energy balance was restored and the pressure plateaued. The PORV also cycled once at about 540 s in the PWR calculation. The fact that the PWR calculation indicated the PORV was required to control the transient and the LSTF calculation did not, implies the results of LSTF tests will not be able to be applied directly to PWR operation. Some form of intermediate analysis will be necessary to assess the affect of LSTF's limitation

At the end of the calculations, the primary systems had stabilized, but were at pressures and temperatures higher than their initial values. They were being maintained in this condition by secondary systems operating at a higher than initial pressure in order to remove full core power using the feedwater and turbine bypass valve systems.

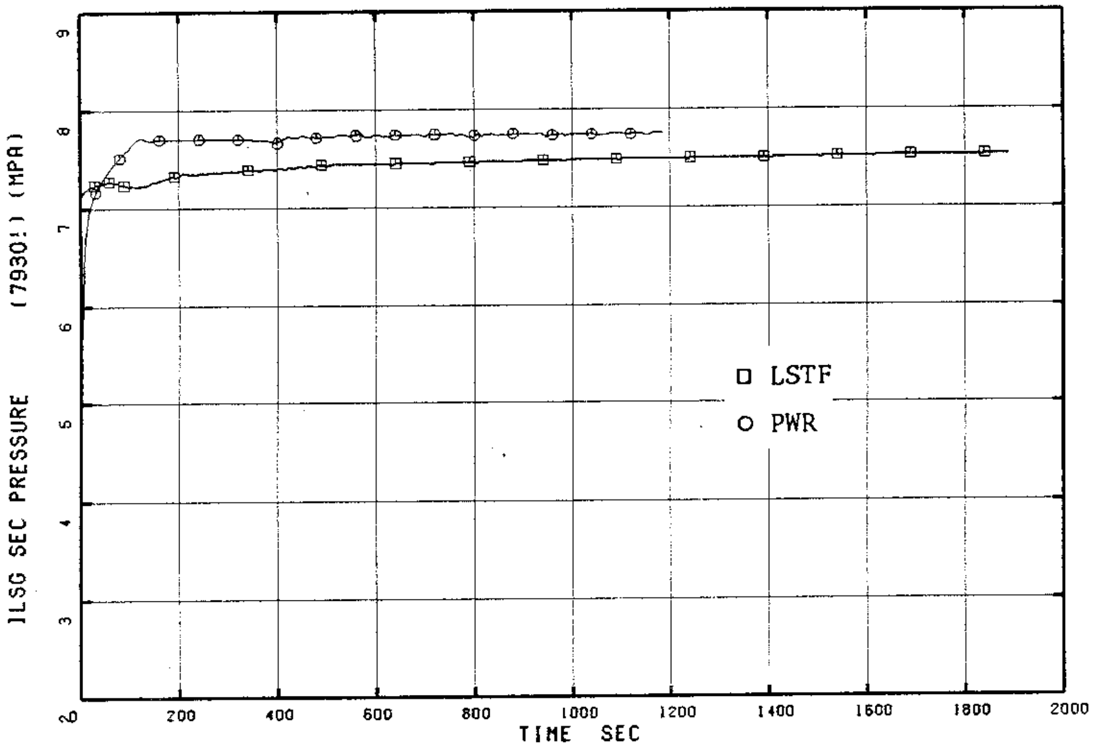

Fig. 4.1 Intact Loop Steam Generator Secondary Pressure - Case 1

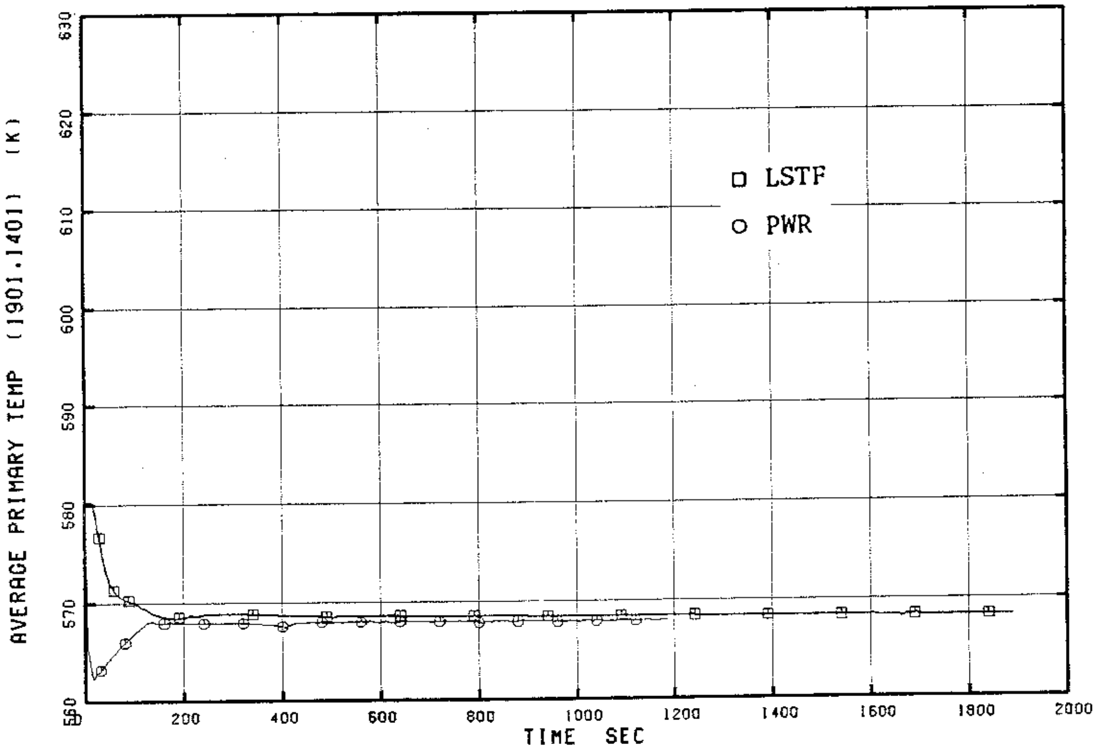

Fig. 4.2 Primary Mean Temperature - Case 1

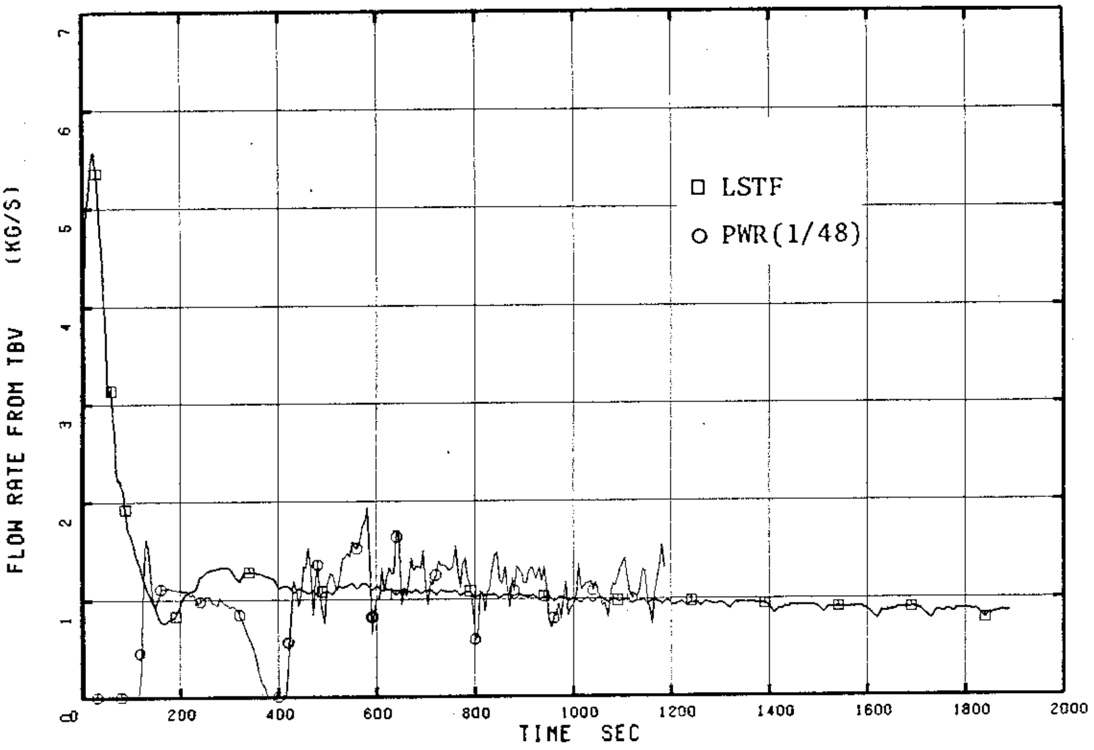

Fig. 4.3 Turbine Bypass Valve Flow Rate - Case 1

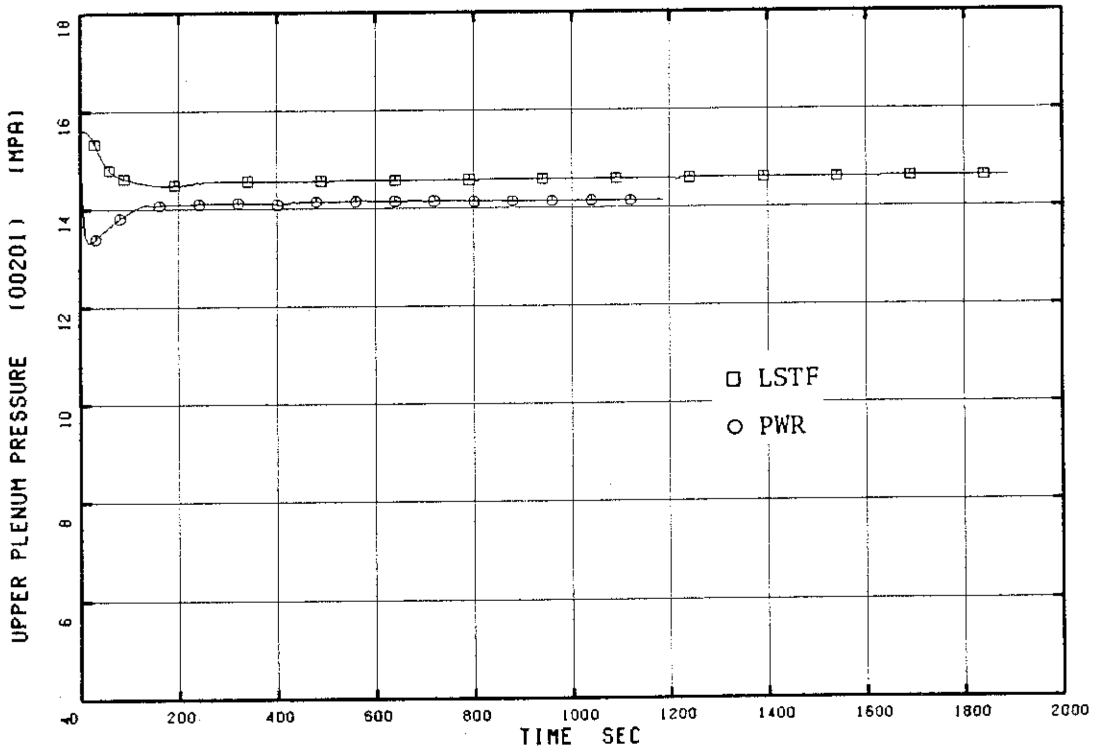

Fig. 4.4 Upper Plenum Pressure - Case 1

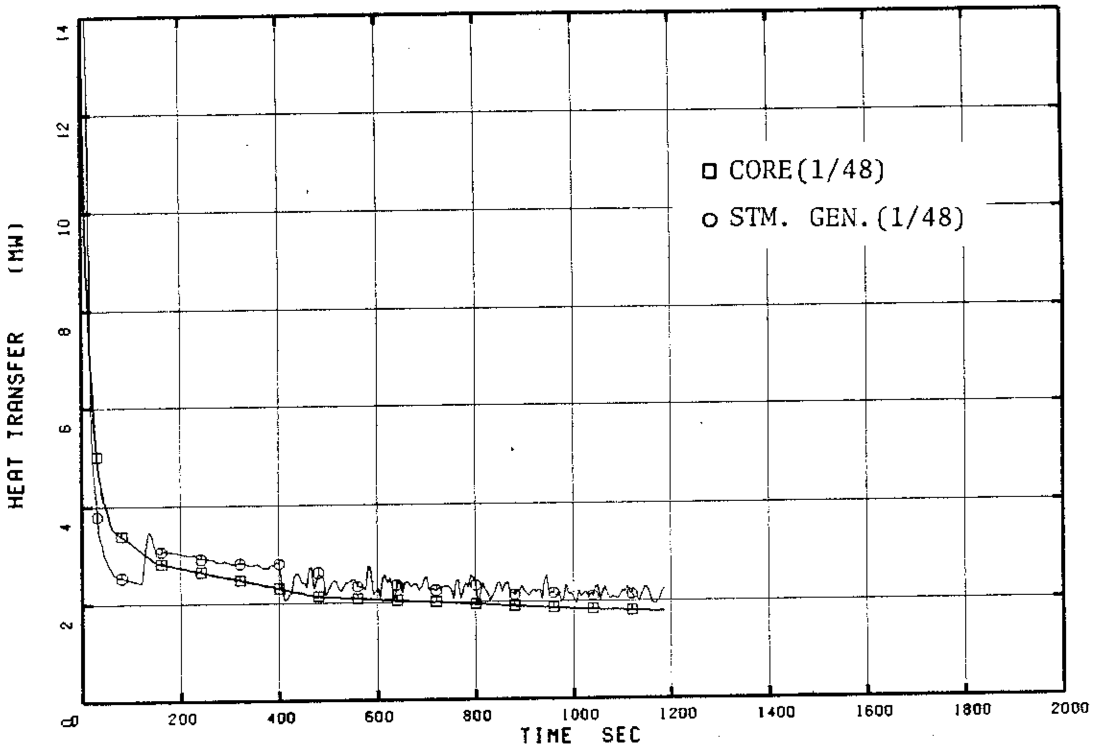

Fig. 4.5 PWR Core and Steam Generator Heat Transfer - Case 1

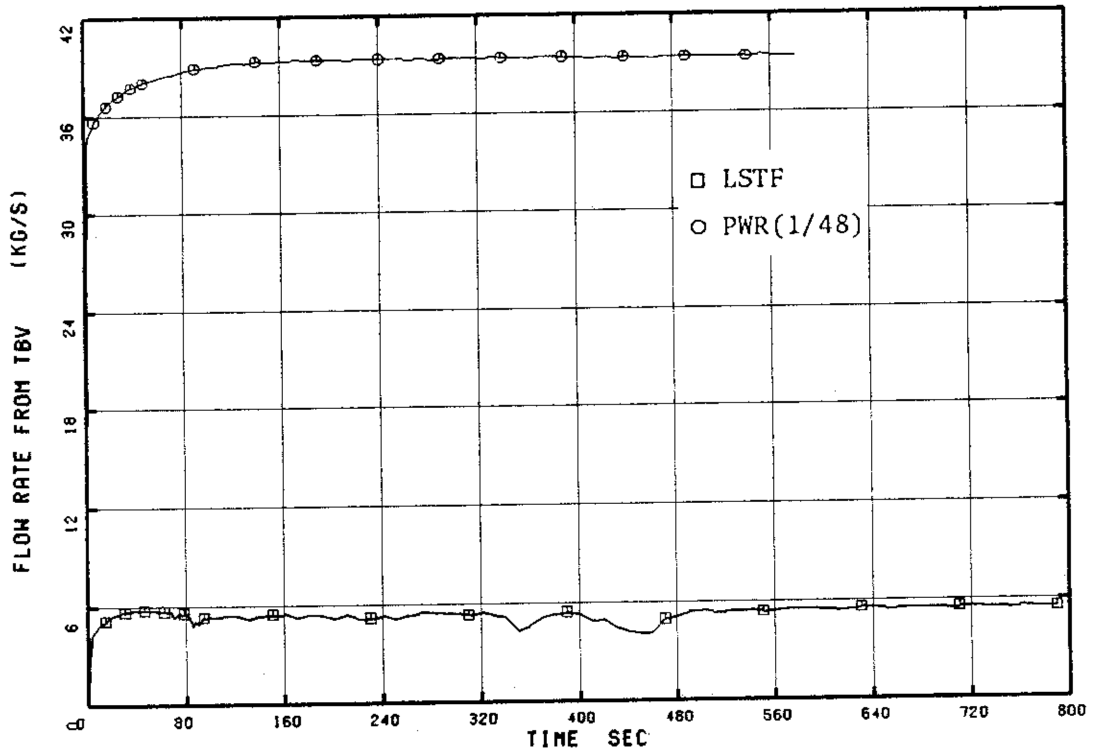

Fig. 4.6 Turbine Bypass Valve Flow Rate - Case 2

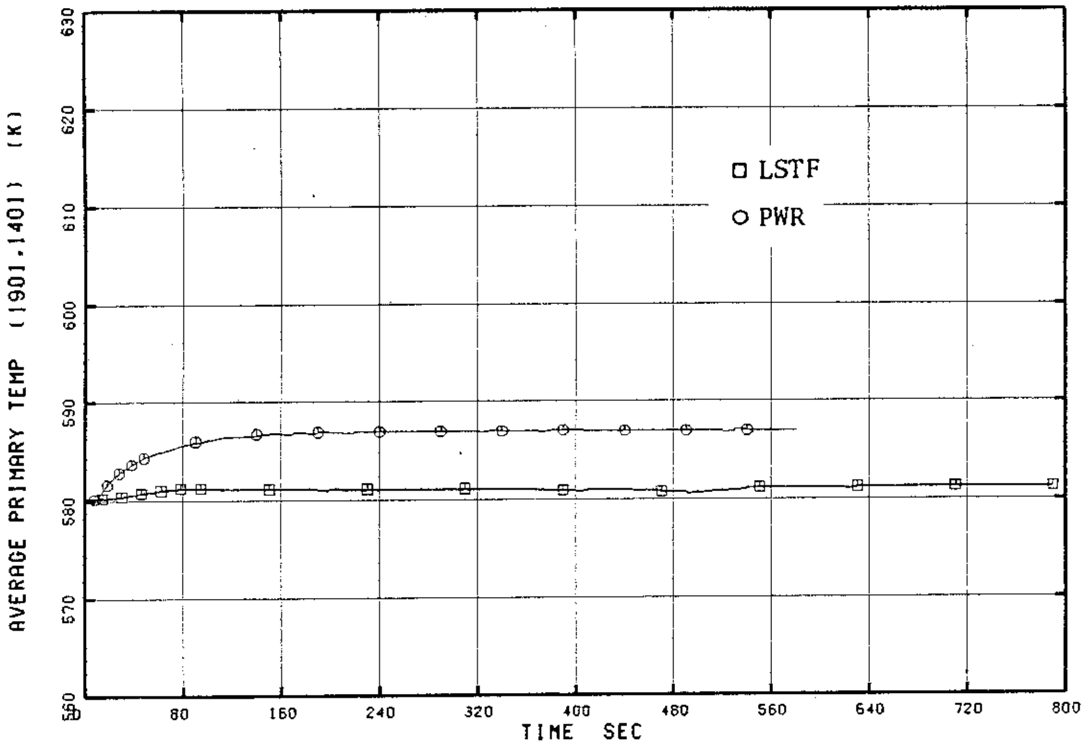

Fig. 4.7 Primary Mean Temperature - Case 2

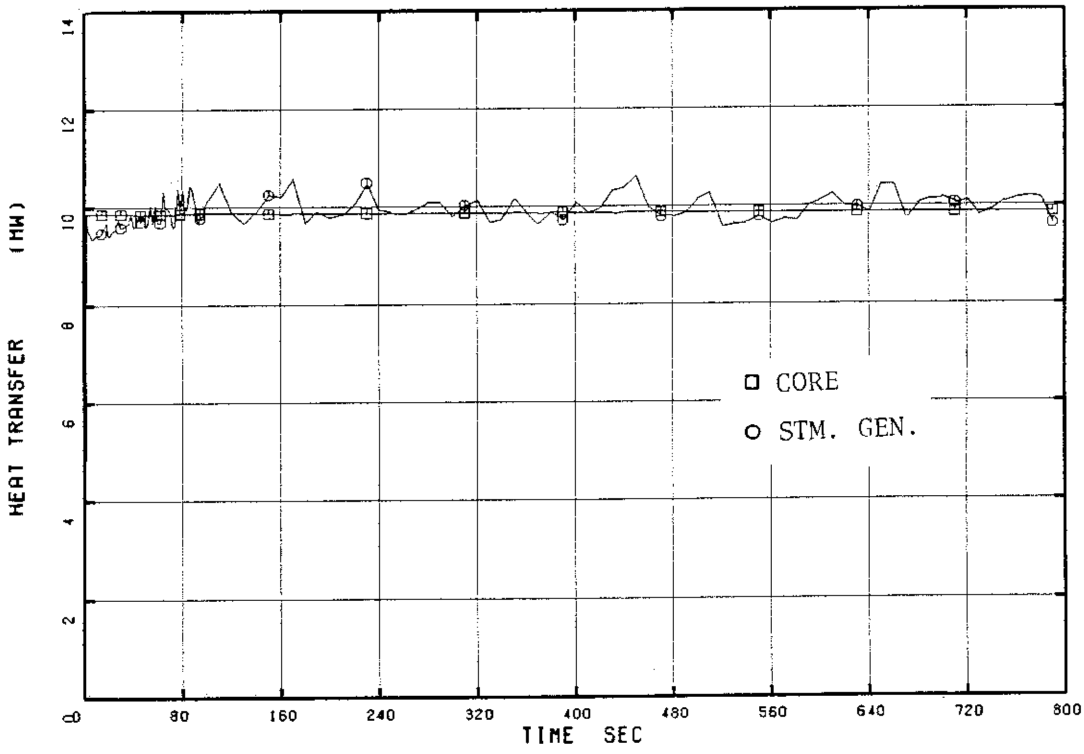

Fig. 4.8 LSTF Core and Steam Generator Heat Transfer - Case 2

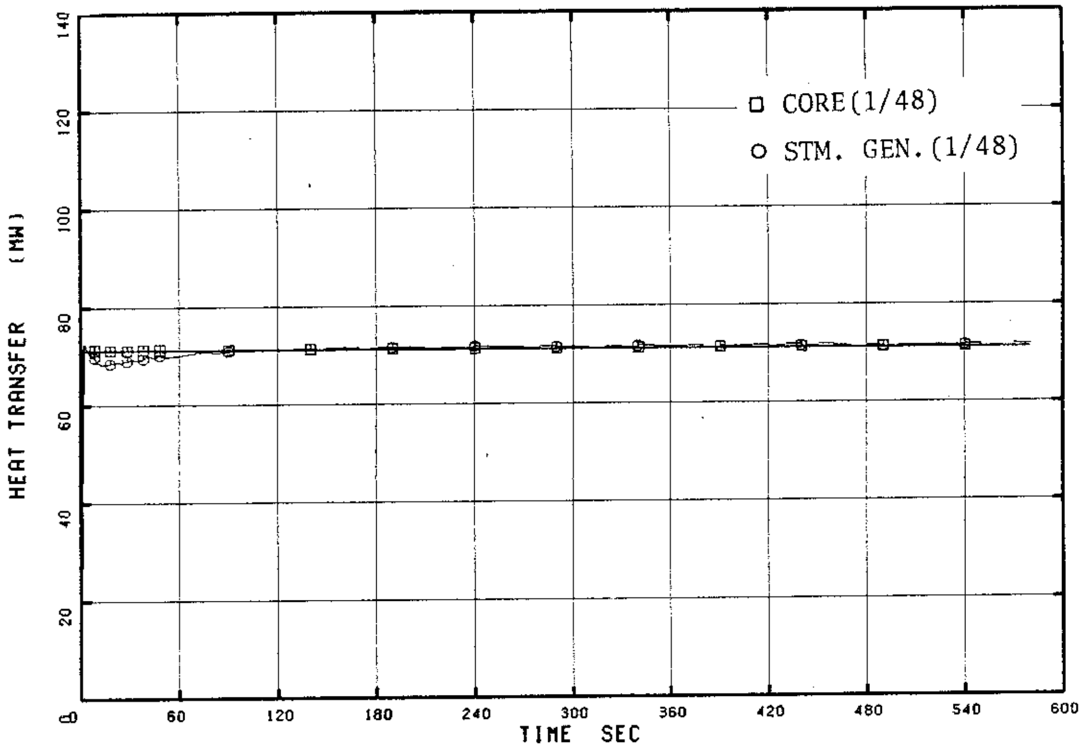

Fig. 4.9 PWR Core and Steam Generator Heat Transfer - Case 2

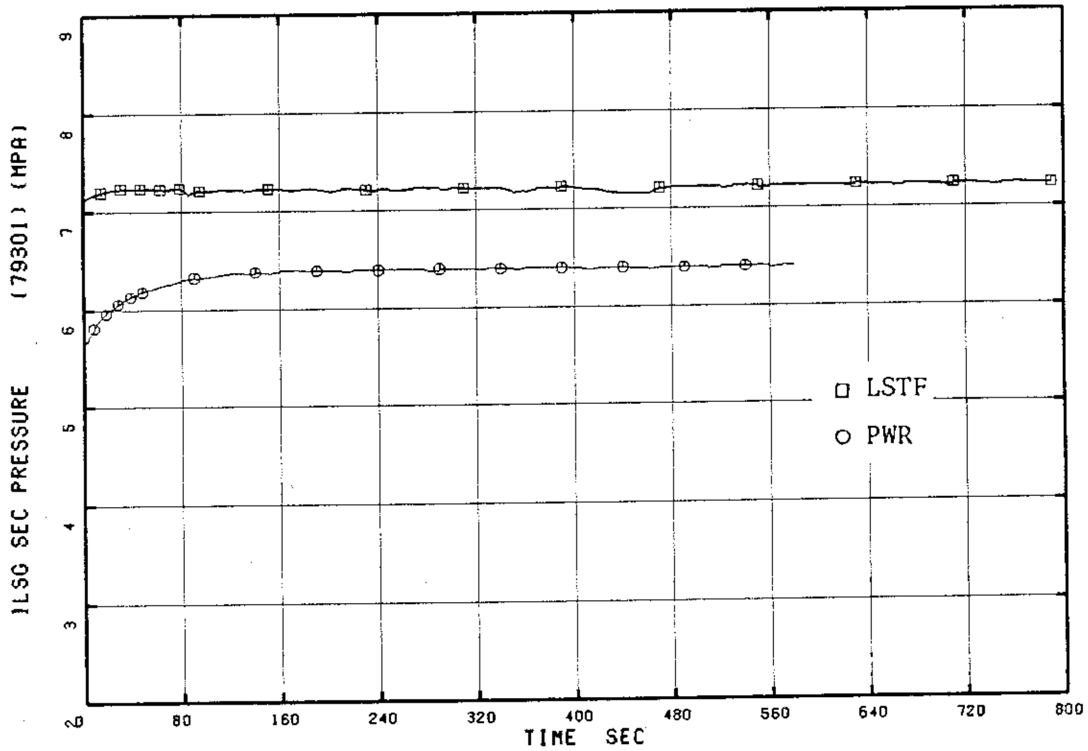

Fig. 4.10 Intact Loop Steam Generator Secondary Pressure - Case 2

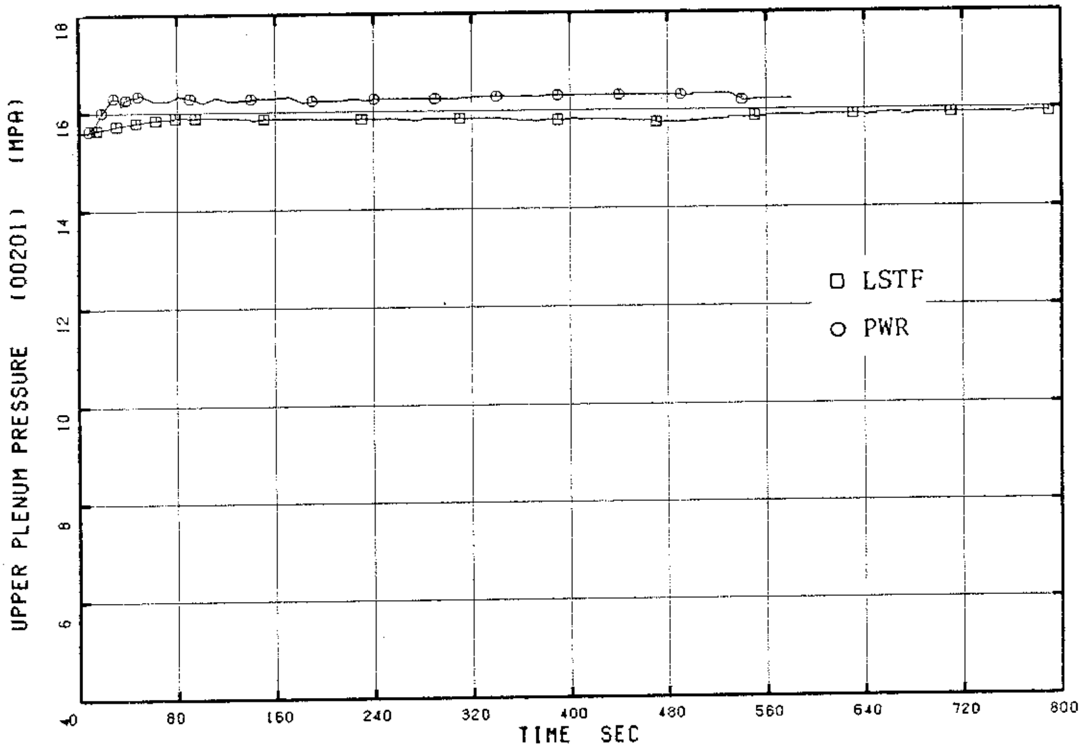

Fig. 4.11 Upper Plenum Pressure - Case 2

5. Conclusions

The loss-of-load calculations described in this report indicated the overall system response in LSTF would be the same as the overall system response in the reference PWR. For both transients calculated, the final state of LSTF and the PWR were the same, in that the primary systems had stabilized and were maintained in that condition by the same type of secondary system operation. The LSTF data will, therefore, be useful for code assessment and development because phenomena similiar to that in a PWR will be simulated.

Because of differences in primary flow rate and core power, however, the details of the thermal-hydraulic response (such as the system pressure and temperature response) were different. These differences in the details of the system response indicate the results of LSTF tests will not be able to be applied directly to PWR operation. Some form of intermediate analysis will be necessary to assess the affect of LSTF's limitations on the system response.

Because the present calculations do not take into account the influence of reactivity feedback due to fuel and moderator temperature changes on core power, it is recommended the PWR loss-of-load calculation without scram be redone, taking these factors into account, in order to provide a more realistic analysis of the PWR response in this situation. This would also provide useful information on the capability of LSTF to simulate the PWR response in a situation where reactivity feedback was an important part of the PWR system response.

ACKNOWLEDGEMENTS

The Authors are grateful to Dr. Y. Koizumi and Dr. Y. Kukita for their review of the text of this report.

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ACKNOWLEDGEMENTS

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