NUREG/IA-0059

International Agreement Report

Assessment of RELAP5/MOD2 Against Natural Circulation Experiments Performed with the REWET-III Facility

Prepared by
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Office of Nuclear Regulatory Research
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ABSTRACT

Natural circulation experiments carried out in the REWET-III facility in 1985 have been used for RELAP5/MOD2 assessment. The REWET-III facility is a scaled-down model of VVER-440 type reactors. The facility consists of a pressure vessel in which the downcomer is simulated with an external pipe assembly, hot and cold legs with loop seals and a horizontal steam generator. The volume scaling factor compared to the reference reactor is 1:2333.

The present paper summarizes the experiences gained in the RELAP5/MOD2 calculations of selected REWET-III single- and two-phase natural circulation experiments. The code's ability to represent the main phenomena of experiments in both cases was satisfactory.

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EXECUTIVE SUMMARY

Single- and two-phase natural circulation can play an important role as a passive heat removal mechanism in LWRs during transients and accidents. To investigate natural circulation phenomena in the primary circuit of the VVER-440-type pressurized water reactors in Loviisa, Finland, the REWET-III facility was built in 1985 by the Technical Research Centre of Finland and the Lappeenranta University of Technology.

One of the principal objectives of the experiments with this scaled facility was to generate a data base for the assessment of computer codes used to predict full-scale plant behaviour. The REWET-III facility is an electrically heated model of the Loviisa VVER-440 pressurized water reactor. The facility is scaled down with a scaling factor of 1:2333 by preserving the power to coolant volume ratio. The elevations are in scale 1:1 (except the reactor upper heade). The facility consists of a model of the reactor vessel and one primary loop with loop seals and a horizontal steam generator. The primary loop represents to the five intact loops of the reference reactor. The heat transfer area of the tube bundle is scaled down with the above scaling factor 1:2333.

Two experiments have been chosen from the natural circulation experiment series as assessment case for the RELAP5/MOD2 cycle 36.04 code. The first experiment is a single-phase case at 20 kW thermal power corresponding to about 3 % decay heat level in the reference reactor. The second experiment is a two-phase case at 80 % water inventory and 30 kW thermal power of the facility. The main results of the experiments are the stationary final states into which the natural circulation process converges.

The nodalization of the REWET-III facility contains 64 volumes. The core nodalization is based on the chopped cosine power distribution of the fuel rod simulators. The hot leg has been divided into nine relatively short volumes in order to allow a more precise prediction of steam flow in the two-phase case. The modelling of the horizontal steam generator has been one of the difficulties during the analysis. The horizontal steam generator has been divided into two horizontal pipe sections. The sections are placed one on top of the other. A vertical pipe component of three volumes is used to simulate the secondary side during the analysis. The nodalization used is capable of predicting both the distribution of flows on the primary side and, to some extent, the void distribution on the secondary side. On the other hand, the volumes on the secondary side have a very low L/D ratio which may cause numerical problems.

The form loss coefficients in the junction have caused numerous difficulties during the assessment. In the preliminary analysis, the code grossly overpredicted the primary mass flow in the single-phase calculation, but calculated the two-phase case reasonably well. Consequently, in the single-phase case the loss coefficients were chosen large enough to obtain the correct mass flow which in turn results in different coefficient values in the two cases.

After this choice, RELAP5/MOD2 succeeded in predicting the main parameters of the experiments, namely final pressures, mass flows and temperature distributions, reasonably well. The differences between the measured and calculated quantities are mostly within the error band of the measurements.

Comparison of the measured and calculated final states in REWET-III natural circulation experiments is given below.

		Pressure, MPa	Mass flow, kg/s
Single-phase:	measured	0.68	0.08 ± 0.01
	calculated	0.68	0.073
Two-phase:	measured	0.45	0.17 ± 0.06
	calculated	0.47	0.13

1 INTRODUCTION

The objective of this study is to assess the RELAP5/Mod2 cycle 36.04 code against natural circulation experiments performed with the REWET-III facility. The REWET-III facility is an 1:2333 volume scaled simulator of the Soviet VVER-440 type PWR, having one loop at the primary side and a horizontal steam generator. All the elevations (except the upper part of the upper plenum) in the facility match 1:1 with the reference reactor. The results of the experiments have been published in /1/

Two experiments have been used in the assessment process. The first one is a single-phase case at 20 kW thermal power, corresponding about 3 % decay heat level in the reference reactor. The second experiment is a two-phase flow case at 80 % filling ratio and 30 kW thermal power. The main goals of these experiments have been to recognize the various natural circulation modes in the facility and to determine the heat removal capability of the natural circulation process.

The main results of the experiments are the stationary final states into which the natural circulation process converges. The assessment has concentrated on an attempt to reproduce these final states as closely as possible, less attention has been paid to the transition behavior of the experiment. During the course of the analysis several interesting problems concerning the sensitivity of the code with respect to the requested time step have been detected.

In the following chapters the facility, the experiments, the model used and the results of the calculations will be described.

2 FACILITY AND TEST DESCRIPTION

2.1 THE REWET-III FACILITY

The REWET-III test facility /2/ is a rather comprehensive scaled model of the primary circuit of Loviisa NPP. It was mainly designed for investigations of natural circulation phenomena in VVER-440 reactors. The REWET-III facility is an extented version of the earlier REWET-II facility. The main design principle is the accurate simulation of the rod bundle geometry and the primary system elevations (Fig. 1). The reactor vessel is simulated by a stainless steel U-tube construction consisting downcomer, lower plenum, core and upper plenum.

All the elevations except the reactor upper head in the reactor vessel simulator are scaled to 1:1 (Fig. 2). The scale of the volumes and flow areas is 1:2333 referring to the number of the fuel rod simulators in the facility and the fuel rods in the reference reactor.

The simulation of the fuel-rod bundle consists of 19 indirectly electrically heated simulator rods. The heating coils are inside stainless steel claddings in magnesium oxide insulation. The heated length and the lattice pitch of the fuel-rod simulators as well as the number (= 10) and construction of the rod bundle spacers are the same as in the reference reactor. The characteristics of the rod bundle are presented in appendix A. The upper ends of the rods are attached to the upper tie plate (Fig. 3). The location of spacers are shown in Fig. 4. A schematic picture of the REWET-III facility are presented in Fig. 5 and the dimensions of pipes are given in Table 1.

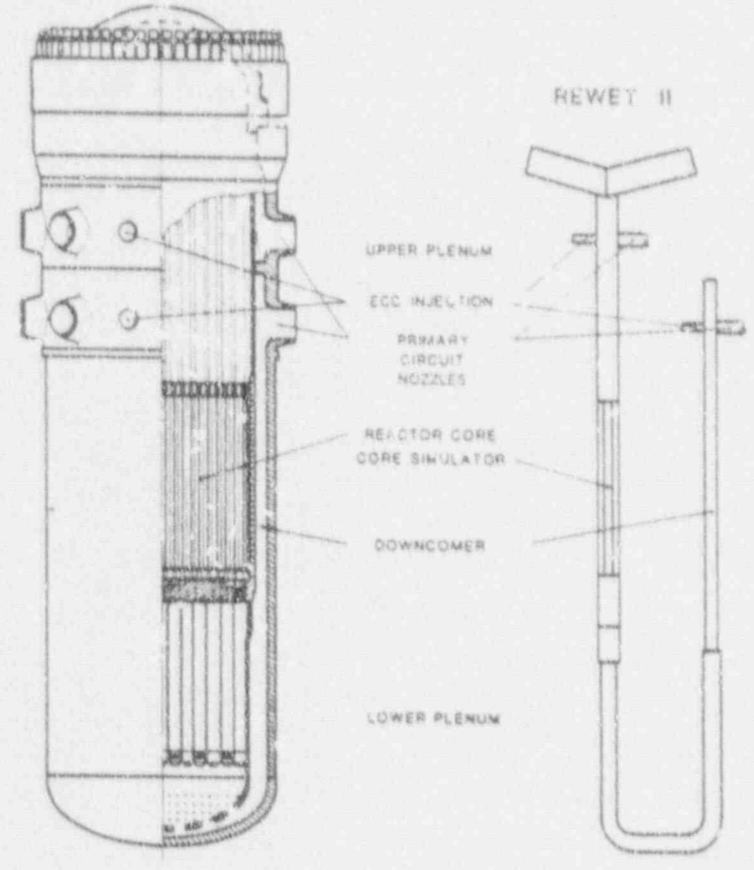


Fig. 1. Simulation of the VVER-440 reactor vessel by the REWET-III facility

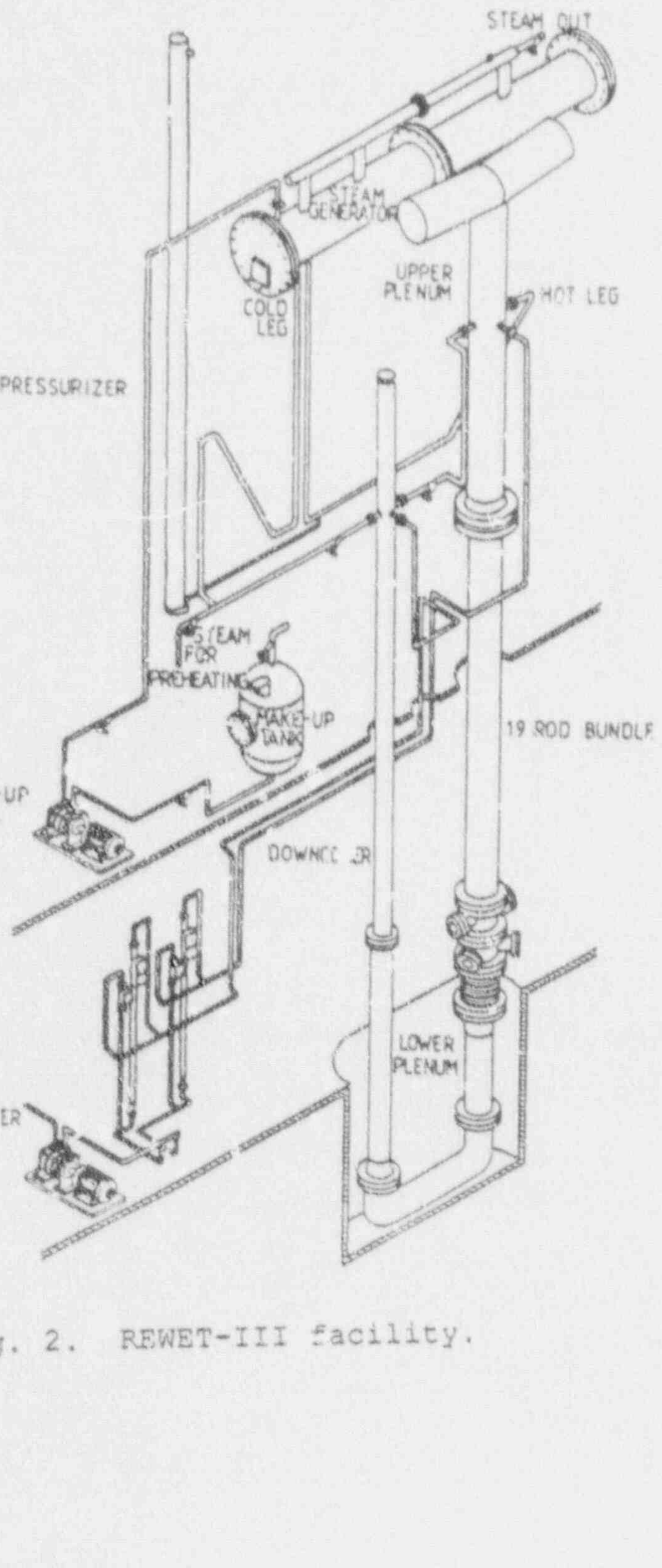


Fig. 2. REWET-III facility.

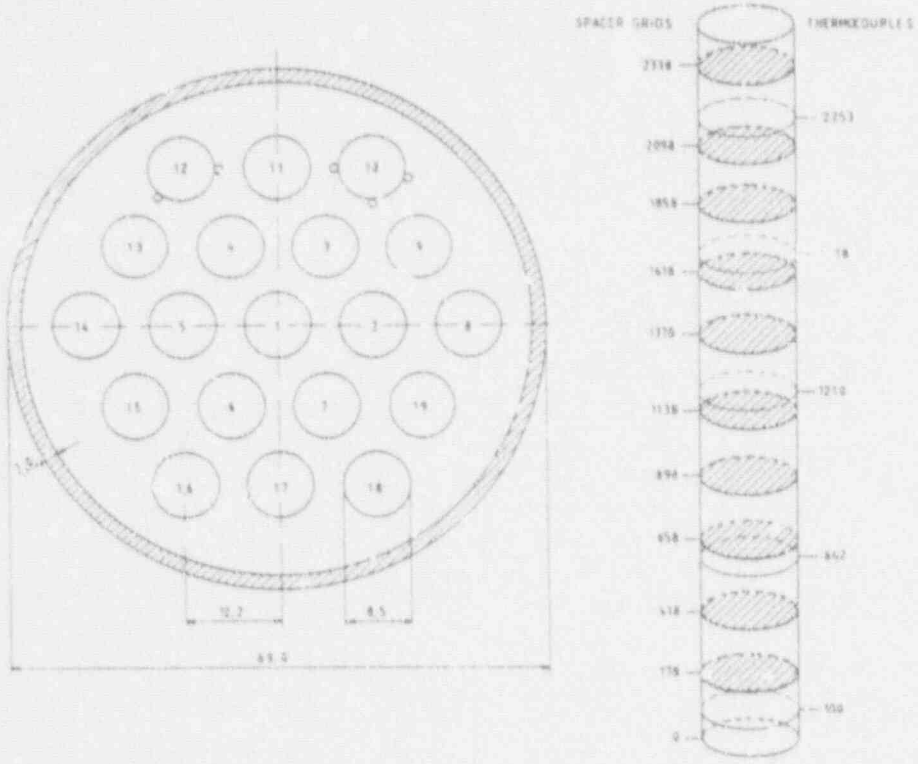


Fig. 3. Round rod bundle with rod simulators, (8,5 mm) and elevations of spacers.

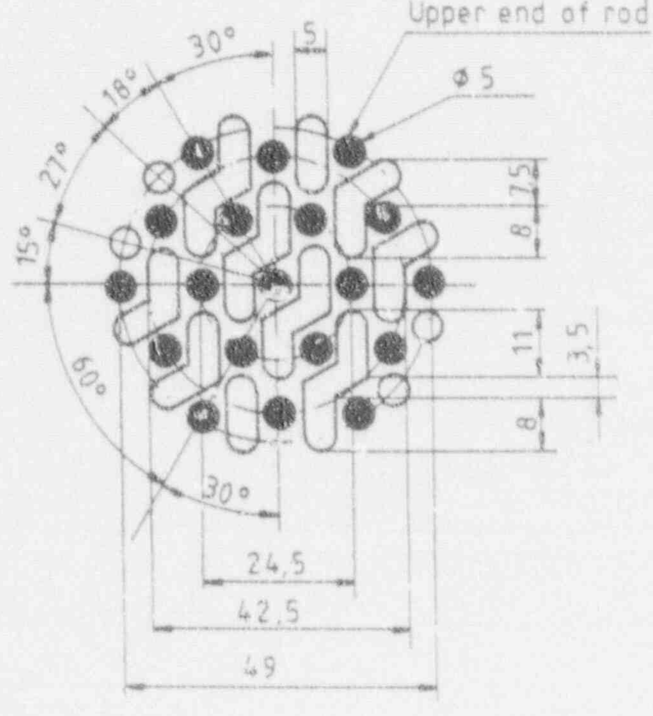


Fig. 4. Upper tie plate of REWET-II and REWET-III.

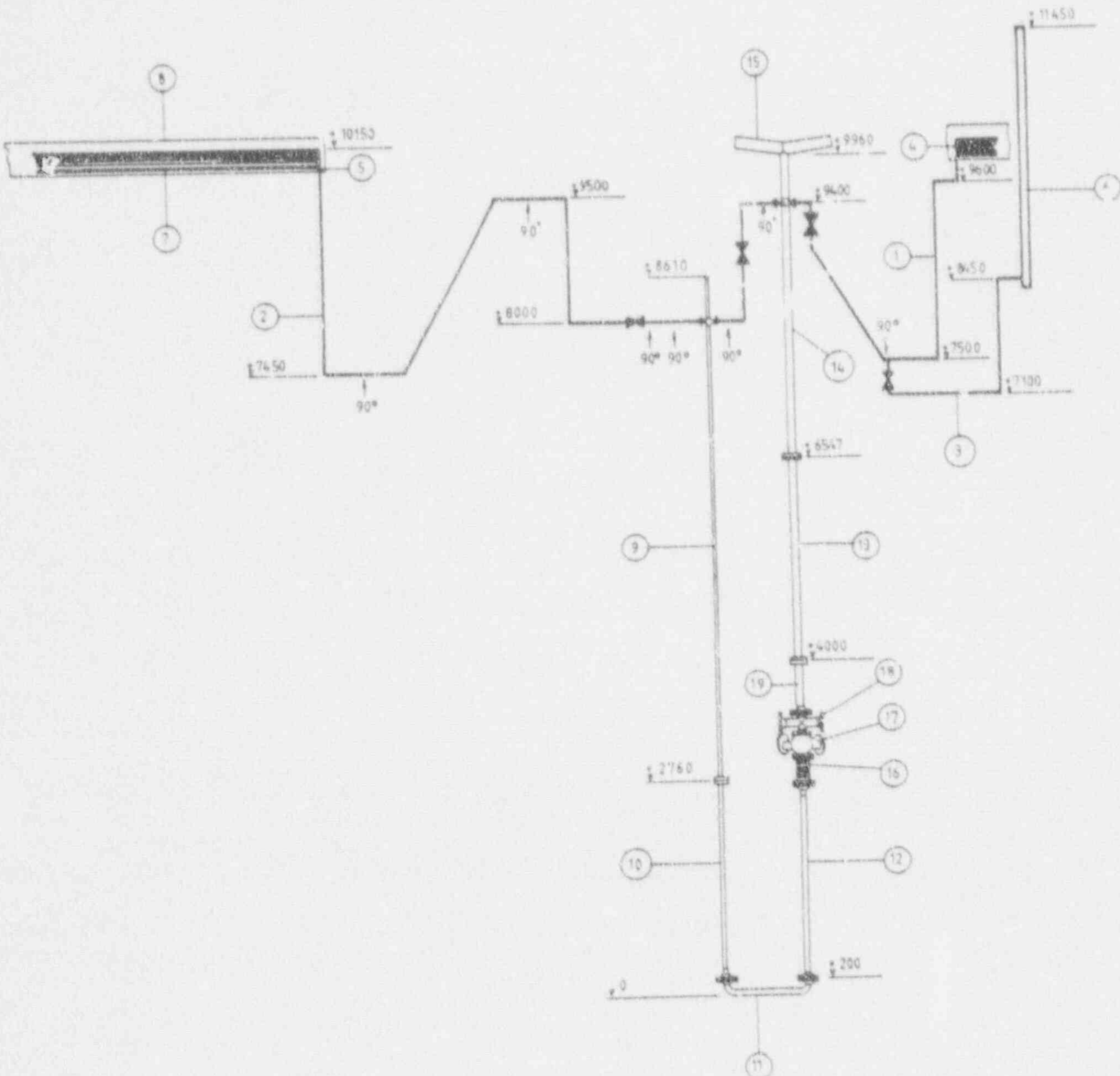


Fig. 5. Schematic picture of REWET-III facility.

Table 1. Pipe dimensions in REWET-III.

Name	Comments	Dimensions
1. Hot leg	5 x 90°, 1 x 30°	ø 26.9 x 2.0 d_i = 22.5 l = 5400
2. Cold leg	7 x 90°, 2 x 60°	ø 26.9 x 2.0 d_i = 22.9 l = 9470
3. Pressurizer line	3 x 90°	ø 21.3 x 1.5 d_i = 18.3 l = 3200
4. Hot leg SG collector (Cu)		ø 54.0 x 1.5 d_i = 51.0 l = 320
5. Cold leg SG collector (Cu)		ø 54.0 x 1.5 d_i = 51.0 l = 320
6. Pressurizer		ø 70.0 x 2.0 d_i = 66.0 l = 3100
7. SG-tubes (Cu)	(12 U-tubes)	ø 15.0 x 1.0 d_i = 13.0 l = 7674
8. SG		ø 406.4 x 8.8 d_i = 388.8 l = 4030
9. Downcomer	upper part	ø 33.7 x 1.5 d_i = 30.7 l = 5920
10. Downcomer	lower part	ø 44.5 x 2.5 d_i = 39.4 l = 2560
11. Lower plenum	horizontal	ø 60.3 x 2.0 d_i = 56.0 l = 740
12. Lower plenum	vertical	ø 55.0 x 2.5 d_i = 50.0 l = 2420
13. Core 1.	hexagonal shroud d_{hydr} = 7.2 mm, s = 2mm, dist of opposite walls = 54.3,	l = 2547
13. Core 2.	round shroud d_{hydr} = 14.1 mm	ø 70.0 x 2.0 d_i = 66.0 l = 2547
14. Unper plenum	vertical	ø 69.0 x 2.0 d_i = 6[illegible].0 l = 3540
15. Upper plenum	([illegible] x 400 mm)	ø 88.9 x 2.5 d_i = 83.9 l = 800
16. Bellow	(l = 184 - 244 mm)	- d_i = 65.0 l = 240
17. Instrumentation nozzles.	Vol = 1.0 l	ø 69.0 x 2.0 d_i = 65.0 l = 200
18. Power wire nozzles.	Vol = 0.9 l	ø 69.0 x 2.0 d_i = 65.0 l = 190
19. Core inlet tube.	Vol = 1.6 l, d_{hydr} = 11.1 mm	ø 69.0 2.0 d_i = 65.0 l = 750

The elevations of the loops correspond to the centerline of the loops of the reference reactor (Fig. 6). The horizontal steam generator simulator consists of 12 full length (7.7 m) horizontal U-tubes. The diameter of the U-tubes and the space between them are the same as in the reference reactor. The heat transfer area of the tube bundle is scaled down with the same scaling factor as the plena, and it corresponds to the total heat transfer area of the steam generators in the five intact loops of the reference reactor. In Fig. 7 the dimensions of the steam generator simulator are shown.

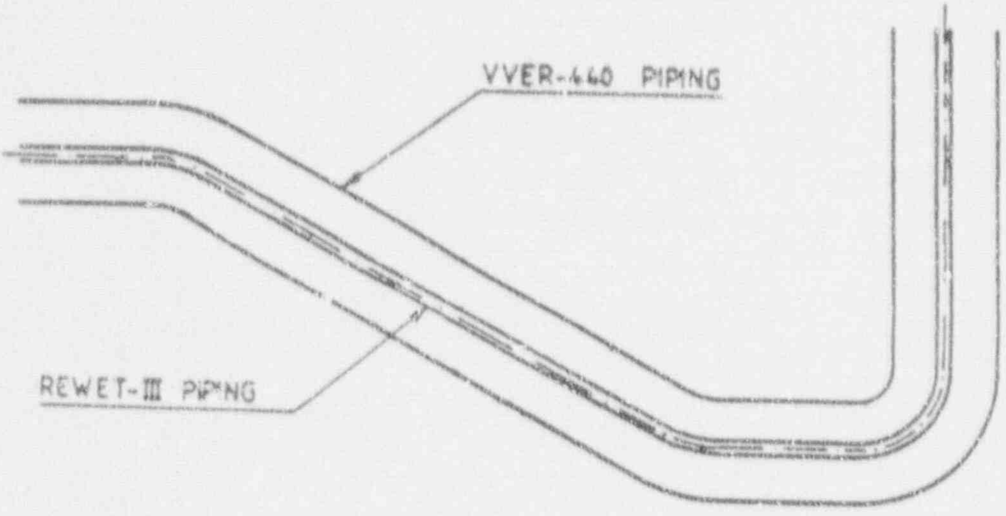


Fig. 6. REWET-III piping compared to VVER-440 piping.

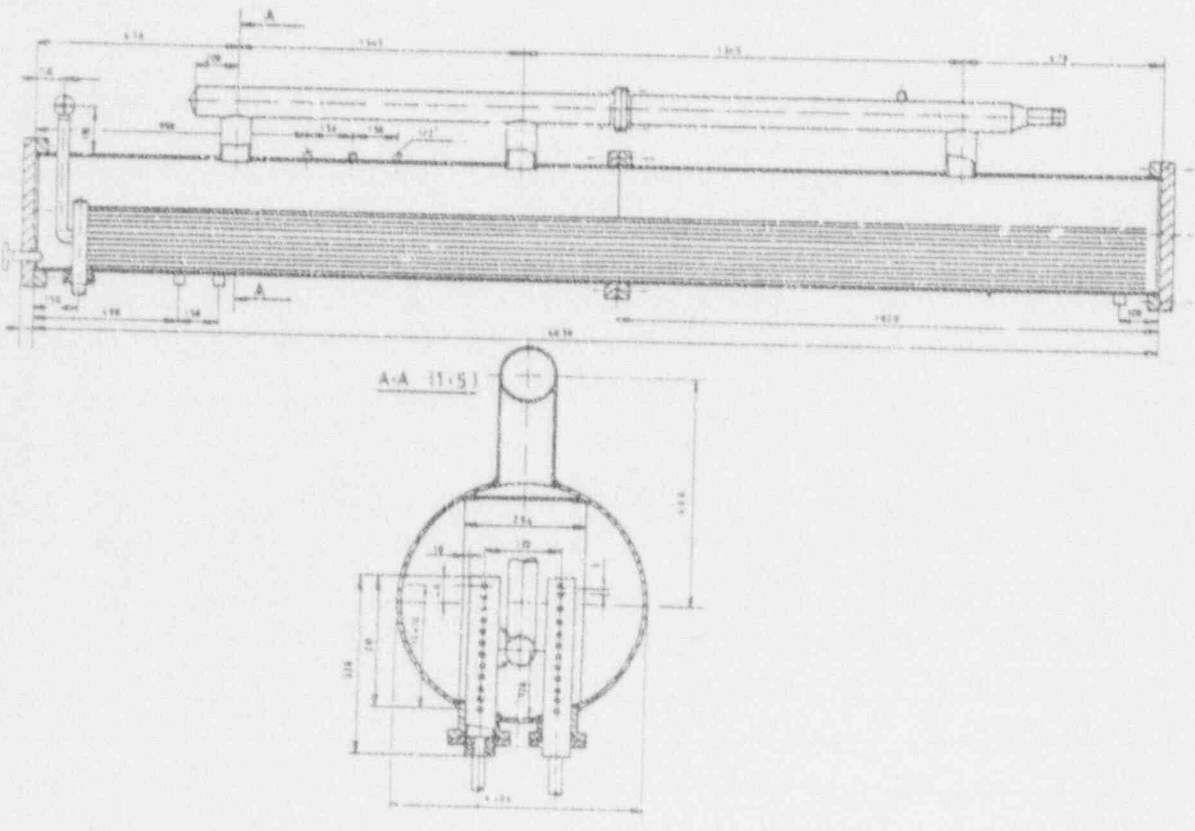


Fig. 7. REWET-III steam generator simulator.

2.2 Instrumentation and data acquisition system of the REWET-III facility

The main measurements in the experiments are coolant and rod cladding temperatures with thermocouples at different radial and axial locations. System pressure, pressure difference along the test section (core simulator), coolant flow rates and heating power are also measured. The primary and secondary fluid temperatures and the primary pipe temperature are measured from seven places in every second pipe in the steam generator. The measurement system is shown in Fig. 8 and the locations in Fig. 9. The data acquisition system consists of a measurement and control processor, a digital voltmeter and a desk-top computer (Fig. 10). The maximum speed to scan all 96 data channels during an experiment is once per second. With this speed it takes 10 minutes to collect a maximum of 58,800 readouts.

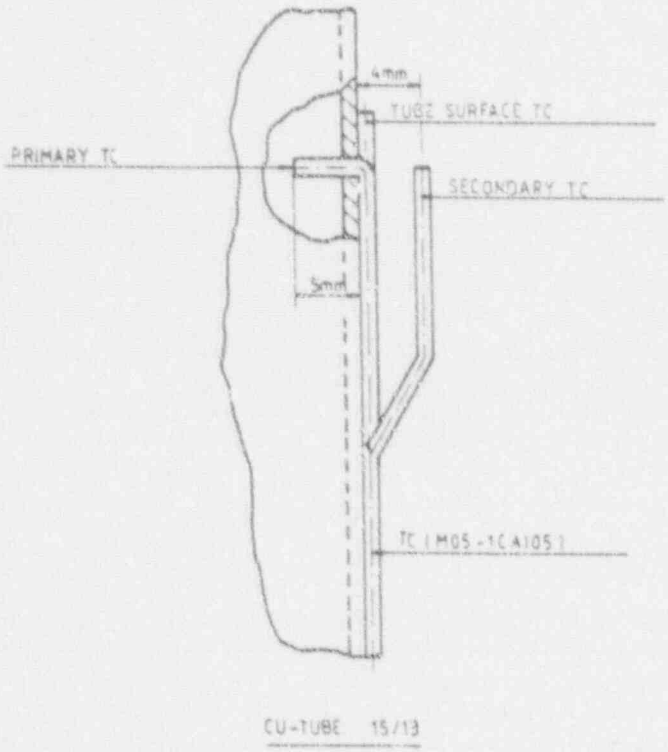


Fig. 8. SG tube thermocouple positions.

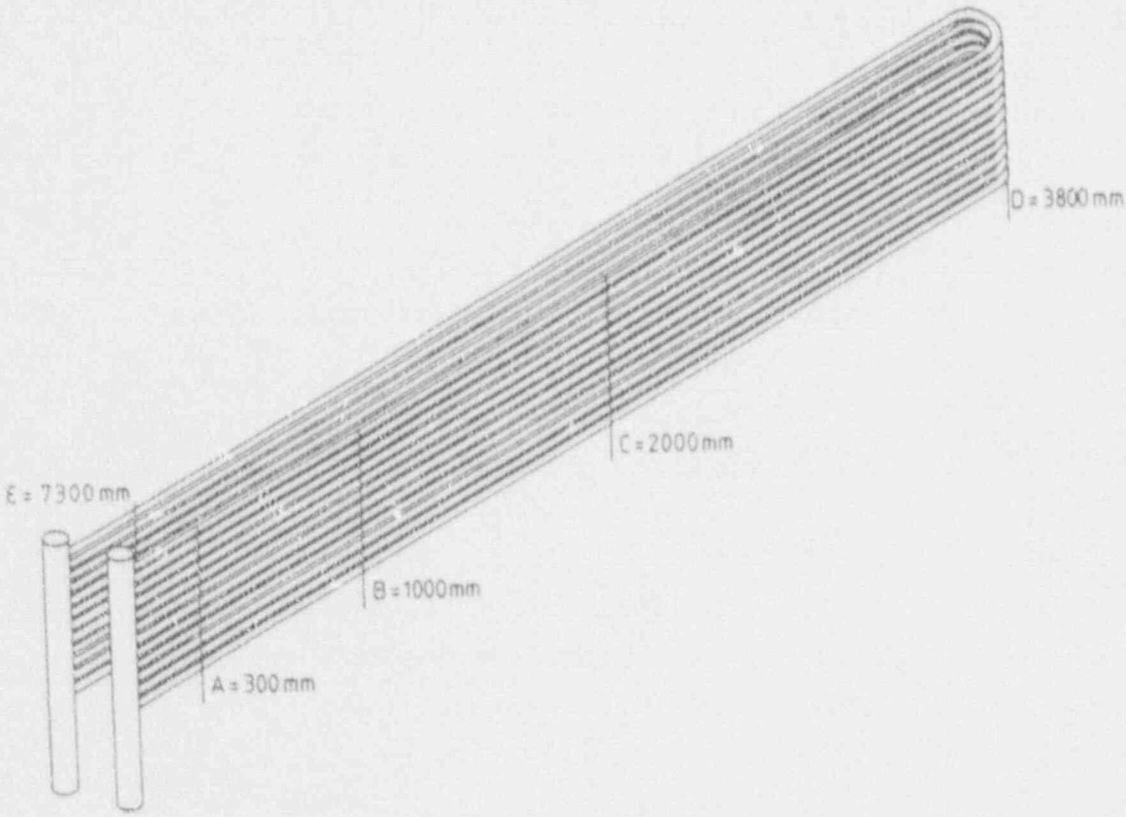


Fig. 9. SG thermocouple locations.

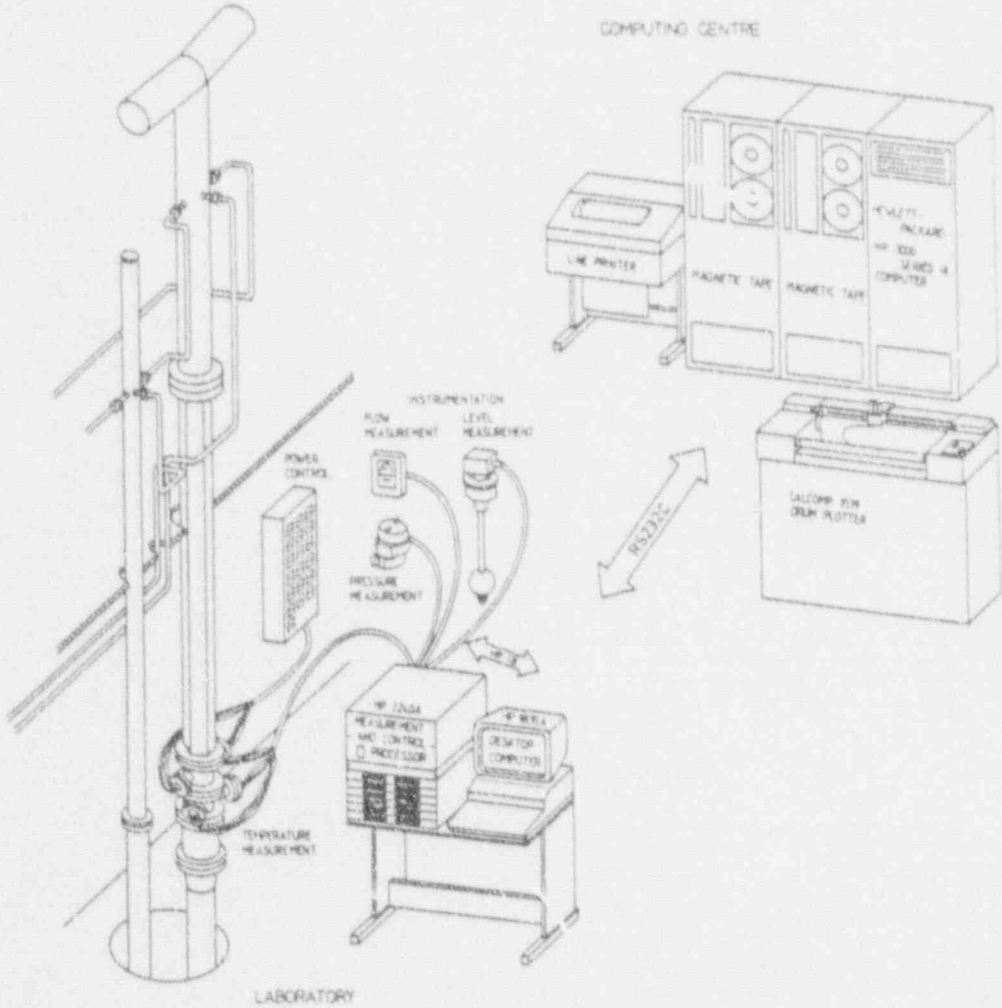


Fig. 10. REWET-III data acquisition system.

3. TEST CONDITIONS

A total of 22 experiments were made in this series. The principal objectives of the experiments were to characterize natural circulation phenomena under a variety of conditions and to generate a data base for computer codes used to predict full-scale plant behavior. The main parameters varied in the experiments were heating power, primary water inventory and noncondensible gas (air) content. The test matrix of the experiments is shown in Table 2.

Table 2. The REWET-III natural circulation experiments.

Number of the experiment		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Water inventory	100 %	X	X																				
	90 %			X									X	X	X	X							
	80 %				X	X	X										X						
	70 %							X	X	X								X	X	X			
	65 %																				X	X	X
	60 %										X	X											
Core power	30 kW						X			X					X					X			X
	20 kW		X			X			X			X		X			X		X			X	
	15 kW	X		X	X			X			X		X			X		X			X		
Noncondensible Gases Present														X	X	X	X	X	X	X	X	X	X

Instead of regulating primary pressure during the experiments it was allowed to seek its equilibrium as a function of heating power and water inventory. The secondary side of the steam generators operated at saturated conditions and atmospheric pressure. The pressurizer was not used in the experiments (closed valve).

For the experiments the primary side of the facility was filled up and the heating up was performed by the fuel rod simulators at a low power level. The secondary side was heated to saturated condition by an electrical heating coil. While the temperatures and the pressure increased in the facility the required quantity of water was depleted from the primary circuit. After that the heating power was adjusted to the specified level. The behavior of the facility was examined for 60 minutes from the moment the facility had reached the steady- state condition.

In the experiments with noncondensible gases the quantity of air required was left in the primary circuit (steam generator and/or upper plenum) during the filling up of the facility.

4 CODE INPUT DESCRIPTION

The nodalization used in analyzing both of the experiments is shown in Fig. 11. The core nodalization is based on the chopped cosine power distribution of the fuel rods. Connection to the hot leg has been modelled using a crossflow junction. The hot leg (loop seal) has been divided into nine relatively short volumes in order to allow a more precise prediction of steam flow in the two-phase case. The horizontal steam generator has been divided into two horizontal pipe sections, each simulating six of the 12 U-tubes. The sections have been placed one on top of the other. A vertical pipe component of three volumes is used to simulate the secondary side. The top volume has a connection to time-dependent volume 260 that determines the boundary condition in the secondary side, which is the atmospheric pressure. The two other volumes have one section of primary tubing each. The hot and cold collectors have both been built of two stacked branches that have crossflow junctions to connect them into the U-tubes. The cold leg consists of relatively long volumes, especially in comparison with the cold collector, but this has not caused any problems. The connection to the downcomer is a crossflow junction, and the downcomer is a pipe of six volumes. The lower plenum has a connection to the boundary valve 300 and time-depended volume 310, which were used to determine initial states of the system in both experiments and during the slow outflow transient at the beginning of the two-phase calculation.

A reasonable modelling of the horizontal steam generator has been one of the most difficult tasks during this analysis. The model described here is capable of predicting both the void distribution on the secondary side and the distribution of flows on the primary side. Similar nodalization has been used to analyze the behavior of the steam generators of an actual plant /3/. On the other hand, it has at least two drawbacks: the volumes on the secondary side have a very low length to diameter (L/D) ratio, which in turn may have caused some numerical problems, and the uneven distribution of primary side volumes within the pipe components cause a slightly distorted distribution of heat transfer from primary to secondary side.

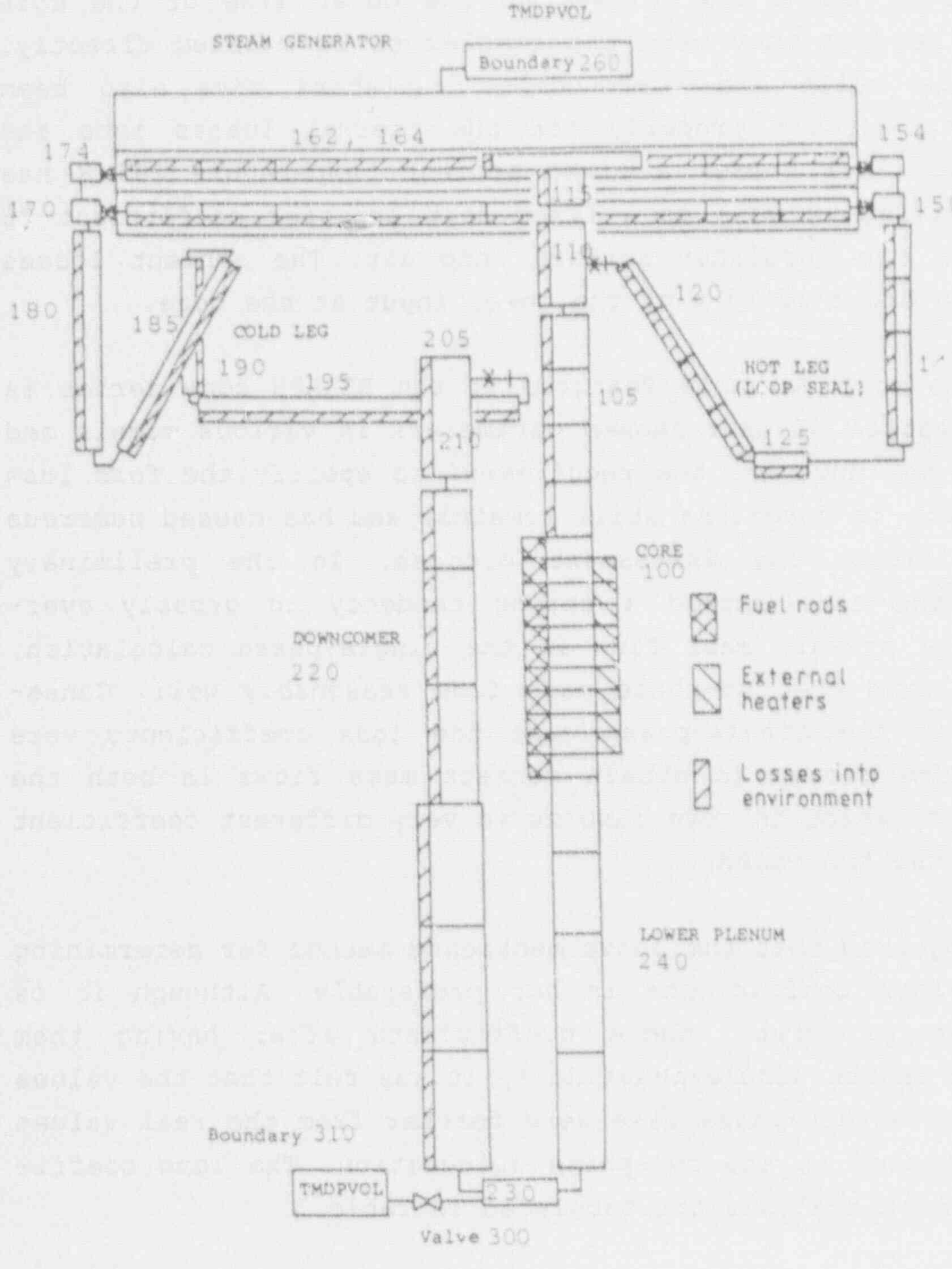


Fig. 11. The nodalization of REWET-III facility for RELAP5/Mod2 Natural Circulation Analysis.

The fuel rods have been modeled using cylindrical heat structures with appropriate attention being paid to both axial and radial power distribution. The external heaters have been described as fixed heat fluxes on the outer side of the core housing, because they were too complex to be modeled directly. The piping walls and surrounding insulators have also been modeled to account properly for the thermal losses into the environment. For these, a fixed ambient temperature 293 K has been specified as well as a fixed heat transfer coefficient 26 W/m^2K from the insulator surface into air. The ambient losses are of the order of 10 % of the power input at the core.

One of the most valuable features of the RELAP5 code series is the elimination of user-chosen parameters in various models and correlations. However, the requirement to specify the form loss coefficients in junctions still remains, and has caused numerous problems during the assessment process. In the preliminary analysis the code showed a strong tendency to grossly overpredict the primary mass flow in the single-phase calculation, but calculated the two-phase mass flow reasonably well. Consequently, in the single-phase case the loss coefficients were chosen large enough to obtain correct mass flows in both the experiments, which in turn results in very different coefficient values in the two cases.

It is recognized that the above mentioned method for determining the flow loss coefficients is not preferable. Although it is better not to adjust these coefficients after having them determined on the single-phase data, it was felt that the values used in the single-phase case were farther from the real values than those used in the two-phase calculation. The loss coefficients of both analyses are tabulated in Table 3.

Table 3. Primary loop form loss coefficients in the REWET-III natural circulation analyses with RELAP5/Mod2.

Junction	Location	Single-phase Forward	Single-phase Backward	Two-phase Forward	Two-phase Backward
100-01 to 10	core	4.81	4.81	0.41	0.41
102	core to upp. ple.	7.9	7.9	1.9	1.9
105-01 to 03	upp. ple., lower	3.22	3.22	0.0	0.0
110-01	u.p. low to conx	3.26	3.26	0.66	0.66
110-02	conx to hot leg	6.22	6.22	1.22	1.22
110-03	conx u.p. upper	3.25	3.25	0.85	0.85
115-01	upp. ple. up	5.16	5.16	0.16	0.16
120-01 to 03	hot leg 1	1.9	1.9	0.0	0.0
125-01,02	loop seal bottom	3.25	3.25	0.36	0.36
140-01 to 03	hot leg 2	3.22	3.22	0.0	0.0
150-01	hot leg to SG coll	5.5	6.1	2.5	3.1
150-02	SG coll to low U-tb	8.7	4.1	3.7	2.1
150-03	to upper collector	7.9	5.3	1.3	1.3
154-01	upp. coll to up U-tb	17.9	13.0	3.7	2.1
162-01,02	SG low tubes begin	0.7	0.7	0.0	0.0
162-03	U-bend, SG low tb	2.11	2.11	0.11	0.11
162-04,05	SG low tubes end	0.7	0.7	0.0	0.0
164-01,02	SG upp tubes begin	0.7	0.7	0.0	0.0
164-03	U-bend, SG upp tb	2.11	2.11	0.11	0.11
164-04,05	SG upp tubes end	0.7	0.7	0.0	0.0
174-01	upp. tb to coll	11.0	13.9	2.3	4.1
170-01	SG coll to cold leg	6.1	4.5	3.1	2.5
170-02	low tubes to coll	4.1	8.7	2.3	4.1
170-03	from upp coll	7.3	7.9	1.3	1.3
183	cold leg loop seal	9.6	9.6	0.6	0.6
187	cold leg top	9.6	9.6	0.6	0.6
193	cold leg flat	9.6	9.6	0.6	0.6
210-01	cold leg to downc	11.82	11.82	1.42	1.42
210-02	downcomer	9.94	9.94	0.94	0.94
220-01 to 05	downcomer	1.1	1.1	0.0	0.0
230-01	downc to low ple.	14.89	14.89	0.89	0.89
230-02	lower plenum	14.29	14.29	0.89	0.89
240-01	lower plenum	18.63	18.63	0.63	0.63
240-02,03	lower plenum	27.63	27.63	3.63	3.63
245	low ple to core	16.87	16.87	0.87	1.87

The initial conditions of the single-phase case were chosen to match the final state as closely as possible. To facilitate this search the boundary 310 was set to a fixed pressure 0.74 MPa, corresponding to the measured final pressure 0.65 MPa at the primary pressure measurement location. The temperature (the specific internal energy) of volume 310 was set to follow volume 220-06. Because a closed water-filled loop is very stiff against even minor fluctuations of the energy balance due to the extremely small compressibility of water, a small bubble of air was left into the upper part of the upper plenum to smoothen the pressure variations while the system was on the way to the steady final state. The presence of such a bubble is justified, because ordinary tap water was used in the experiments and some of the dissolved air will be released during the test.

The steady-state search algorithm of RELAP5/Mod2 proved to be almost useless, because it predicted the existence of a steady state in most calculations too early, i.e. while the system was still changing (although relatively slowly). In this case an algorithm based on setting the time derivatives zero would most probably have yielded more reasonable results in much less time and with less effort.

In the two-phase case the calculation was started with a stable single-phase natural circulation at about 0.3 MPa pressure and 12 kW heating power. The air bubble in the upper plenum had to be removed because of a number of code failures during the inital state search. All of these failures were caused by steam property table overflows and occured in volumes that were almost completely filled with air, with very small amounts of steam and water still present. The volumes that caused these failures also had heat structures representing pipe walls connected to them.

The transient part of the two-phase case was initiated by lifting the core power to 28 kW (the missing 2 kW were assumed to leak from the external heaters of the core directly at the surroundings), setting the primary boundary 310 at atmospheric pressure and opening valve 300. The mass flow rate through this valve was about 0.03 kg/s, which was slightly less than the upper limit of the outlet flow in the experiment. The valve was closed when the integrated mass flow through it reached a preset value, 8 kg, which corresponds to the 80 % filling ratio with sufficient accuracy. The final state was the steady state into which the primary circuit converged after closing the valve.

Both of these calculations are sensitive to the initial thermodynamic state of the system. This is obvious from the fact that the solution of the system equations in the primary side is bounded only by the heat transfer from or to the walls (except during the short outflow period in the beginning of the two-phase case).

5 RESULTS

RELAP5/Mod2 succeeded in predicting the main parameters of the experiment, namely final pressures, mass flows and temperature distributions, very well. Some small differences between measured and calculated quantities can be found, but they are usually within the error band of the measurement.

The final pressures and mass flows of both calculations are compared to those of the experiments in Table 4 and the measured and calculated temperature distributions are shown in Figs. 12 and 13.

Table 4. Comparison of measured and calculated (in brackets) final states of the REWET-III natural circulation tests.

	Pressure, MPa	Mass flow, kg/s
Single-phase	0.68	0.08±0.01
	(0.68)	(0.073)
Two-phase	0.45	0.17±0.06
	(0.47)	(0.13)

The single-phase experiment shows relatively large mass flow oscillations that could not be reproduced. In the two-phase case both measured and calculated mass flows oscillate quite strongly, but in the calculations the oscillations die out much faster. These oscillations have far too small frequency to be of a numerical origin. In the both cases the final state is sensitive to the ambient losses and the form loss coefficients. If the ambient losses from the hot leg are neglected, the oscillations have considerably larger amplitude and survive much longer (see Appendix B).

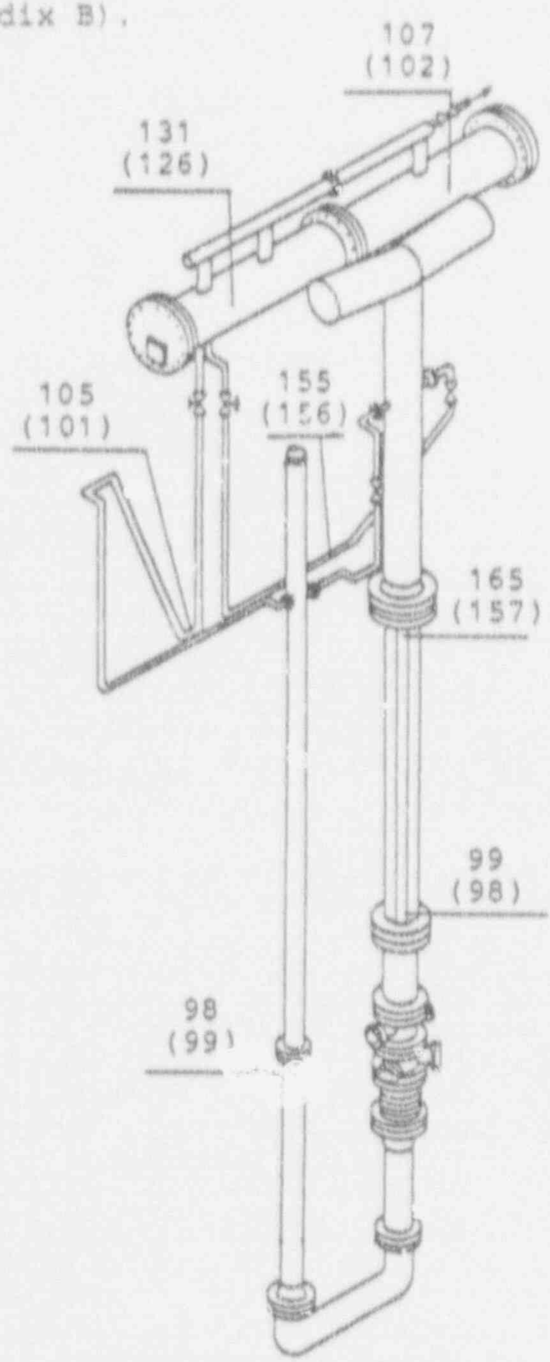


Fig. 12. Measured and calculated (in brackets) temperature in the steady single-phase natural circulation.

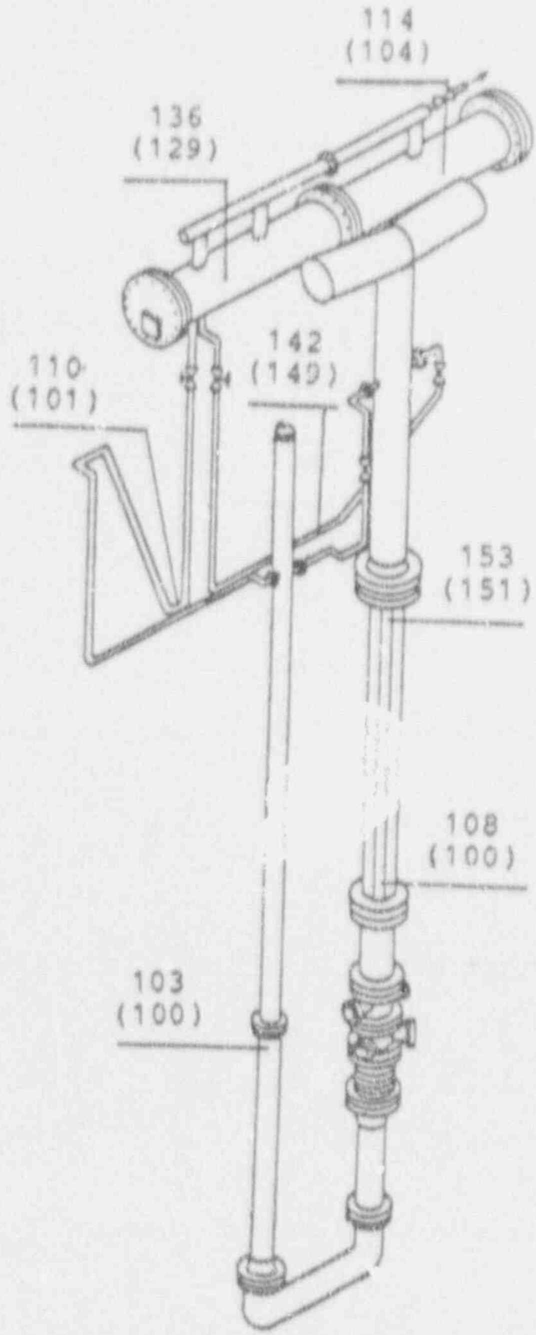


Fig. 13. Measured and calculated (in brackets) temperatures in steady two-phase natural circulation.

The steam generator secondary side starts to show unstable characteristics even at maximum requested time steps clearly below the Courant limit (Fig. 14). The vast majority of minimum Courant limits gathered into the second volume of the steam generator.

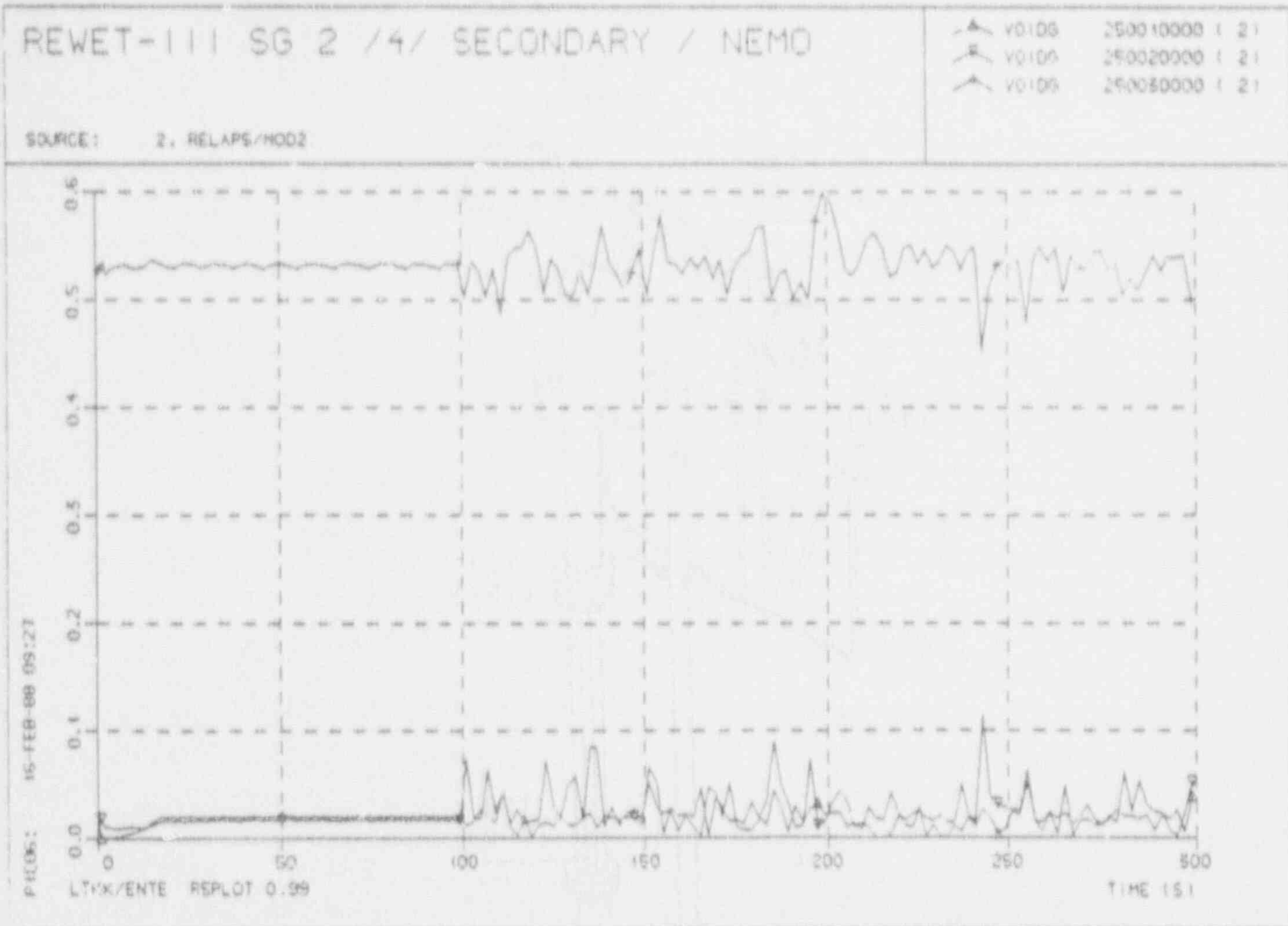


Fig. 14. Steam generator hydrodynamic instability appears when the requested time step is increased from 0.25 to 1.0 s. The Courant limit is about 0.7 s, and the code immediately resets the time step to 0.5 s.

The solution of the system equations in the steam generator secondary side remains stable when the requested time step is shortened to 1/3 ... 1/4 of the Courant limit. This is obviously due to the relatively low L/D value of the secondary side volumes, and has also to do with the stability of wall to fluid heat transfer, which is not controlled in the code at all.

The run statistics in the single-phase case show that when 0.2 s is used as the maximum time step, the CPU consumption is 0.00578 s per volume per time step. 1568 time steps were requir- ed to simulate 312.8 seconds of experiment, and the time step had to be reduced only twice. The Courant limit in the single-phase case is 0.56 s. In the two-phase case 10181 time steps were used to simulate 999 s of transient. The requested time step was 0.1 s, Courant limit 0.44 s and 63 time step reductions took place. The CPU consumption was 0.00586 seconds per volume per time step.

During the analysis of the two-phase case it soon turned out that the bubbles condense on the pipe walls, and saturated liquid passes through the loop seal. As the liquid rises towards the steam generator collector, hydrostatic pressure may sometimes decrease sufficiently to allow some evaporation to take place (Fig. 15).

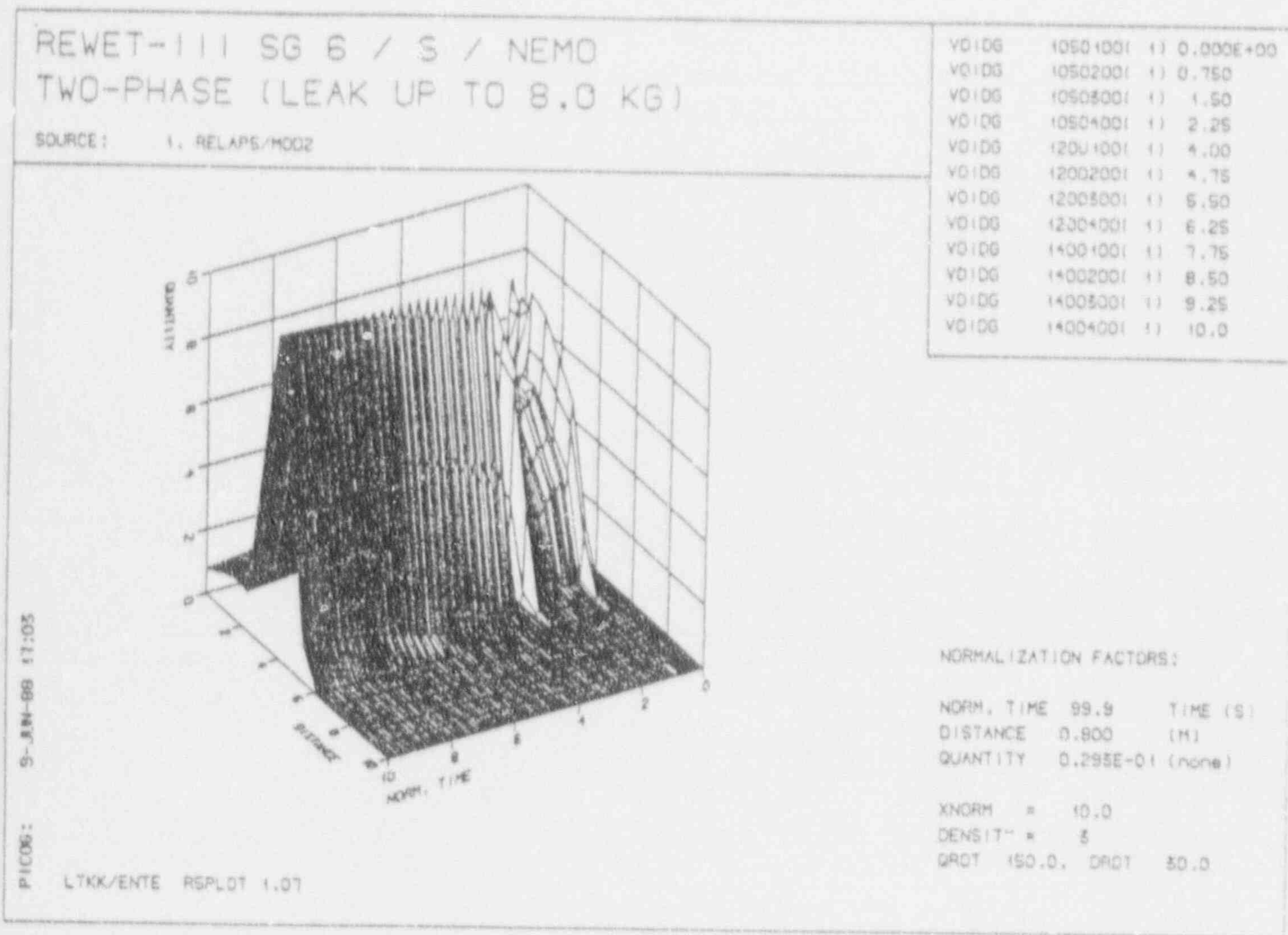


Fig. 15. Steam void fraction distribution in the hot leg.

6. CONCLUSIONS

The calculations show that RELAP5/Mod2 is capable of calculating natural circulation phenomena satisfactorilly also in facilities with horizontal steam generators and thus relatively low gravity head. However, several shortcomings of the code were observed.

To model the natural circulation phenomena one must know the pressure losses in various part of the facility accurately. The amount of heat lost into environment has a very strong effect on the result, too.

It was observed during the analysis that volumes with small L/D ratio, such as those used to model the steam generator secondary side in the REWET-III facility, show unstable behaviour at time steps considerably smaller than the Courant limit. In this case the stable results required setting the maximum time step to one fourth to one third of the Courant limit.

A number of code failures were observed, when an air bubble was let to travel along the hot leg. These failures were caused by steam table overflows which occured in a volume filled with air, with only small quantities of water or steam being present. It is suggested that the non-condensible gas model be improved to handle this type of situation properly.

The steady state search algorithm was found to be insufficient. In these experiments most quantities change relatively slowly, and the algorithm predicted the existence of a steady state too early, while the thermodynamic state still undergoing a change. Although the benefits of the current algorithm are recognized, it is suggested that an additional algorithm will be added to the code. This additional steady state algorithm could be based on setting the time derivatives in all equations to zero.

The fact that the steam bubbles do not penetrate the hot leg loop seal requires an explanation. A large number of more thorough analyses with various filling ratios and modified nodalizations may be needed to further examine this phenomenon.

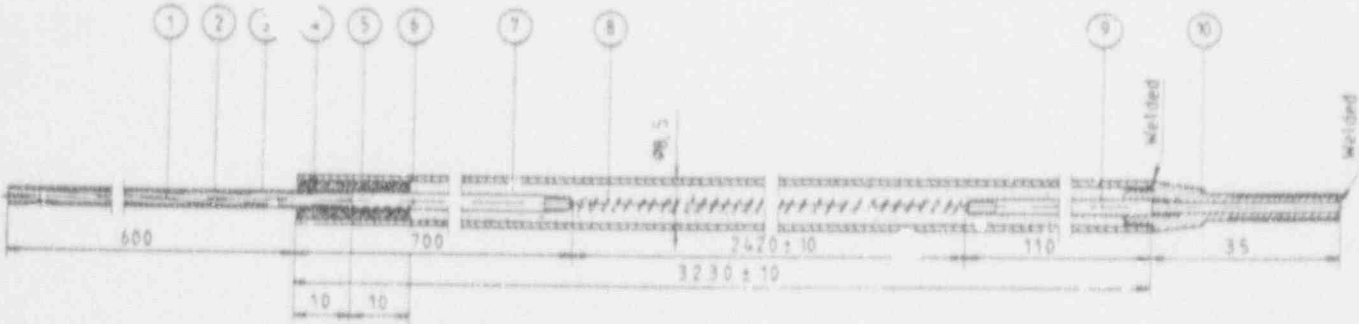
REFERENCES

1. T. Kervinen, O. Hongisto, Natural Circulation Experiments in the REWET-III Facility. ANS/ENS Topical Meeting on Thermal Reactor Safety, San Diego 2-6.2.1988.

2. T. Kervinen, H. Purhonen, T. Haapalehto, Description of REWET-II and REWET-III Facilities. Technical Research Centre of Finland, Espoo. Research Note 929, 1989.

3. Ismo Karppinen, Nodalization of a horizontal steam generator by the RELAP-5 code. Diploma Thesis, Helsinki University of Technology, 1987.

APPENDIX A



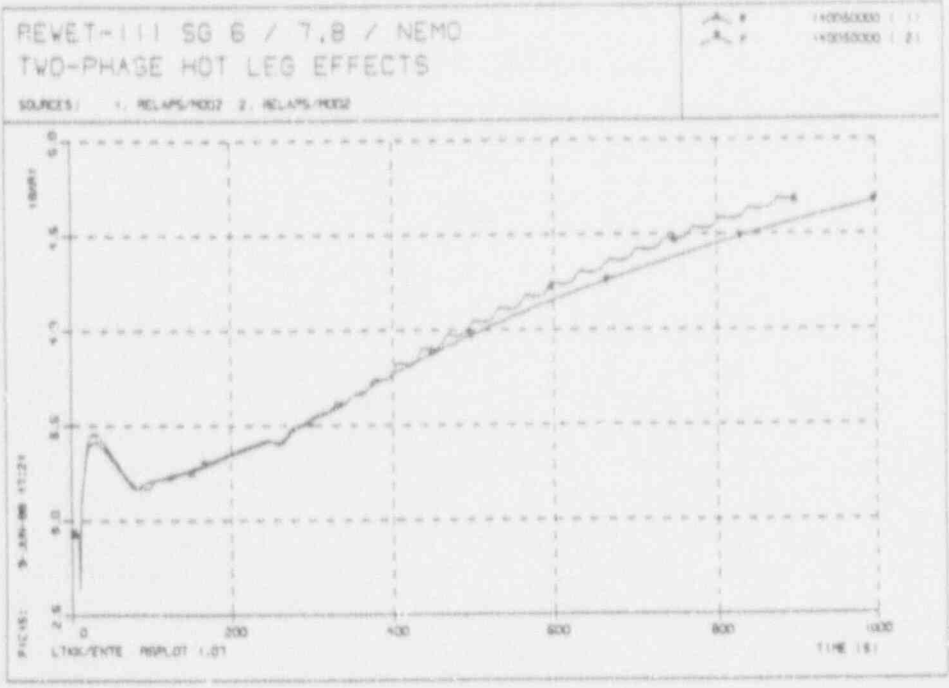
10	Top boss	AISI 304
9	Conduct[illegible] pin	St37k/h11
8	Heating el[illegible]ment	[illegible]-Cr
7	MgO	
6	Cladding	AISI 316L
5	Conductor pin	St37k/h11
4	Silicone filling	Rhodosil[illegible]Fluide
3	Shrink-on plastic tube	[illegible] 6,4
2	Shrink-on plastic tube	d. = 3,2
1	Lead wire	Cu 1,5 mm²

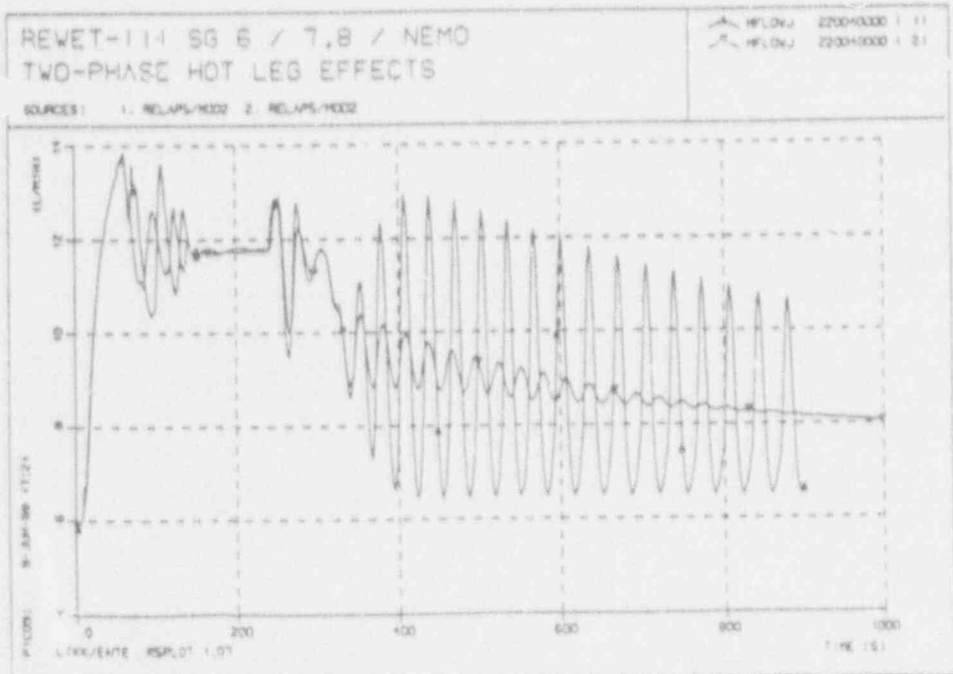
LOVAL

Fuel rod simulator (Ø8,5)

APPENDIX B. The effect of ambient thermal losses

The two figures below show the primary pressure and mass flow respectively during two-phase natural circulation. The strongly oscillating curves marked with Δ were obtained when the conduction losses from the hot leg were not modeled (that is, they were assumed zero). The smoother curves with marker ∇ were obtained when the hot leg losses were included in the calculation. Losses from other parts of the system were equal in both cases.





APPENDIX C LISTING OF INPUT DATA FOR SINGLE PHASE CASE

```
* REWET-III NATURAL CIRCULATION, SG 2 FINAL /8/ L16-5 / JUHANI HYVARINEN
*
* ----- MOD2 VERSION ----
*
* FILLING RATIO 100 % AND POWER 14+5 KW = THE APPROXIMATE FINAL STATE
* PRESSURE ABOUT 6.6 BAR
*
*=====================================================================
*
100  NEW TRANSNT
101  RUN
102  SI    SI
*
* CPU-REMAINING CARD
*
105   5.0    10.0
*
* HYDRODYNAMIC SYSTEM CARDS
*
*    REF. VOLUME    REF. ELEVATION  FLUID       SYSTEM NAME
120  230010000        0.0           WATER       PRIMARY
121  250010000        9.5           WATER       SECONDRY
*
*=====================================================================
*
* TIME STEP CONTROL CARD(S)
*
*   OPTION ssd03: ss= 7 = 4+2+1 = OMIT
*                                   -SECOND BLOCKS OF VOL&JUN DATA
*                                   -HEAT STRUCTURE TEMPERATURES
*                 d = 2          = OBTAIN MINOR EDITS AT EVERY HYDRODYNAMIC
*                                  TIME STEP
*
*201   10.0    0.5E-6  0.8          00003   1    100   3000
*203   600.0   0.5E-6  0.666666666  00003   3    450   3000
*202    99.0   0.5E-6  0.2          00003   5   1200   3000
203   300.0   0.5E-6  0.2         00003   5   1500   3000
*
*=====================================================================
*
* TRIPS
*
*--------------------------------------------------------------------
*
* TRIP FROM SG INLET PRESSURE >= 2.0 MPA (20 BAR) OR  <= 0.20 MPA
*
*  VARIABLE   OF VOLUME   RELATION  2ND VAR  OF 2ND VOL  +CONST   NOT LATCHED
501   P       140030000   GE        NULL     0            2.00E6      N
502   P       140030000   LE        NULL     0            0.20E6      N
*
* TRIP TO STOP NEAR THE STEADY STATE
*
*503   MFLOWJ  300000000   LT        NULL     0            1.0E-4      N
*504   TIME    0           GT        NULL     0          150.0         L
*--------------------------------------------------------------------
* LOGICAL TRIP(S)
*
601   501   OR   502    N
*602   503  AND   504    N
*
*--------------------------------------------------------------------
* TRANSIENT TERMINATING TRIP(S)
*
600   601
*
*=====================================================================
```

```
*
* MINOR EDIT REQUESTS:
*
* TEMPERATURES
*
301  TEMPF  100010000
302  TEMPF  100110000
303  TEMPF  125010000
304  TEMPF  150010000
305  TEMPF  162010000
306  TEMPF  162020000
307  TEMPF  162040000
308  TEMPF  162050000
307  TEMPF  162060000
308  TEMPF  164010000
309  TEMPF  164020000
310  TEMPF  164040000
311  TEMPF  164050000
312  TEMPF  164060000
313  TEMPF  170010000
314  TEMPF  180010000
315  TEMPF  250010000
316  TEMPF  250020000
317  TEMPF  250030000
*
* HEAT INPUTS IN CORE
*
320  Q      100010000
321  Q      100020000
322  Q      100030000
323  Q      100040000
324  Q      100050000
325  Q      100060000
326  Q      100070000
327  Q      100080000
328  Q      100090000
329  Q      100100000
330  Q      100110000
*
* MASS FLOWS
*
332  MFLOWJ   102000000
333  MFLOWJ   162020000
334  MFLOWJ   164020000
335  MFLOWJ   220040000
*336  MFLOWJ   300000000
*
* VELOCITIES
*
*349  VELFJ    256000000
*350  VELGJ    256000000
*
* PRESSURES
*
337  P        140030000
338  P        100110000
339  P        250030000
*
* SOME HEAT STRUCTURE TEMPERATURES AT SG TUBES
*
*354  HTTEMP   162100103
*355  HTTEMP   162100603
*356  HTTEMP   164100103
*357  HTTEMP   164100603
*
* HEAT INPUT RATES AT SG TUBES
```

```
*
340  Q    162010000
341  Q    162020000
342  Q    162030000
343  Q    162040000
344  Q    162050000
345  Q    162060000
*
346  Q    164010000
347  Q    164020000
348  Q    164030000
349  Q    164040000
350  Q    164050000
351  Q    164060000
*
* STEAM VOID FRACTIONS
*
353 VOIDG      250010000
354 VOIDG      250020000
355 VOIDG      250030000
*
356 VOIDG      115010000
357 VOIDG      115020000
*
358 QUALA      115020000
*
* CONTROL VARIABLES (DPS, EXCESS STEAM GENERATION, HEAT INPUTS)
*
385 CNTRLVAR    1
386 CNTRLVAR    2
387 CNTRLVAR    3
388 CNTRLVAR    4
389 CNTRLVAR    7
390 CNTRLVAR   20
391 CNTRLVAR   21
392 CNTRLVAR   22
393 CNTRLVAR   23
394 CNTRLVAR   24
395 CNTRLVAR   25
396 CNTRLVAR   26
397 CNTRLVAR   27
398 CNTRLVAR   28
*
* SPECIALITIES
*
399 CPUTIME    0
*
*=====================================================================
*
* CONTROL VARIABLES
*
*---------------------------------------------------------------------
*   PRESSURE DIFFERENCES:
*     DP = A0 + A1*VAR1 + A2*VAR2. DIMENSIONS NOT SCALED (SCALE=1.0)
*
*   - OVER CORE
*
*           NAME    TYPE  SCALE   INIT.VAL   INIT.FLG=COMPUTE  NO LIMITS
20500100    DPCORE  SUM   1.0     0.0              1               0
*           A0    A1     VAR1 CODE  VOL1 CODE
*           +     A2     VAR2       VOL2
20500101    0.0   1.0    P          100010000      * CORE BOTTOM
+                -1.0    P          100110000      * CORE TOP
*
*   - OVER HOT LEG
*
```

```
*           NAME      TYPE  SCALE   INIT.VAL   INIT.FLG=COMPUTE  NO LIMITS
20500200   DPHTLEG   SUM    1.0     0.0               1            0
*           A0    A1      VAR1 CODE  VOL1 CODE       *     A2,VAR2,VOL2
20500201   0.0  -1.0      P          150010000       * HOT LEG COLLECTOR
+                1.0      P          230010000       * LOWER PLENUM
*
*   - OVER COLD LEG
*
*           NAME      TYPE  SCALE   INIT.VAL   INIT.FLG=COMPUTE  NO LIMITS
20500300   DPCDLEG   SUM    1.0     0.0               1            0
*           A0    A1      VAR1 CODE  VOL1 CODE       *     A2,VAR2,VOL2
20500301   0.0  -1.0      P          170010000       * COLD LEG COLLECTOR
+                1.0      P          230010000       * LOWER PLENUM
*
*---------------------------------------------------------------------
* DIFFERENCE OF DP'S OVER HOT AND COLD LEG
*
20500400   DPBCHLG    SUM    1.0      0.0                1            0
20500401   0.0  1.0   CNTRLVAR  3    -1.0    CNTRLVAR  2
*
*---------------------------------------------------------------------
* VAPOR GENERATION IN CORE
*
20500500   VGENCORE   SUM   1.0      0.0                1             0
20500501   0.0  1.0   VAPGEN    100010000    1.0   VAPGEN    100020000
+               1.0   VAPGEN    100030000    1.0   VAPGEN    100040000
+               1.0   VAPGEN    100050000    1.0   VAPGEN    100060000
+               1.0   VAPGEN    100070000    1.0   VAPGEN    100080000
+               1.0   VAPGEN    100090000    1.0   VAPGEN    100100000
+               1.0   VAPGEN    100110000
*
* VAPOR CONDENSATION IN STEAM GENERATOR PRIMARY SIDE
*
20500600   VCONDSG    SUM   1.0      0.0                1             0
20500601   0.0  1.0   VAPGEN    162010000    1.0   VAPGEN    164010000
+               1.0   VAPGEN    162020000    1.0   VAPGEN    164020000
+               1.0   VAPGEN    162030000    1.0   VAPGEN    164030000
+               1.0   VAPGEN    162040000    1.0   VAPGEN    164040000
+               1.0   VAPGEN    162050000    1.0   VAPGEN    164050000
+               1.0   VAPGEN    162060000    1.0   VAPGEN    164060000
*
* VAPORIZATION ALONG UPPER PLENUM AND HOT LEG
*
20500800  VGENHLG     SUM   1.0      0.0                1             0
20500801   0.0  1.0   VAPGEN    105010000    1.0   VAPGEN    105020000
+               1.0   VAPGEN    105030000    1.0   VAPGEN    105040000
+               1.0   VAPGEN    110010000    1.0   VAPGEN    125010000
+               1.0   VAPGEN    120010000    1.0   VAPGEN    120020000
+               1.0   VAPGEN    120030000    1.0   VAPGEN    120040000
+               1.0   VAPGEN    140010000    1.0   VAPGEN    140020000
+               1.0   VAPGEN    140030000    1.0   VAPGEN    140040000
+               1.0   VAPGEN    150010000
*
* STEAM CONDENSATION IN COLD LEG SIDE COLLECTOR & FALLING PIPE
*
20500900  VCONDCL     SUM   1.0      0.0                1             0
20500901   0.0  1.0   VAPGEN    170010000    1.0   VAPGEN    180010000
*
*  EXCESS VAPOR GENERATION
*
20500700  VGENEXCS    SUM   1.0      0.0                1             0
20500701  0.0   1.0   CNTRLVAR  5    1.0   CNTRLVAR  6
+               1.0   CNTRLVAR  8    1.0   CNTRLVAR  9
*
*---------------------------------------------------------------------
*
```

```
* HEAT INPUT IN CORE
*
20502000  QCORE        SUM   1.0      0.0                 1              0
20502001  0.0    1.0   Q    100010000    1.0   Q    100020000
+                1.0   Q    100030000    1.0   Q    100040000
+                1.0   Q    100050000    1.0   Q    100060000
+                1.0   Q    100070000    1.0   Q    100080000
+                1.0   Q    100090000    1.0   Q    100100000
+                1.0   Q    100110000
*
* HEAT INPUT IN SG SECONDARY SIDE
*
20502100  QSGSEC       SUM   1.0      0.0    1   0
20502101  0.0    1.0   Q    250010000    1.0   Q    250020000
+                1.0   Q    250030000
*
* EXCESS HEAT INPUT
*
20502200  QLEXCESS      SUM   1.0      0.0    1   0
20502201  0.0    1.0   CNTRLVAR 20    -1.0   CNTRLVAR 21
*
* HEAT LOSSES AT UPPER PLENUM
*
20502500  QLOSSUP      SUM   1.0      0.0    1   0
20502501  0.0    1.0   Q    105010000    1.0   Q    105020000
+                1.0   Q    105030000    1.0   Q    105040000
+                1.0   Q    115010000    1.0   Q    115020000
+                1.0   Q    110010000
*
* HEAT LOSSES AT HOT LEG
*
20502600  QLOSSHL      SUM   1.0      0.0    1   0
20502601  0.0    1.0   Q    120010000    1.0   Q    120020000
+                1.0   Q    120030000    1.0   Q    120040000
+                1.0   Q    140010000    1.0   Q    140020000
+                1.0   Q    140030000    1.0   Q    140040000
+                1.0   Q    125010000
*
* HEAT LOSSES AT COLD LEG
*
20502700  QLOSSCL      SUM   1.0      0.0    1   0
20502701  0.0    1.0   Q    180010000    1.0   Q    185010000
+                1.0   Q    190010000    1.0   Q    195010000
*
* HEAT LOSSES AT DOWNCOMER
*
20502800  QLOSSDC      SUM   1.0      0.0    1   0
20502801  0.0    1.0   Q    220010000    1.0   Q    220020000
+                1.0   Q    220030000    1.0   Q    220040000
+                1.0   Q    220050000    1.0   Q    220060000
+                1.0   Q    210010000
*
* SUM OF LOSSES
*
20502400  QLOSSSUM      SUM   1.0      0.0    1   0
20502401  0.0    1.0   CNTRLVAR 25    1.0    CNTRLVAR 26
+                1.0   CNTRLVAR 27    1.0    CNTRLVAR 28
*
* TOTAL EXCESS HEAT INPUT
*
20502300  QTEXCESS      SUM   1.0      0.0    1   0
20502301  0.0    1.0   CNTRLVAR 22     1.0   CNTRLVAR 24
*
*================================================================
*
* HYDRODYNAMIC COMPONENTS:
```

```
*
* CORE
*
1000000    CORE   PIPE
1000001    11
1000101    0.00219   11
1000301    0.232     11
1000401    0.0       11
1000601    90.0      11
1000801    5.E-5     7.6E-3   11
1000901    4.81      4.81     10
1001001    00        11
1001101    1000      10
*
* INITIAL VALUES (P, UF, UG, VOIDG)
*
1001201   0   7.0025E5  4.14E5    2.570E6    0.0        0.0    1
1001202   0   6.9300E5  4.29E5    2.570E6    0.0        0.0    2
1001203   0   6.9590E5  4.52E5    2.570E6    0.0        0.0    3
1001204   0   6.9370E5  4.81E5    2.570E6    0.0        0.0    4
1001205   0   6.9150E5  5.17E5    2.570E6    0.0        0.0    5
1001206   0   6.8940E5  5.54E5    2.570E6    0.0        0.0    6
1001207   0   6.8730E5  5.89E5    2.570E6    0.0        0.0    7
1001208   0   6.8516E5  6.21E5    2.570E6    0.0        0.0    8
1001209   0   6.8304E5  6.45E5    2.570E6    0.0        0.0    9
1001210   0   6.8093E5  6.60E5    2.570E6    0.0        0.0    10
1001211   0   6.7883E5  6.60E5    2.570E6    0.0        0.0    11
1001300   1
1001301   0.072       0.0         0.0     10
*
1020000    CORTOUPL    SNGLJUN
1020101    100010000 105000000
1020102    1.08E-3   7.9   7.9   1000
1020201    1   0.072     0.0      0.0
*
* UPPER PLENUM, LOWER PART
*
1050000    UPPLELOW    PIPE
1050001    4
1050101    0.00312    4
1050301    0.572      4
1050401    0.000      4
1050601    90.0       4
1050801    5.0E-5     0.063     4
1050901    3.22       3.22      3
1051001    00         4
1051101    1000       3
1051201    0       6.751E5  6.59E5    2.570E6   0.0        0.0    1
1051202    0       6.700E5  6.59E5    2.570E6   0.0        0.0    2
1051203    0       6.648E5  6.58E5    2.570E6   0.0        0.0    3
1051204    0       6.596E5  6.56E5    2.570E6   0.0        0.0    4
1051300    1
1051301    0.072       0.0        0.0   3
*
*-------------------------------------------------------------
* UPPER PLENUM ( TO THE HOT LEG )
*
1100000    UPLCONX    BRANCH
1100001    3   1
1100101    0.00312  0.858   0.0   0.0   90.0   0.858   5.0E-5   0.063   00
1100200    0       6.5309E5    6.52E5    2.570E6       0.0
1101101    105010000    110000000    0.00312   3.26  3.26  1000
1102101    110010000    120000000    0.000412  6.22  6.22  1002
1103101    110010000    115000000    0.00312   3.25  3.25  1000
1101201    0.072       0.0         0.0
1102201    0.072       0.0         0.0
```

```
1103201    0.0       0.0       0.0
*
* UPPER PLENU . FROM THE HOT LEG )
*
1150000    UPLHEAD    PIPE
1150001    2
1150101    0.00312    1
1150102    0.0553     2
1150301    0.414      1
1150302    0.1        2
1150401    0.0        2
1150601    90.0       2
1150801    5.E-5     0.063    1
1150802    5.E-5     0.265    2
1150901    5.16      5.16     1
1151001    00        2
1151101    1100      1
1151201    0     6.512E5    6.40E5    2.570E6   0.0    0.0    1
1151202    4     6.598E5    415.0     8.0E-4    0.0    0.0    2
1131300    1
1151301    0.0   0.0   0.0   1
*
*-----------------------------------------------------------------
* HOT LEG ( FIRST PART )
*
1200000    HTLGDOWN    PIPE
1200001    4                           * NUMBER OF VOLUMES
1200101    0.000412     4              * FLOW AREAS
1200301    0.5685       4              * LENGTHS
1200501    0.0          4              * HORIZ.ANGLES
1200601   -60.0         4              * VERTICAL ORIENTATION
1200701   -0.4925       4              * ELEVATION CHANGE
1200801    5.0E-5   0.0229     4       * ROUGHNESS, HYDR. DIAMETER
1200901    1.9       1.9       3
1201001    00                  4       * VOL FLAGS=FRICTION+NONEQUILIBRIUM
1201101    1000                3       * JUN FLAGS=NOCHOKE,SMOOTH,2VEL,FUL
* VOLUME INITIAL CONDITIONS=PRESSURE, INTERNAL ENERGIES, VAPOUR VOID FRACTION
1201201    0    6.5950E5   6.512E5    2.570E6   0.0         0.0    2
1201202    0    6.6440E5   6.490E5    2.570E6   0.0         0.0    4
* JUNCTION INITIAL CONDITIONS=MASS FLOWS
1201300    1
1201301    0.072      0.0      0.0   3
*
* HOT LEG ( CONNECTION TO THE PRESSURISER )
***** PRESSURIZER REMOVED BY JT
*
1250000    HTLGFLAT    BRANCH
1250001    2           1       * NO OF JUNS, INIT=MFLOW
1250101    0.412E-3    0.559   0.0   0.0   0.0   0.0  5.0E-5  0.0229  00
1250200    0           6.707E5    6.48E5    2.570E6   0.0
* CONNECTIONS
1251101     120010000   125000000   4.12E-4   3.26 3.26 1000
1252101     125010000   140000000   4.12E-4   3.26 3.26 1000
* JUNCTION INITIAL CONDITIONS: MFLOWL, MFLOWG, INTERPHASE
1251201     0.072     0.0       0.0
1252201     0.072     0.0       0.0
*
* HOT LEG ( TO THE STEAM GENERATOR )
*
1400000    HOTLEGUP   PIPE
1400001    4
1400101    4.12E-4          4
1400301    0.580            4
1400501    0.0              4
1400601    90.0             4
1400701    0.580            4
```

```
1400801     5.0E-5  0.0229  4
1400901     3.22      3.22  3
1401001     00              4
1401101     1000            3
* INITIAL CONDITIONS
1401201     0   6.759E5   6.460E5    2.570E6   0.0  0.0  2
1401202     0   6.650E5   6.442E5    2.570E6   0.0  0.0  4
1401300     1
1401301     0.072       0.0   0.0    3
*
*-----------------------------------------------------------
*
*   STEAM GENERATOR, EXTENDED VERSION 2/JH 1.9.87
*
*   HOT LEG SIDE COLLECTOR (2 BRANCHES WITH CROSSFLOW JUNCTIONS TO SG TUBES)
*
1500000      HOTCOLLW   BRANCH
1500001      3   1            * NO OF JUNS, INIT=FLOWS
* GEOMETRY
1500101      2.043E-3   0.200   0.0   0.0   90.0   0.200
+            5.0E-5     0.051   00
* VOLUME INITIAL CONDITIONS: PRESS, UF, UG, VOIDG
1500200      0   6.485E5   6.430E5    2.570E6   0.0
* CONNECTIONS
1501101      140010000   150000000   4.12E-4   5.5  6.1  1000
1502101      150000000   162000000   7.96E-4   8.7  4.1  1002
1503101      150010000   154000000   2.043E-3  7.9  5.3  1000
* JUNCTION INITIAL CONDITIONS: MFLOWL, MFLOWG, INTERPHASE
1501201      0.072      0.0        0.0
1502201      0.030      0.0        0.0
1503201      0.042      0.0        0.0
*
1540000      HOTCOLUP   BRANCH
1540001      1   1            * NO OF JUNS, INIT=FLOWS
* GEOMETRY
1540101      2.043E-3   0.120   0.0   0.0   90.0   0.120
+            5.0E-5     0.051   00
* VOLUME INITIAL CONDITIONS: PRESS, UF, UG, VOIDG
1540200      0   6.470E5   6.430E5    2.570E6   0.0
* CONNECTIONS
1541101      154000000   16[illegible]00000   7.96E-4  17.9 13.0  1002
* JUNCTION INITIAL CONDITIONS: MFLOWL, MFLOWG, INTERPHASE
1541201      0.042    0.0       0.0
*
* STEAM GENERATOR, PRIMARY SIDE TUBING (2 PIPES)
*
1620000      SGPRIBOT   PIPE
1620001      6                  * NO OF PIPE VOLUMES
1620101      0.7964E-3    6     * AREAS
1620301      0.762        2     * LENGTHS
1620302      2.313        4
1620303      0.762        6
1620501      90.0         3     * HORIZ ANGLES (U-TUBE)
1620503      -90.0        6
1620601      0.0          6     * VERTIC ANGLES
1620701      0.0          6     * ELEV CHANGES
1620801      5.0E-5  0.013  6   * FRICTION DATA
1620901      0.7     0.7    2   * JUNCTION LOSS COEFF
1620902      2.11    2.11   3
1620903      0.7     0.7    5
1621001      00             6    * VOL FLAGS: FRIC+NONEQ
1621101      1000           5    * JUN FLAGS: NOCHOKE, SMOOTH, 2VEL, CENTRAL
* INITIAL VOLUME CONDITIONS: PRESS, UF, UG, VOIDG
1621201      0  6.485E5  5.01E5    2.570E6  0.0      0.0   1
1621202      0  6.485E5  4.67E5    2.570E6  0.0      0.0   2
1621203      0  6.485E5  4.38E5    2.570E6  0.0      0.0   3
```

```
1621204      0  6.485E5  4.28E5     2.570E6  0.0      0.0   4
1621205      0  6.485E5  4.26E5     2.570E6  0.0      0.0   5
1621206      0  6.485E5  4.25E5     2.570E6  0.0      0.0   6
* INITIAL JUNCTION CONDITIONS
1621300      1                     * FLOWS FOLLOW
1621301      0.030   0.0    0.0    5
*
1640000      SGPRITOP    PIPE
1640001      6                     * NO OF PIPE VOLUMES
1640101      0.7964E-3    6        * AREAS
1640301      0.762        2        * LENGTHS
1640302      2.313        4
1640303      0.762        6
1640501      90.0         3        * HORIZ ANGLES
1640503      -90.0        6
1640601      0.0          6        * VERTIC ANGLES
1640701      0.0          6        * ELEV CHANGES
1640801      5.0E-5   0.013   6    * FRICTION DATA
1640901      0.7      0.7     2    * JUNCTION LOSS COEFF
1640902      2.11     2.11    3
1640903      0.7      0.7     5
1641001      00           6        * VOL FLAGS: FRIC+NONEQ
1641101      1000         5        * JUN FLAGS: NOCHOKE, SMOOTH, 2VEL, FULL I
* INITIAL VOLUME CONDITIONS: PRESS, UF, UG, VOIDG
1641201      0  6.470E5  5.47E5     2.570E6  0.0      0.0   1
1641202      0  6.470E5  4.96E5     2.570E6  0.0      0.0   2
1641203      0  6.470E5  4.48E5     2.570E6  0.0      0.0   3
1641204      0  6.470E5  4.32E5     2.570E6  0.0      0.0   4
1641205      0  6.470E5  4.29E5     2.570E6  0.0      0.0   5
1641206      0  6.470E5  4.26E5     2.570E6  0.0      0.0   6
* INITIAL JUNCTION CONDITIONS
1641300      1                     * FLOWS FOLLOW
1641301      0.042        0.0         0.0   5
*
* COLD LEG SIDE COLLECTOR
*
1700000      COLDCOLL    BRANCH
1700001      3   1            * NO OF JUNS, INIT=FLOWS
* GEOMETRY
1700101      2.043E-3   0.200   0.0    0.0    -90.0    -0.200
+            5.0E-5     0.051   00
* VOLUME INITIAL CONDITIONS: PRESS, UF, UG, VOIDG
1700200      0   6.485E5    4.266E5     2.570E6    0.0
* CONNECTIONS
1701101      170010000    180000000    4.12E-4     6.1  4.5  1000
1702101      162010000    170000000    7.96E-4     4.1  8.7  1001
1703101      174010000    170000000    2.043E-3    7..  7.9  1000
* JUNCTION INITIAL CONDITIONS: MFLOWL, MFLOWG, INTERPHASE
1701201      0.072        0.0         0.0
1702201      0.030        0.0         0.0
1703201      0.042        0.0         0.0
*
1740000      COLDCOLU    BRANCH
1740001      1   1            * NO OF JUNS, INIT=FLOWS
* GEOMETRY
1740101      2.043E-3   0.120   0.0    0.0    -90.0    -0.120
+            5.0E-5     0.051   00
* VOLUME INITIAL CONDITIONS: PRESS, UF, UG, VOIDG
1740200      0   6.470E5    4.245E5     2.570E6    0.0
* CONNECTIONS
1741101      164010000    174000000    7.96E-4    11.0 13.9  1001
* JUNCTION INITIAL CONDITIONS: MFLOWL, MFLOWG, INTERPHASE
1741201      0.042        0.0         0.0
*
*-------------------------------------------------------------
* COLD LEG
```

```
*
1800000      CLGUP   SN('.VOL
* GEOMETRY
1800101      4.12E-4    2.32     0.0    0.0    -90.0    -2.32
+            5.0E-5     0.0229   00
* INITIAL COND
1800200      0   6.601E5   4.24E5      2.570E6  0.0
*
1830000      COLDLEG1     SNGLJUN
1830101      180010000     185000000
1830102      0.0    9.6     9.6     1000
1830201      1    0.072          0.0        0.0
*
1850000      CLGRISE      SNGLVOL
1850101      4.12E-4      2.30       0.0     0.0    60.0
1850102      2.0          5.00E-5   0.0      00
1850200      0            6.614E5    4.23E5     2.570E6  0.0
*
1870000      COLDLEG2     SNGLJUN
1870101      185010000     190000000
1870102      0.0    9.6     9.6     1000
1870201      1    0.072          0.0        0.0
*
1900000      CLGDOWN      SNGLVOL
1900101      4.12E-4      1.41       0.0      0.0  -90.0
1900102      -1.41        5.0E-5    0.0      00
1900200       0      6.565E5   4.21E5     2.570E6   0.0
*
1930000      COLDLEG3    SNGLJUN
1930101      190010000     195000000
1930102      0.0    9.6     9.6     1000
1930201      1    0.072          0.0        0.0
*
1950000      CLGFLAT      SNGLVOL
1950101      4.12E-4      3.40       0.0      0.0    0.0
1950102       0.0         5.0E-5    0.0       00
1950200       0           6.650E5   4.19E5     2.570E6    0.0
*
*---------------------------------------------------------------
* DOWNCOMER ( UPPER PART )
*
*2050000     DCMRHEAD     SNGLVOL
*2050101     8.04E-4     0.61     0.0        0.0   90.0
*2050102     0.61        5.0E-5   0.0        00
*2050200     0           4.336E5  4.20E5     2.570E6   0.0
*
* DOWNCOMER ( CONNECTION TO THE COLD LEG )
*
2100000      DCMRCONX      BRANCH
2100001      2             1
2100101      8.04E-4     1.22      0.0       0.0     -90.0
2100102      -1.22       5.0E-5    0.0      00
2100200      0           6.649E5   4.18E5      2.570E6  0.0
2101101      195010000  210000000  0.0      11.82 11.82  1001
2102101      210010000  220000000  0.0        9.94  9.94  1000
*2103101      210000000  205000000  0.0        0.2  0.2   1000
2101201      0.072        0.0            0.0
2102201      0.072        0.0            0.0
*
* DOWNCOMER
*
2200000      DOWNCOMR     PIPE
2200001      6
2200101      0.804E-3  4
2200105      1.225E-3  6
2200301      1.0945    1
```

```
2200302     1.22275   3
2200305     1.283     6
2200601     -90.0     6
2200801     5.0E-5    0.032    4
2200802     5.0E-5    0.0395   6
2200901     1.1       1.1    5
2201001     00        6
2201104     1000      5
2201201     0      6.758E5     4.177E5     2.570E6    0.0    0.0    1
2201202     0      6.866E5     4.167E5     2.570E6    0.0    0.0    2
2201203     0      6.981E5     4.157E5     2.570E6    0.0    0.0    3
2201204     0      7.098E5     4.146E5     2.570E6    0.0    0.0    4
2201205     0      7.219E5     4.136E5     2.570E6    0.0    0.0    5
2201206     0      7.340E5     4.125E5     2.570E6    0.0    0.0    6
2201300     1
2201301     0.072         0.0       0.0       5
*
*----------------------------------------------------------
* LOWER PLENUM
*
* NEW LOWER PLENUM
*
2300000     LPFLAT2   BRANCH
2300001     2         1
2300101     1.83E-3   0.740   0.0      0.0     0.0    0.0    5.0E-5  0.0  00
2300200     0         7.40E5   4.126E5  2.57E6 0.0
2301101     220010000 230000000   0.0  14.89 14.89  1000
2302101     230010000 240000000   0.0  14.29 14.29  1000
2301201     0.072     0.0          0.0
2302201     0.072     0.0          0.0
*
2400000      LOWPLUP    PIPE
2400001      4
2400101      4.083E-3  2
2400102      2.736E-3  4
2400301      1.20      1
2400302      1.20      2
2400303      0.884     3
2400304      0.826     4
2400601      90.0      4
2400801      5.0E-5   0.0   -
2400901     18.63     18.63  1   * JUNCTION LOSS COEFF.
2400902     27.63     27.63  3
2401001      00        4
2401101      1000      3
2401201      0      7.343E5     4.129E5     2.570E6    0.0   0.0    1
2401202      0      7.231E5     4.134E5     2.570E6    0.0   0.0    2
2401203      0      7.133E5     4.137E5     2.570E6    0.0   0.0    3
2401204      0      7.052E5     4.139E5     2.570E6    0.0   0.0    4
2401300      1
2401301      0.072         0.0       0.0       3
*
2450000     LPTOCORE    SNGLJUN
2450101     240010000    100000000
2450102     0.0  16.87  16.87   1000
2450201     1    0.072        0.0       0.0
*
*----------------------------------------------------------
* STEAM GENERATOR SECONDARY SIDE
* (PIPE OF 3 COMPONENTS, SNGLJUN, TMPDVOL)
*
2500000     SGSEC   PIPE
2500001     3                     * NO OF VOLS
2500101     0.7501          2     * FLOW AREAS
2500102     0.8302          3
2500301     0.120           2     * HEIGHTS
```

```
2500302    0.166         3
2500601    90.0          3        * VERTICAL ANGLES
2500801    5.0E-5  0.0   3        * ROUGHNESS, DHY
2500901    1.3     1.3   2        * JUNCTION LOSSES
2501001    00            3        * VOL FLAGS: FRICT, NON-EQUIL
2501101    1000          2        * JUN FLAGS: NOCHOKE, SMOOTH, 2VEL. IN
2501201    2     1.035E5   1.5E-5  0.0
*          0.0   0.0       2      * INITIAL VOL COND: PRESS, STAT X
2501202    2   1.023E5     6.9E-4  0.0  0.0  0.0  3
2501300    0                        * INITIAL JUN COND:
2501301    0.0  0.0  0.0   2        * VELOCITIES
*
2560000    SECTOBRY    SNGLJUN
2560101    250010000  260000000  0.05  10.0  5.0  1100
2560201    0    0.00    0.00    0.0
*
2600000    SECBRY      TMDPVOL
* SECONDARY SIDE BOUNDARY CONDITIONS
2600101    1.0  0.20  0.0  0.0  0.0  0.0  5.0E-5  0.0  10
* BOUNDARY COND: PRESSURE = 1.02 BAR, QUALITY 0.07 % (=> VOIDG=0.52)
2600200    2
2600201    0.0   1.02E5    0.0007
*
*---------------------------------------------------
*
* LEAK JUNCTION - TRY CLOSING
*
3000000    LEAK      TMDPJUN              * SNGLJUN
3000101    230000000 310000000    9.2E-4  * 10.0   1.0   1000
*3000201    0          0.0       0.0    0.0
3000200    0
3000201    0.0        0.0       0.0    0.0
*
* LEAK BOUNDARY
*
3100000    LEAKBDRY  TMDPVOL
3100101    1.0E-3    0.5    0.0    0.0    0.0    0.0    5.0E-5  0.0  00
3100200    0       0    UF   220060000
* PRESSURE & INTERNAL ENERGIES & VOIDG  FOLLOW  UF 220-06
3100201    4.00E5    7.4E5  4.00E5    2.573E6    0.0
3100202    4.30E5    7.4E5  4.30E5    2.573E6    0.0
*
*===================================================
*
* HEAT STRUCTURES
*
* STEAM GENERATOR TUBES (2 SIMILAR STRUCTURES
*                       WITH DIFFERENT BOUNDARY VOLUMES)
*
* LOWER PART
* NO OF STRS, NO OF MESHP, CYL, STDY-ST-INIT, LEFT BDRY COORD
11621000  6      3        2       1          6.5E-3
11621100  0   1                 * MESH LOC FLAG, MESH FORMAT FLAG
11621101  2   7.5E-3            * NO OF INTERVALS, RIGHT BDRY COORD
11621201  3   2                 * COMPOSITION NO, INTERVAL NO
11621301  0.0 2                 * SOURCE TERM,     -"-
11621400  0                     * INITIAL COND FLAG: TEMPERATURES FOLLOW
11621401  375.0   1             * MESH POINT TEMPERATURES
11621402  374.0   2
11621403  374.0   3
* LEFT HYDROD BDRY VOLUME, INCR, BDRY=CONV, SURF AREA FLG, -VAL, STR NO
11621501  162010000        10000  1        1             4.5720   2
11621502  162030000        10000  1        1             13.878   4
11621503  162050000        10000  1        1             4.5720   6
* RIGHT (AS LEFT)
11621601  250010000        0      1        1             4.5720   2
```

```
11621602  250010000        0    1       1           13.878   4
11621603  250010000        0    1       1           4.5720   6
11621701  0    0.0    0.0      0.0   6     * NO INTERNAL SOURCE
* LEFT BDRY DATA: CHF FLAG, DHY, HEATED EQU. DIAM, LENGTH
11621801  0    0.013  0.013    0.762  2
11621802  0    0.013  0.013    2.313  4
11621803  0    0.013  0.013    0.762  6
* RIGHT AS LEFT
11621901  0    0.015  0.015    0.762  2
11621902  0    0.015  0.015    2.313  4
11621903  0    0.015  0.015    0.762  6
*
* UPPER PART
11641000  6   3   2   1   6.5E-3
11641100  0   1
11641101  2   7.5E-3
11641201  3   2
11641301  0.0 2
11641400  0
11641401  375.0   1
11641402  374.0   2
11641403  374.0   3
11641501  164010000     10000    1   1   4.5720  2
11641502  164030000     10000    1   1   13.878  4
11641503  164050000     10000    1   1   4.5720  6
11641601  250020000     0    1   1   4.5720  2
11641602  250020000     0    1   1   13.878  4
11641603  250020000     0    1   1   4.5720  6
11641701  0    0.0    0.0      0.0    6
11641801  0    0.013  0.013    0.762  2
11641802  0    0.013  0.013    2.313  4
11641803  0    0.013  0.013    0.762  6
11641901  0    0.015  0.015    0.762  2
11641902  0    0.015  0.015    2.313  4
11641903  0    0.015  0.015    0.762  6
*
*--------------------------------------------
*
* FUEL RODS:
*   CORE (MgO) + CLADDING (S-STEEL)
*
*         NSTR  NP     CYL   STDY=YES  LEFT COORD
11003000  11     5      2     1         0.0
11003100   0    1             * MESH LOC = ENTER HERE
11003101   3   3.55E-3        * NO OF INTERVALS, RIGHT COORDINATE
11003102   1   4.55E-3
11003201   2   3              * COMPOSITION 2 (MGO) / FIRST 3 INTERVALS
11003203   1   4              * COMPOSITION 1 (STEEL) / 4TH INTERVAL
11003301   0.0   1            * SOURCE = 1.0 IN MID-MGO, 0.0 ELSEWHERE
11003302   1.0   2
11003303   0.0   4
11003400   -1                 * INIT. TEMP FLAG = ALL STRS SEPARATELY
* MESH POINT TEMPS FOR ALL HEAT STRUCTURES
11003401   372.27       372.27       372.27       372.27       372.27
11003402   383.26       383.26       382.34       381.02       380.70
11003403   397.29       397.29       395.25       392.32       391.64
11003404   409.18       409.18       406.32       402.23       401.30
11003405   422.07       422.07       418.37       413.07       411.88
11003406   429.58       429.58       425.67       420.08       418.85
11003407   434.09       434.09       430.32       424.93       423.76
11003408   434.34       434.34       431.16       426.61       425.63
11003409   430.29       430.29       428.11       424.97       424.29
11003410   422.87       422.87       421.91       420.51       420.21
11003411   415.07       415.07       415.07       415.07       415.07
11003501   0    0    0   1   0.0    11                  * LEFT BDRY DATA
11003601   100010000   10000   1   1   4.408    11     * RIGHT  -"-
```

```
11003701   100  0.0        0.0   0.0   1                    * SOURCE DISTRIBUTION
11003702   100  0.0407     0.0   0.0   2
11003703   100  0.0887     0.0   0.0   3
11003704   100  0.1221     0.0   0.0   4
11003705   100  0.1559     0.0   0.0   5
11003706   100  0.1628     0.0   0.0   6
11003707   100  0.1559     0.0   0.0   7
11003708   100  0.1313     0.0   0.0   8
11003709   100  0.0908     0.0   0.0   9
11003710   100  0.0406     0.0   0.0   10
11003711   100  0.0        0.0   0.0   11
11003801   0    0.0        0.0         0.232    11     * LEFT EXTRA DATA
11003901   0    7.6E-3     3.1E-3      0.232    11     * RIGHT  -"-
*
* CORE HOUSING (EXTERNAL HEATERS)
*
*          NSTR  NP     RECT  STDY=YES  LEFT COORD
11005000   9     3      1     1         0.0
11005100   0     1         * MESH LOC = ENTER HERE
11005101   2     5.0E-3    * NO OF INTERVALS, RIGHT COORDINATE
11005203   1     2         * COMPOSITION 1 (STEEL)
11005301   0.0   2         * NO (RADIAL) SOURCE
1005400    -1              * INIT. TEMP FLAG: SEPARATE FOR ALL STRS
1005401    389.32      391.02      392.72
1005402    393.14      394.83      396.52
1005403    398.02      399.70      401.39
1005404    404.00      405.68      407.35
1005405    410.23      411.90      413.57
1005406    416.24      417.90      419.57
1005407    421.44      423.10      424.76
1005408    425.34      426.99      428.65
1005409    427.61      429.27      430.92
 LEFT  BDRY DATA
 1005501   100020000  10000   1    0   0.03762   9
 RIGHT BDRY DATA (VOL 310010000 IS USED AS A DUMMY VOLUME)
 WITH FIXED HEAT FLUX FROM TABLE 101
 1005601   310010000  0       2101   0   0.03762   9
 NO (AXIAL) SOURCE
 1005701   0        0.0     0.0     0.0       9
 LEFT EXTRA DATA
 1005801   0    7.6E-3  0.0          0.232        9

---------------------------------------------------------------

 UPPER PLENUM (ENVIRONMENTAL LOSSES)

           NSTR  NMP   CYL  STDY=Y    LEFT COORD
1101000    7     5     2    1         0.0315
1101100    0     1              * MESH LOC & FORMAT
101101     2     0.034          * INTERVALS, RIGHT COORD
1101102    2     0.100
1101201    1     2              * COMPOSITION, INTERVALS
1101202    4     4
101301     0.0   4              * RADIAL SOURCE DISTRIB
101401     413.3 1              * INITIAL TEMPERATURES
101403     413.2 3
101404     340.7 4
101405     297.2 5
 LEFT BOUNDARY DATA
 101501    105010000   10000   1    1     0.572     4
 101502    110010000       0   1    1     0.858     5
 101503    115010000   10000   1    1     0.414     7
 RIGHT BOUNDARY
 101601      -200          0   3110  1    0.572     4
 101602      -200          0   3110  1    0.858     5
 101603      -200          0   3110  1    0.414     7
```

```
* AXIAL SOURCE
11101701   0    0.0     0.0     0.0    7
* ADDITIONAL LEFT BOUNDARY DATA
11101801   0    0.063   0.063   0.0    7
*
* HOT LEG (ENVIRONMENTAL LOSSES)
*
*            NSTR   NMP   CYL  STDY=Y    LEFT COORD
11201000     9      5     2     1          0.01145
11201100     0      1               * MESH LOC & FORMAT
11201101     2      0.01345         * INTERVALS, RIGHT COORD
11201102     2      0.0635
11201201     1      2               * COMPOSITION, INTERVALS
11201202     4      4
11201301     0.0    4               * RADIAL SOURCE DISTRIB
11201401     413.1 3                * INITIAL TEMPERATURES
11201402     336.6 4
11201403     297.7 5
* LEFT BOUNDARY DATA
11201501   120010000      10000    1      1     0.5685    4
11201502   125010000          0    1      1     0.559     5
11201503   140010000      10000    1      1     0.580     9
* RIGHT BOUNDARY
11201601      -200            0   3110    1     0.5685    4
11201602      -200            0   3110    1     0.559     5
11201603      -200            0   3110    1     0.580     9
* AXIAL SOURCE
11201701   0     0.0     0.0      0.0     9
* ADDITIONAL LEFT BOUNDARY DATA
11201801   0     0.0229  0.0229   0.0     9
*
* COLD LEG (ENVIRONMENTAL LOSSES)
*
*          NSTR   NMP   CYL  STDY=Y    LEFT COORD    REFLOOD=NO
11901000   4      5     2     1          0.01145       0
11901100   1201                    * MESH DATA EQUAL TO HOT LEG
11901401   374.4    3
11901402   322.3    4
11901403   296.2    5
* LEFT BOUNDARY DATA
11901501   180010000          0     1      1     2.320      1
11901502   185010000          0     1      1     2.300      2
11901503   190010000          0     1      1     1.410      3
11901504   195010000          0     1      1     3.400      4
* RIGHT BOUNDARY
11901601      -200            0    3120    1     2.320      1
11901602      -200            0    3120    1     2.300      2
11901603      -200            0    3120    1     1.410      3
11901604      -200            0    3120    1     3.400      4
* AXIAL SOURCE
11901701   0     0.0     0.0      0.0     4
* ADDITIONAL LEFT BOUNDARY DATA
11901801   0     0.063   0.063    0.0     4
*
* DOWNCOMER
*
*          NSTR   NMP   CYL  STDY=Y    LEFT COORD
12201000   7      5     2     1          0.019
12201100   0      1               * MESH LOC & FORMAT
12201101   2      0.021           * INTERVALS, RIGHT COORD
12201102   2      0.071
12201201   1      2               * COMPOSITION, INTERVALS
12201202   4      4
12201301   0.0    4               * RADIAL SOURCE DISTRIB
12201401   372.1 3                * INITIAL TEMPERATURES
12201402   324.0 4
```

```
12201403   296.5 5
* LEFT BOUNDARY DATA
12201501   210010000         0    1    1    1.220      1
12201502   220010000         0    1    1    0.880      2
12201503   220020000     10000    1    1    1.22275    4
12201504   220040000     10000    1    1    1.2830     7
* RIGHT BOUNDARY
12201601      -200           0  3120   1    1.220      1
12201602      -200           0  3120   1    0.880      2
12201603      -200           0  3120   1    1.22275    4
12201604      -200           0  3120   1    1.2830     7
* AXIAL SOURCE
12201701   0    0.0    0.0    0.0    7
* ADDITIONAL LEFT BOUNDARY DATA
12201801   0    0.0380  0.0380  0.0    7
*
*=====================================================
*
* COMPOSITION TABLES
*
*-----------------------------------------------------
* MATERIAL PROPERTIES FOR COMPOSITION 1, CLADDING & CORE SHROUD
*
20100100  TBL/FCTN    1      1
*  THERMAL CONDUCTIVITY
20100101  293.15    14.2
20100102  323.15    15.5
20100103  373.15    16.0
20100104  573.15    18.3
20100105  723.15    21.0
20100106  973.15    24.1
20100107 1173.15    27.6
*  VOLUMETRIC HEAT CAPACITY
20100151  293.15     3.718E6
20100152  323.15     3.763E6
20100153  373.15     4.069E6
20100154  573.15     4.408E6
20100155  773.15     4.748E6
20100156 1273.15     5.027E6
*
*-----------------------------------------------------
* MATERIAL PROPERTIES OF MGO, COMPOSITION 2
20100200  TBL/FCTN    1      1
*  THERMAL CONDUCTIVITY
20100201  273.15     7.10
20100202  473.15     5.48
20100203  673.15     3.85
20100204  723.15     3.46
20100205  773.15     3.18
20100206  823.15     2.98
20100207  873.15     2.82
20100208  923.15     2.68
20100209  973.15     2.57
*
*  VOLUMETRIC HEAT CAPACITY
20100251  273.15     3.300E6
20100252  293.15     3.300E6
20100253  573.15     3.296E6
20100254  673.15     3.323E6
20100255  723.15     3.314E6
20100256  923.15     3.865E6
20100257  973.15     3.884E6
*
*-----------------------------------------------------
* PROPERTIES OF COMPOSITION 3, STEAM GENERATOR TUBES, COPPER
```

```
*         TYPE       COND = TABLE     VOLUM. CP = TABLE
20100200  TBL/FCTN    1               1
*
* THERMAL CONDUCTIVITY (ASSUMED CONSTANT)
20100301  385.0
*
* VOLUMETRIC HEAT CAPACITY (ASSUMED CONSTANT)
20100351  3.435E6
*
*---------------------------------------------------------
* COMPOSITION 4, MINERAL WOOL, LEG OUTER INSULATOR
*
20100400  TBL/FCTN    1               1
* CONDUCTIVITY
20100401  0.16
* VOLUMETRIC HEAT CAPACITY
20100451  2.1E5
*
*=========================================================
*
* GENERAL TABLES: POWERS & LOSS BOUNDARY HEAT TRANSFER COEFFICIENTS
*
* - FUEL RODS
20210000  POWER
20210002  0.0    14.0E3
20210004  1.0E4  14.0E3
*
* - EXTERNAL HEATERS,  5 KW = 13.8 KW/M2
20210100  HTRNRATE
20210102  0.0    -13.8E3
20210104  1.0E4  -13.8E3
*
* UPPER PLENUM & HOT LEG
20211000  HTC-T
20211001  0.0     6.1
20211002  10.0   26.1
20211003  1.0E4  26.1
*
* COLD LEG & DOWNCOMER
20212000  HTC-T
20212001  0.0     6.1
20212001  10.0   26.1
20212002  1.0E4  26.1
*
* ENVIRONMENT TEMPERATURE
20220000  TEMP
20220001  0.0    293.0
20220002  1.0E4  293.0
*
. * ================== END OF INPUT =================
```

APPENDIX D LISTING OF INPUT DATA FOR TWO-PHASE CASE

```
= REWET-III NATURAL CIRCULATION, SG 6 INIT /7/ L16-5 / JUHANI HYVARINEN
*
* ---- MOD2 VERSION ----
*
* FILLING RATIO 100 % AND POWER 12+5 kW = THE APPROXIMATE INITIAL STATE
* OF THE LEAK. PRESSURE ABOUT 3.0 BAR
*
*================================================================
*
100  NEW STDY-ST
101  RUN
102  SI    SI
*
* CPU-REMAINING CARD
*
105   5.0    10.0
*
* HYDRODYNAMIC SYSTEM CARDS
*
*    REF. VOLUME    REF. ELEVATION  FLUID        SYSTEM NAME
120  230010000        0.0           WATER        PRIMARY
121  250010000        0.5           WATER        SECONDRY
*
*================================================================
*
* TIME STEP CONTROL CARD(S)
*
*   OPTION ssd03: ss= 7 = 4+2+1 = OMIT
*                                  -SECOND BLOCKS OF VOL&JUN DATA
*                                  -HEAT STRUCTURE TEMPERATURES
*                 d = 2          = OBTAIN MINOR EDITS AT EVERY HYDRODYNAMIC
*                                  TIME STEP
*
*201   10.0    0.5E-6  0.8          00003   1    100   3000
*203  600.0    0.5E-6  0.666666666  00003   3    450   3000
*202   99.0    0.5E-6  0.2          00003   5   1200   3000
203   180.0    0.5E-6  0.2          00003   5   1500   3000
*
*================================================================
*
* TRIPS
*
*----------------------------------------------------------------
*
* TRIP FROM SG INLET PRESSURE >= 2.0 MPA (20 BAR) OR  <= 0.20 MPA
*
* VARIABLE   OF VOLUME   RELATION  2ND VAR  OF 2ND VOL  +CONST   NOT LATCHED
501   P        140030000   GE        NULL     0           2.00E6     N
502   P        140030000   LE        NULL     0           0.20E6     N
*
* TRIP TO STOP NEAR THE STEADY STATE
*
503   MFLOWJ  300000000   LT        NULL     0           1.0E-4     N
504   TIME    0           GT        NULL     0         150.0        L
*----------------------------------------------------------------
* LOGICAL TRIP(S)
*
601   501   OR   502    N
602   503  AND   504    N

 ---------------------------------------------------------------
* TRANSIENT TERMINATING TRIP(S)
*
600   601
*
*================================================================
```

```
*
* MINOR EDIT REQUESTS:
*
* TEMPERATURES
*
301  TEMPF  100010000
302  TEMPF  100110000
303  TEMPF  125010000
304  TEMPF  150010000
305  TEMPF  162010000
306  TEMPF  162020000
307  TEMPF  162040000
308  TEMPF  162050000
307  TEMPF  162060000
308  TEMPF  164010000
309  TEMPF  164020000
310  TEMPF  164040000
311  TEMPF  164050000
312  TEMPF  164060000
313  TEMPF  170010000
314  TEMPF  210010000
315  TEMPF  250010000
316  TEMPF  250020000
317  TEMPF  250030000
*
* HEAT INPUTS IN CORE
*
320  Q      100010000
321  Q      100020000
322  Q      100030000
323  Q      100040000
324  Q      100050000
325  Q      100060000
326  Q      100070000
327  Q      100080000
328  Q      100090000
329  Q      100100000
330  Q      100110000
*
* MASS FLOWS
*
332  MFLOWJ   102000000
333  MFLOWJ   162020000
334  MFLOWJ   164020000
335  MFLOWJ   220040000
336  MFLOWJ   300000000
*
* VELOCITIES
*
*349  VELFJ    256000000
*350  VELGJ    256000000
*
* PRESSURES
*
337  P         140030000
338  P         100110000
339  P         250030000
*
* SOME HEAT STRUCTURE TEMPERATURES AT SG TUBES
*
*354  HTTEMP   162100103
*355  HTTEMP   162100603
*356  HTTEMP   164100103
*357  HTTEMP   164100603
*
* HEAT INPUT RATES AT SG TUBES
```

```
*
340  Q    162010000
341  Q    162020000
342  Q    162030000
343  Q    162040000
344  Q    162050000
345  Q    162060000
*
346  Q    164010000
347  Q    164020000
348  Q    164030000
349  Q    164040000
350  Q    164050000
351  Q    164060000
*
* STEAM VOID FRACTIONS
*
353 VOIDG      250010000
354 VOIDG      250020000
355 VOIDG      250030000
*
356 VOIDG      115010000
357 VOIDG      115020000
*
358 QUALA      115020000
*
359 VOIDG      120010000
360 VOIDG      120020000
361 VOIDG      120030000
362 VOIDG      120040000
*
363 VOIDG      105010000
364 VOIDG      105020000
365 VOIDG      105030000
366 VOIDG      105040000
*
* CONTROL VARIABLES (DPS, EXCESS STEAM GENERATION, HEAT INPUTS)
*
385 CNTRLVAR    1
386 CNTRLVAR    2
387 CNTRLVAR    3
388 CNTRLVAR    4
389 CNTRLVAR    7
390 CNTRLVAR   20
391 CNTRLVAR   21
392 CNTRLVAR   22
393 CNTRLVAR   23
394 CNTRLVAR   24
395 CNTRLVAR   25
396 CNTRLVAR   26
397 CNTRLVAR   27
398 CNTRLVAR   28
*
* SPECIALITIES
*
399 CPUTIME    0
*
*=================================================================
*
* CONTROL VARIABLES
*
*-----------------------------------------------------------------
*   PRESSURE DIFFERENCES:
*     DP = A0 + A1*VAR1 + A2*VAR2, DIMENSIONS NOT SCALED (SCALE=1.0)
*
*   - OVER CORE
```

```
*
*          NAME     TYPE  SCALE   INIT.VAL   INIT.FLG=COMPUTE  NO LIMITS
20500100   DPCORE   SUM   1.0     0.0                1              0
*          A0    A1     VAR1 CODE  VOL1 CODE
*          +     A2     VAR2       VOL2
20500101   0.0   1.0    P          100010000     * CORE BOTTOM
+               -1.0    P          100110000     * CORE TOP
*
*   - OVER HOT LEG
*
*          NAME      TYPE  SCALE   INIT.VAL   INIT.FLG=COMPUTE  NO LIMITS
20500200   DPHTLEG   SUM   1.0     0.0                1              0
*          A0    A1      VAR1 CODE  VOL1 CODE      +     A2,VAR2,VOL2
20500201   0.0  -1.0     P          150010000      * HOT LEG COLLECTOR
+                1.0     P          230010000      * LOWER PLENUM
*
*   - OVER COLD LEG
*
*          NAME      TYPE  SCALE   INIT.VAL   INIT.FLG=COMPUTE  NO LIMITS
20500300   DPCDLEG   SUM   1.0     0.0                1              0
*          A0    A1      VAR1 CODE  VOL1 CODE      +     A2,VAR2,VOL2
20500301   0.0  -1.0     P          170010000      * COLD LEG COLLECTOR
+                1.0     P          230010000      * LOWER PLENUM
*
*------------------------------------------------------------------
* DIFFERENCE OF DP'S OVER HOT AND COLD LEG
*
20500400   DPBCHLG     SUM    1.0     0.0              1            0
20500401   0.0  1.0    CNTRLVAR  3   -1.0    CNTRLVAR  2
*
*------------------------------------------------------------------
* VAPOR GENERATION IN CORE
*
20500500   VGENCORE    SUM   1.0     0.0              1              0
20500501   0.0  1.0    VAPGEN    100010000    1.0   VAPGEN    100020000
+               1.0    VAPGEN    100030000    1.0   VAPGEN    100040000
+               1.0    VAPGEN    100050000    1.0   VAPGEN    100060000
+               1.0    VAPGEN    100070000    1.0   VAPGEN    100080000
+               1.0    VAPGEN    100090000    1.0   VAPGEN    100100000
+               1.0    VAPGEN    100110000
*
* VAPOR CONDENSATION IN STEAM GENERATOR PRIMARY SIDE
*
20500600   VCONDSG     SUM   1.0     0.0              1              0
20500601   0.0  1.0    VAPGEN    162010000    1.0   VAPGEN    164010000
+               1.0    VAPGEN    162020000    1.0   VAPGEN    164020000
+               1.0    VAPGEN    162030000    1.0   VAPGEN    164030000
+               1.0    VAPGEN    162040000    1.0   VAPGEN    164040000
+               1.0    VAPGEN    162050000    1.0   VAPGEN    164050000
+               1.0    VAPGEN    162060000    1.0   VAPGEN    164060000
*
* VAPORIZATION ALONG UPPER PLENUM AND HOT LEG
*
20500800  VGENHLG      SUM   1.0     0.0              1              0
20500801   0.0  1.0    VAPGEN    105010000    1.0   VAPGEN    105020000
+               1.0    VAPGEN    105030000    1.0   VAPGEN    105040000
+               1.0    VAPGEN    110010000    1.0   VAPGEN    125010000
+               1.0    VAPGEN    120010000    1.0   VAPGEN    120020000
+               1.0    VAPGEN    120030000    1.0   VAPGEN    120040000
+               1.0    VAPGEN    140010000    1.0   VAPGEN    140020000
+               1.0    VAPGEN    140030000    1.0   VAPGEN    140040000
+               1.0    VAPGEN    150010000
*
* STEAM CONDENSATION IN COLD LEG SIDE COLLECTOR & FALLING PIPE
*
20500900  VCONDCL      SUM   1.0     0.0              1              0
```

```
20500901   0.0  1.0   VAPGEN    170010000    1.0   VAPGEN    180010000
*
*  EXCESS VAPOR GENERATION
*
20500700  VGENEXCS    SUM   1.0     0.0              1           0
20500701  0.0   1.0   CNTRLVAR  5   1.0   CNTRLVAR  6
+               1.0   CNTRLVAR  8   1.0   CNTRLVAR  9
*
*----------------------------------------------------------------------
*
* HEAT INPUT IN CORE
*
20502000  QCORE       SUM   1.0     0.0              1           0
20502001  0.0   1.0   Q    100010000    1.0   Q    100020000
+               1.0   Q    100030000    1.0   Q    100040000
+               1.0   Q    100050000    1.0   Q    100060000
+               1.0   Q    100070000    1.0   Q    100080000
+               1.0   Q    100090000    1.0   Q    100100000
+               1.0   Q    100110000
*
* HEAT INPUT IN SG SECONDARY SIDE
*
20502100  QSGSEC      SUM   1.0     0.0    1   0
20502101  0.0   1.0   Q    250010000    1.0   Q    250020000
+               1.0   Q    250030000
*
* EXCESS HEAT INPUT
*
20502200  QLEXCESS     SUM   1.0     0.0    1   0
20502201  0.0   1.0   CNTRLVAR 20    -1.0   CNTRLVAR 21
*
* HEAT LOSSES AT UPPER PLENUM
*
20502500  QLOSSUP     SUM   1.0     0.0    1   0
20502501  0.0   1.0   Q    105010000    1.0   Q    105020000
+               1.0   Q    105030000    1.0   Q    105040000
+               1.0   Q    115010000    1.0   Q    115020000
+               1.0   Q    110010000
*
* HEAT LOSSES AT HOT LEG
*
20502600  QLOSSHL     SUM   1.0     0.0    1   0
20502601  0.0   1.0   Q    120010000    1.0   Q    120020000
+               1.0   Q    120030000    1.0   Q    120040000
+               1.0   Q    140010000    1.0   Q    140020000
+               1.0   Q    140030000    1.0   Q    140040000
+               1.0   Q    125010000
*
* HEAT LOSSES AT COLD LEG
*
20502700  QLOSSCL     SUM   1.0     0.0    1   0
20502701  0.0   1.0   Q    180010000    1.0   Q    185010000
+               1.0   Q    190010000    1.0   Q    195010000
*
* HEAT LOSSES AT DOWNCOMER
*
20502800  QLOSSDC     SUM   1.0     0.0    1   0
20502801  0.0   1.0   Q    220010000    1.0   Q    220020000
+               1.0   Q    220030000    1.0   Q    220040000
                1.0   Q    220050000    1.0   Q    220060000
                1.0   Q    210010000

  SUM OF LOSSES

:0502400  QLOSSSUM     SUM   1.0     0.0    1   0
:0502401  0.0   1.0   CNTRLVAR 25    1.0    CNTRLVAR 26
```

```
*                1.0   CNTRLVAR 27    1.0    CNTRLVAR 28
*
* TOTAL EXCESS HEAT INPUT
*
20502300  QTEXCESS      SUM   1.0      0.0    1   0
20502301  0.0   1.0   CNTRLVAR 22     1.0   CNTRLVAR 24
*
*=====================================================================
*
* HYDRODYNAMIC COMPONENTS:
*
* CORE
*
1000000    CORE   PIPE
1000001    11
1000101    0.00219   11
1000301    0.232     11
1000401    0.0       11
1000601    90.0      11
1000801    5.E-5     7.6E-3   11
1000901    0.41      0.41     10
1001001    00       11
1001101    1000     10
*
* INITIAL VALUES (P, UF, UG, VOIDG)
*
1001201   0   3.4025E5  4.14E5    2.530E6    0.0        0.0    1
1001202   0   3.3800E5  4.30E5    2.530E6    0.0        0.0    2
1001203   0   3.3590E5  4.60E5    2.530E6    0.0        0.0    3
1001204   0   3.3370E5  4.72E5    2.530E6    0.0        0.0    4
1001205   0   3.3150E5  4.88E5    2.530E6    0.0        0.0    5
1001206   0   3.2940E5  5.08E5    2.530E6    0.0        0.0    6
1001207   0   3.2730E5  5.28E5    2.530E6    0.0        0.0    7
1001208   0   3.2516E5  5.43E5    2.530E6    0.0        0.0    8
1001209   0   3.2304E5  5.49E5    2.530E6    0.0        0.0    9
1001210   0   3.2093E5  5.50E5    2.530E6    0.0        0.0   10
1001211   0   3.1883E5  5.50E5    2.530E6    0.0        0.0   11
1001300   1
1001301   0.072       0.0        0.0     10
*
1020000    CORTOUPL    SNGLJUN
1020101    100010000 105000000
1020102    1.08E-3   1.9   1.9   1000
1020301    1   0.072     0.0      0.0
*
* UPPER PLENUM, LOWER PART
*
1050000    UPPLELOW    PIPE
1050001    4
1050101    0.00312    4
1050301    0.572     4
1050401    0.000     4
1050601    90.0      4
1050801    5.0E-5    0.063    4
1050901     0.0       0.0     3
1051001    00        4
1051101    1000      3
1051201    0       3.151E5  5.50E5    2.530E6   0.0        0.0    1
1051202    0       3.100E5  5.50E5    2.530E6   0.0        0.0    2
1051203    0       3.048E5  5.49E5    2.530E6   0.0        0.0    3
1051204    0       2.996E5  5.49E5    2.530E6   0.0        0.0    4
1051300    1
1051301    C.072      0.0       0.0    3

 ----------------------------------------------------------------------
 UPPER PLENUM ( TO THE HOT LEG )
```

```
*
1100000    UPLCONX    BRANCH
1100001    3   1
1100101    0.00312  0.858   0.0   0.0   90.0   0.858   5.0E-5    0.063   00
1100200    0        2.9309E5      5.49E5      2.530E6      0.0
1101101    105010000    110000000     0.00312    0.66  0.66  1000
1102101    110010000    120000000     0.000412   1.22  1.22  1002
1103101    110010000    115000000     0.00312    0.85  0.85  1000
1101201    0.072        0.0        0.0
1102201    0.072        0.0        0.0
1103201    0.0      0.0        0.0
*
* UPPER PLENUM ( FROM THE HOT LEG )
*
1150000    UPLHEAD     PIPE
1150001    2
1150101    0.00312     1
1150102    0.0553      2
1150301    0.414       1
1150302    0.1         2
1150401    0.0         2
1150601    90.0        2
1150801    5.E-5      0.063     1
1150802    5.E-5      0.265     2
1150901    0.16       0.16      1
1151001    00         2
1151101    1100
1151201    0     2.912E5    5.49E5    2.530E6   0.0    0.0     1
1151202    4     2.908E5    415.0     4.0E-4    0.0    0.0     2
1151300    1
1151301    0.0   0.0   0.0   1
*
*------------------------------------------------------------------------
* HOT LEG ( FIRST PART )
*
1200000    HTLGDOWN    PIPE
1200001    4                                 * NUMBER OF VOLUMES
1200101    0.000412      4                   * FLOW AREAS
1200301    0.5605        4                   * LENGTHS
1200501    0.0           4                   * HORIZ.ANGLES
1200601   -60.0          4  -->              * VERTICAL ORIENTATION
1200701   -0.4925        4                   * ELEVATION CHANGE
1200801    5.0E-5   0.0229     4             * ROUGHNESS, HYDR. DIAMETER
1200901    0.0      0.0        3
1201001    00                  4             * VOL FLAGS=FRICTION+NONEQUILIBRIUM
1201101    1000                3             * JUN FLAGS=NOCHOKE,SMOOTH,2VEL,FUL
* VOLUME INITIAL CONDITIONS=PRESSURE, INTERNAL ENERGIES, VAPOUR VOID FRACTION
1201201    0    2.9450E5   5.502E5    2.530E6   0.0         0.0    2
1201202    0    2.9640E5   5.500E5    2.530E6   0.0         0.0    4
* JUNCTION INITIAL CONDITIONS=MASS FLOWS
1201300    1
1201301    0.072      0.0      0.0   3
*
* HOT LEG ( CONNECTION TO THE PRESSURISER )
***** PRESSURIZER REMOVED BY JT
*
1250000    HTLGFLAT    BRANCH
1250001    2           1       * NO OF JUNS, INIT=MFLOW
1250101    0.412E-3    0.559   0.0   0.0   0.0   0.0  5.0E-5  0.0229  00
1250200    0           2.907E5    5.49E5    2.530E6   0.0
* CONNECTIONS
1251101     120010000   125000000   4.12E-4   0.36 0.36 1000
1252101     125010000   140000000   4.12E-4   0.36 0.36 1000
* JUNCTION INITIAL CONDITIONS: MFLOWL, MFLOWG, INTERPHASE
1251201     0.072      0.0       0.0
1252201     0.072      0.0       0.0
```

```
*
* HOT LEG ( TO THE STEAM GENERATOR )
*
1400000    HOTLEGUP   PIPE
1400001    4
1400101    4.12E-4          4
1400301    0.580            4
1400501    0.0              4
1400601    90.0             4
1400701    0.580            4
1400801    5.0E-5  0.0229   4
1400901     0.0        0.0  3
1401001    00               4
1401101    1000             3
* INITIAL CONDITIONS
1401201    0   2.959E5   5.490E5    2.530E6   0.0  0.0  2
1401202    0   2.950E5   5.[illegible]E5    2.530E6   0.0  0.0  4
1401300    1
1401301    0.072       0.0   0.0    3
*
*-------------------------------------------------------
*
*   STEAM GENERATOR, EXTENDED VERSION 2/JH 1.9.87
*
*   HOT LEG SIDE COLLECTOR (2 BRANCHES WITH CROSSFLOW JUNCTIONS TO SG TUBES)
*
1500000     HOTCOLLW   BRANCH
1500001     3   1            * NO OF JUNS, INIT=FLOWS
* GEOMETRY
1500101     2.043E-3   0.200   0.0   0.0   90.0   0.200
+           5.0E-5     0.051   00
* VOLUME INITIAL CONDITIONS: PRESS, UF, UG, VOIDG
1500200     0   2.985E5   5.520E5    2.530E6   0.0
* CONNECTIONS
1501101     140010000   150000000   4.12E-4   2.5  3.1  1000
1502101     150000000   162000000   7.96E-4   3.7  2.1  1002
1503101     150010000   154000000   2.043E-3  1.3  1.3  1000
* JUNCTION INITIAL CONDITIONS: MFLOWL, MFLOWG, INTERPHASE
1501201     0.072      0.0       0.0
1502201     0.030      0.0       0.0
1503201     0.042      0.0  -    0.0
*
1540000     HOTCOLUP   BRANCH
1540001     1   1            * NO OF JUNS, INIT=FLOWS
* GEOMETRY
1540101     2.043E-3   0.120   0.0   0.0   90.0   0.120
+           5.0E-5     0.051   00
* VOLUME INITIAL CONDITIONS: PRESS, UF, UG, VOIDG
1540200     0   2.970E5   5.520E5    2.530E6   0.0
* CONNECTIONS
1541101     154000000   164000000   7.96E-4   3.7  2.1  1002
* JUNCTION INITIAL CONDITIONS: MFLOWL, MFLOWG, INTERPHASE
1541201     0.042     0.0      0.0
*
* STEAM GENERATOR, PRIMARY SIDE TUBING (2 PIPES)
*
1620000     SGPRIBOT   PIPE
1620001     6                 * NO OF PIPE VOLUMES
1620101     0.7964E-3    6    * AREAS
1620301     0.762        2    * LENGTHS
1620302     2.313        4
1620303     0.762        6
1620501     90.0         3    * HORIZ ANGLES (U-TUBE)
1620503     -90.0        6
1620601     0.0          6    * VERTIC ANGLES
1620701     0.0          6    * ELEV CHANGES
```

```
1620801      5.0E-5  0.013  6  * FRICTION DATA
1620901      0.0     0.0    2  * JUNCTION LOSS COEFF
1620902      0.11    0.11   3
1620903      0.0     0.0    5
1621001      00             6     * VOL FLAGS: FRIC+NONEQ
1621101      1000           5     * JUN FLAGS: NOCHOKE, SMOOTH, 2VEL, CENTRAL
* INITIAL VOLUME CONDITIONS: PRESS, UF, UG, VOIDG
1621201      0  2.985E5  5.01E5    2.530E6  0.0      0.0   1
1621202      0  2.985E5  4.67E5    2.530E6  0.0      0.0   2
1621203      0  2.985E5  4.38E5    2.530E6  0.0      0.0   3
1621204      0  2.985E5  4.28E5    2.530E6  0.0      0.0   4
1621205      0  2.985E5  4.26E5    2.530E6  0.0      0.0   5
1621206      0  2.985E5  4.25E5    2.530E6  0.0      0.0   6
* INITIAL JUNCTION CONDITIONS
1621300      1                 * FLOWS FOLLOW
1621301      0.030   0.0   0.0    5
*
1640000      SGPRITOP   PIPE
1640001      6                 * NO OF PIPE VOLUMES
1640101      0.7964E-3   6     * AREAS
1640301      0.762       2     * LENGTHS
1640302      2.313       4
1640303      0.762       6
1640501      90.0        3     * HORIZ ANGLES
1640503      -90.0       6
1640601      0.0         6     * VERTIC ANGLES
1640701      0.0         6     * ELEV CHANGES
1640801      5.0E-5  0.013  6  * FRICTION DATA
1640901      0.7     0.7    2  * JUNCTION LOSS COEFF
1640902      2.11    2.11   3
1640903      0.7     0.7    5
1641001      00             6     * VOL FLAGS: FRIC+NONEQ
1641101      1000           5     * JUN FLAGS: NOCHCKE, SMOOTH, 2VEL, FULL I
* INITIAL VOLUME CONDITIONS: PRESS, UF, UG, VOIDG
1641201      0  2.870E5  5.47E5    2.530E6  0.0      0.0  1
1641202      0  2.870E5  4.96E5    2.530E6  0.0      0.0  2
1641203      0  2.870E5  4.48E5    2.530E6  0.0      0.0  3
1641204      0  2.870E5  4.32E5    2.530E6  0.0      0.0  4
1641205      0  2.870E5  4.29E5    2.530E6  0.0      0.0  5
1641206      0  2.870E5  4.26E5    2.530E6  0.0      0.0  6
* INITIAL JUNCTION CONDITIONS
1641300      1                 * FLOWS FOLLOW
1641301      0.042        0.0        0.0   5
*
* COLD LEG SIDE COLLECTOR
*
1700000      COLDCOLL   BRANCH
1700001      3   1            * NO OF JUNS, INIT=FLOWS
* GEOMETRY
1700101      2.043E-3   0.200   0.0   0.0   -90.0   -0.200
+            5.0E-5     0.051   00
* VOLUME INITIAL CONDITIONS: PRESS, UF, UG, VOIDG
1700200      0   2.885E5   4.266E5    2.530E6   0.0
* CONNECTIONS
1701101      170010000   180000000   4.12E-4    3.1  2.5  1000
1702101      162010000   170000000   7.96E-4    2.3  4.1  1001
1703101      174010000   170000000   2.043E-3   1.3  1.3  1000
* JUNCTION INITIAL CONDITIONS: MFLOWL, MFLOWG, INTERPHASE
1701201      0.072        0.0       0.0
1702201      0.030        0.0       0.0
1703201      0.042        0.0       0.0
*
1740000      COLDCOLU   BRANCH
1740001      1   1            * NO OF JUNS, INIT=FLOWS
* GEOMETRY
1740101      2.043E-3   0.120   0.0   0.0   -90.0   -0.120
```

```
+          5.0E-5     0.051   00
* VOLUME INITIAL CONDITIONS: PRESS, UF, UG, VOIDG
1740200     0   2.870E5   4.245E5    2.530E6   0.0
* CONNECTIONS
1741101      164010000   174000000   7.96E-4    2.3  4.1  1001
* JUNCTION INITIAL CONDITIONS: MFLOWL, MFLOWG, INTERPHASE
1741201      0.042          0.0        0.0
*
*-------------------------------------------------------------
* COLD LEG
*
1800000      CLGUP  SNGLVOL
* GEOMETRY
1800101      4.12E-4    2.32     0.0    0.0   -90.0   -2.32
+            5.0E-5    0.0229  00
* INITIAL COND
1800200     0   4.401E5   4.24E5     2.530E6  0.0
*
1830000     COLDLEG1     SNGLJUN
1830101     180010000    185000000
1830102     0.0    0.6     0.6    1000
1830201     1    0.072          0.0        0.0
*
1850000      CLGRISE      SNGLVOL
1850101      4.12E-4     2.30      0.0     0.0    60.0
1850102      2.0         5.00E-5  0.0      00
1850200      0           3.014E5   4.23E5    2.530E6  0.0
*
1870000     COLDLEG2     SNGLJUN
1870101     185010000     190000000
1870102     0.0     0.6     0.6     1000
1870201     1    0.072          0.0        0.0
*
1900000      CLGDOWN      SNGLVOL
1900101      4.12E-4      1.41      0.0      0.0  -90.0
1900102      -1.41        5.0E-5   0.0      00
1900200       0      3.085E5   4.21E5     2.530E6   0.0
*
1930000     COLDLEG3    SNGLJUN
1930101     190010000     195000000
1930102     0.0     0.6     0.6    1000
1930201     1    0.072          0.0        0.0
*
1950000      CLGFLAT      SNGLVOL
1950101      4.12E-4      3.40      0.0      0.0    0.0
1950102       0.0         5.0E-5   0.0      00
1950200       0           3.050E5  4.19E5     2.530E6    0.0
*
*-------------------------------------------------------
* DOWNCOMER ( UPPER PART )
*
*2050000     DCMRHEAD     SNGLVOL
*2050101     8.04E-4     0.61     0.0        0.0   90.0
*2050102     0.61       5.0E-5   0.0        00
*2050200     0          4.336E5  4.20E5     2.550E6    0.0
*
* DOWNCOMER ( CONNECTION TO THE COLD LEG )
*
2100000     DCMRCONX      BRANCH
2100001     2             1
2100101     8.04E-4      1.22      0.0       0.0     -90.0
2100102     -1.22        5.0E-5   0.0       00
2100200     0            3.049E5  4.18E5     2.530E6  0.0
2101101     195010000  210000000  0.0        1.42  1.42  1001
2102101     210010000  220000000  0.0        0.94  0.94  1000
*2103101     210000000  205000000  0.0        0.2  0.2   1000
```

```
2101201     0.072       0.0        0.0
2102201     0.072       0.0        0.0
*
* DOWNCOMER
*
2200000     DOWNCOMR    PIPE
2200001     6
2200101     0.804E-3  4
2200105     1.225E-3  6
2200301     1.0945    1
2200302     1.22275   3
2200305     1.263     6
2200601     -90.0     6
2200801     5.0E-5    0.032    4
2200802     5.0E-5    0.0395   6
2200901     0.0       0.0    5
2201001     00        6
2201104     1000      5
2201201     0     3.158E5    4.177E5    2.530E6   0.0   0.0   1
2201202     0     3.266E5    4.167E5    2.530E6   0.0   0.0   2
2201203     0     3.381E5    4.157E5    2.530E6   0.0   0.0   3
2201204     0     3.498E5    4.146E5    2.530E6   0.0   0.0   4
2201205     0     3.619E5    4.136E5    2.530E6   0.0   0.0   5
2201206     0     3.740E5    4.125E5    2.530E6   0.0   0.0   6
2201300     1
2201301     0.072        0.0       0.0       5
*
*-----------------------------------------------------
* LOWER PLENUM
*
* NEW LOWER PLENUM
*
2300000     LPFLAT2   BRANCH
2300001     2         1
2300101     1.83E-3   0.740   0.0     0.0    0.0    0.0   5.0E-5  0.0  00
2300200     0         3.80E5   4.126E5  2.53E6 0.0
2301101     220010000 230000000   0.0   0.89  0.89  1000
2302101     230010000 240000000   0.0   0.29  0.29  1000
2301201     0.072     0.0         0.0
2302201     0.072     0.0         0.0
*
2400000     LOWPLUP    PIPE
2400001     4
2400101     4.083E-3  2
2400102     2.736E-3  4
2400301     1.20      1
2400302     1.20      2
2400303     0.684     3
2400304     0.826     4
2400601     90.0      4
2400801     5.0E-5    0.0   4
2400901     0.63      0.63  1   * JUNCTION LOSS COEFF.
2400902     3.63      3.63  3
2401001     00        4
2401101     1000      3
2401201     0     3.743E5    4.129E5    2.530E6   0.0   0.0   1
2401202     0     3.631E5    4.134E5    2.530E6   0.0   0.0   2
2401203     0     3.533E5    4.137E5    2.530E6   0.0   0.0   3
2401204     0     3.452E5    4.139E5    2.530E6   0.0   0.0   4
2401300     1
2401301     0.072        0.0       0.0       3
*
2450000     LPTOCORE     SNGLJUN
2450101     240010000     100000000
2450102     0.0   0.87   1.87   1000
2450201     1   0.072        0.0       0.0
```

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*
*-------------------------------------------------------
* STEAM GENERATOR SECONDARY SIDE
* (PIPE OF 3 COMPONENTS, SNGLJUN, TMPDVOL)

2500000    SGSEC   PIPE
2500001    3                        * NO OF VOLS
2500101    0.7501        2          * FLOW AREAS
2500102    0.8302        3
2500301    0.120         2          * HEIGHTS
2500302    0.166         3
2500601    90.0          3          * VERTICAL ANGLES
2500801    5.0E-5  0.0   3          * ROUGHNESS, DHY
2500901    1.3     1.3   2          * JUNCTION LOSSES
2501001    00            3          * VOL FLAGS: FRICT, NON-EQUIL
2501101    1000          2          * JUN FLAGS: NOCHOKE, SMOOTH, 2VEL, IN
2501201    2     1.035E5   1.5E-5  0.0
*          0.0   0.0       2        * INITIAL VOL COND: PRESS, STAT X
2501202    2   1.023E5     6.9E-4   0.0  0.0  0.0  3
2501300    0                           * INITIAL JUN COND:
2501301    0.0  0.0  0.0   2           * VELOCITIES

2560000    SECTOBRY    SNGLJUN
2560101    250010000  260000000  0.05  10.0  5.0  1100
2560201    0   0.00   0.00   0.0
*
2600000    SECBRY      TMDPVOL
* SECONDARY SIDE BOUNDARY CONDITIONS
2600101    1.0  0.20  0.0  0.0  0.0  0.0  5.0E-5  0.0  10
* BOUNDARY COND: PRESSURE = 1.02 BAR, QUALITY 0.07 % (=> VOIDG=0.52)
2600200    2
2600201    0.0   1.02E5    0.0007
*
*-------------------------------------------------------
*
* LEAK JUNCTION
*
3000000    LEAK      SNGLJUN             * TMDPJUN
3000101    230000000 310000000    9.2E-4    10.0   10.0   1000
3000201    0         0.0       0.0     0.0
*3000200    0
*3000201    0.0       0.0       0.0     0.0
*
* LEAK BOUNDARY
*
3100000    LEAKBDRY  TMDPVOL
3100101    1.0E-3    0.5    0.0    0.0    0.0    0.0   5.0E-5  0.0  00
3100200    0      0    UF   220060000
* PRESSURE FIXED, INTERNAL ENERGIES & VOIDG  FOLLOW  UF 220-06
3100201    4.00E5    3.9E5   4.00E5    2.533E6    0.0
3100202    4.30E5    3.9E5   4.30E5    2.533E6    0.0
*
*=======================================================
*
* HEAT STRUCTURES
*
* STEAM GENERATOR TUBES (2 SIMILAR STRUCTURES
*                        WITH DIFFERENT BOUNDARY VOLUMES)
*
* LOWER PART
* NO OF STRS, NO OF MESHP, CYL, STDY-ST-INIT, LEFT BDRY COORD
11621000  6      3        2       1            6.5E-3
11621100  0   1                * MESH LOC FLAG, MESH FORMAT FLAG
11621101  2   7.5E-3           * NO OF INTERVALS, RIGHT BDRY COORD
11621201  3   2                * COMPOSITION NO, INTERVAL NO
11621301  0.0 2                * SOURCE TERM,     -"-
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11621400  0                          * INITIAL COND FLAG: TEMPERATURES FOLLOW
11621401  375.0   1                  * MESH POINT TEMPERATURES
11621402  374.0   2
11621403  374.0   3
* LEFT HYDROD BDRY VOLUME, INCR, BDRY=CONV, SURF AREA FLG  -VAL, STR NO
11621501  162010000         10000  1           1            4.5720   2
11621502  162030000         10000  1           1            13.878   4
11621503  162050000         10000  1           1            4.5720   6
* RIGHT (AS LEFT)
11621601  250010000         0      1           1            4.5720   2
11621602  250010000         0      1           1            13.878   4
11621603  250010000         0      1           1            4.5720   6
11621701  0     0.0    0.0       0.0    6      * NO INTERNAL SOURCE
* LEFT BDRY DATA: CHF FLAG, DHY, HEATED EQU. DIAM  LENGTH
11621801  0     0.013  0.013     0.762  2
11621802  0     0.013  0.013     2.313  4
11621803  0     0.013  0.013     0.762  6
* RIGHT AS LEFT
11621901  0     0.015  0.015     0.762  2
11621902  0     0.015  0.015     2.313  4
11621903  0     0.015  0.015     0.762  6
*
* UPPER PART
11641000  6   3   2   1   6.5E-3
11641100  0   1
11641101  2   7.5E-3
11641201  3   2
11641301  0.0 2
11641400  0
11641401  375.0   1
11641402  374.0   2
11641403  374.0   3
11641501  164010000      10000    1   1   4.5720  2
11641502  164030000      10000    1   1   13.878  4
11641503  164050000      10000    1   1   4.5720  6
11641601  250020000      0    1   1   4.5720  2
11641602  250020000      0    1   1   13.878  4
11641603  250020000      0    1   1   4.5720  6
11641701  0     0.0    0.0       0.0    6
11641801  0     0.013  0.013     0.762  2
11641802  0     0.013  0.013     2.313  4
11641803  0     0.013  0.013     0.762  6
11641901  0     0.015  0.015     0.762  2
11641902  0     0.015  0.015     2.313  4
11641903  0     0.015  0.015     0.762  6
*
*-------------------------------------------
*
* FUEL RODS:
*   CORE (MgO) + CLADDING (S-STEEL)
*
*         NSTR  NP      CYL   STDY=YES  LEFT COORD
11003000  11     5       2     1         0.0
11003100   0   1                  * MESH LOC = ENTER HERE
11003101   3   3.55E-3            * NO OF INTERVALS, RIGHT COORDINATE
11003102   1   4.55E-3
11003201   2   3                  * COMPOSITION 2 (MGO) / FIRST 3 INTERVALS
11003203   1   4                  * COMPOSITION 1 (STEEL) / 4TH INTERVAL
11003301   0.0   1                * SOURCE = 1.0 IN MID-MGO, 0.0 ELSEWHERE
11003302   1.0   2
11003303   0.0   4
11003400   -1                     * INIT. TEMP FLAG = ALL STRS SEPARATELY
* MESH POINT TEMPS FOR ALL HEAT STRUCTURES
11003401   372.27      372.27      372.27      372.27      372.27
11003402   383.26      383.26      382.34      381.02      380.70
11003403   397.29      397.29      395.25      392.32      391.64
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11003404   409.18      409.18      406.32      402.23      401.30
11003405   422.07      422.07      418.37      413.07      411.88
11003406   429.58      429.58      425.67      420.08      418.85
11003407   434.09      434.09      430.32      424.93      423.76
11003408   434.34      434.34      431.16      426.61      425.63
11003409   430.29      430.29      428.11      424.97      424.29
11003410   422.87      422.87      421.91      420.51      420.21
11003411   415.07      415.07      415.07      415.07      415.07
11003501   0    0    0   1   0.0    11                  * LEFT BDRY DATA
11003601   100010000   10000   1   1   4.408    11      * RIGHT  -"-
11003701   100  0.0       0.0   0.0   1                 * SOURCE DISTRIBUTION
11003702   100  0.0407    0.0   0.0   2
11003703   100  0.0887    0.0   0.0   3
11003704   100  0.1221    0.0   0.0   4
11003705   100  0.1559    0.0   0.0   5
11003706   100  0.1628    0.0   0.0   6
11003707   100  0.1559    0.0   0.0   7
11003708   100  0.1313    0.0   0.0   8
11003709   100  0.0908    0.0   0.0   9
11003710   100  0.0406    0.0   0.0   10
11003711   100  0.0       0.0   0.0   11
11003801   0    0.0       0.0         0.232    11    * LEFT EXTRA DATA
11003901   0    7.6E-3    3.1E-3      0.232    11    * RIGHT  -"-
*
* CORE HOUSING (EXTERNAL HEATERS)
*
*          NSTR  NP     RECT  STDY=YES  LEFT COORD
11005000   9     3      1     1         0.0
11005100   0     1        * MESH LOC = ENTER HERE
11005101   2     [illegible].0E-3  * NO OF INTERVALS, RIGHT COORDINATE
11005203   1     2        * COMPOSITION 1 (STEEL)
11005301   0.0   2        * NO (RADIAL) SOURCE
11005400   -1             * INIT. TEMP FLAG: SEPARATE FOR ALL STRS
11005401   389.32     391.02     392.72
11005402   393.14     394.83     396.52
11005403   398.02     399.70     401.39
11005404   404.00     405.68     407.35
11005405   410.23     411.90     413.57
11005406   416.24     417.90     419.57
11005407   421.44     423.10     424.76
11005408   425.34     426.[illegible]     428.65
11005409   427.61     429.27     430.92
* LEFT  BDRY DATA
11005501   100020000  10000   1    0   0.03762  9
* RIGHT BDRY DATA (VOL 310010000 IS USED AS A DUMMY VOLUME)
* WITH FIXED HEAT FLUX FROM TABLE 101
11005601   310010000  0       2101   0   0.03762  9
* NO (AXIAL) SOURCE
11005701   0          0.0     0.0      0.0      9
* LEFT EXTRA DATA
11005801   0   7.6E-3   0.0      0.232       9
*
* ---------------------------------------------------------

* UPPER PLENUM (ENVIRONMENTAL LOSSES)
*
*          NSTR  NMP   CYL  STDY=Y    LEFT COORD
11101000   7     5     2    1         0.0315
11101100   0     1              * MESH LOC & FORMAT
11101101   2     0.034          * INTERVALS  RIGHT COORD
11101102   2     0.100
11101201   1     2              * COMPOSITION, INTERVALS
11101202   4     4
11101301   0.0   4              * RADIAL SOURCE DISTRIB
11101401   413.3 1              * INITIAL TEMPERATURES
11101403   413.2 3
```

```
11101404   340.7 4
11101405   297.2 5
* LEFT BOUNDARY DATA
11101501   105010000      10000    1      1     0.572      4
11101502   110010000          0    1      1     0.858      5
11101503   115010000      10000    1      1     0.414      7
* RIGHT BOUNDARY
11101601      -200            0    3110   1     0.572      4
11101602      -200            0    3110   1     0.858      5
11101603      -200            0    3110   1     0.414      7
* AXIAL SOURCE
11101701   0    0.0     0.0     0.0     7
* ADDITIONAL LEFT BOUNDARY DATA
11101801   0    0.063   0.063   0.0     7
*
* HOT LEG (ENVIRONMENTAL LOSSES)
*
*          NSTR   NMP    CYL   STDY=Y     LEFT COORD
11201000   9      5      2     1          0.01145
11201100   0      1              * MESH LOC & FORMAT
11201101   2      0.01345        * INTERVALS, RIGHT COORD
11201102   2      0.0635
11201201   1      2              * COMPOSITION, INTERVALS
11201202   4      4
11201301   0.0    4              * RADIAL SOURCE DISTRIB
11201401   413.1 3               * INITIAL TEMPERATURES
11201402   336.6 4
11201403   297.7 5
* LEFT BOUNDARY DATA
11201501   120010000      10000    1      1     0.5685     4
11201502   125010000          0    1      1     0.559      5
11201503   140010000      10000    1      1     0.580      9
* RIGHT BOUNDARY
11201601      -200            0    3110   1     0.5685     4
11201602      -200            0    3110   1     0.559      5
11201603      -200            0    3110   1     0.580      9
* AXIAL SOURCE
11201701   0    0.0     0.0     0.0     9
* ADDITIONAL LEFT BOUNDARY DATA
11201801   0    0.0229  0.0229  0.0     9
*
* COLD LEG (ENVIRONMENTAL LOSSES)
*
*          NSTR   NMP    CYL   STDY=Y     LEFT COORD     REFLOOD=NO
11901000   4      5      2     1          0.01145        0
11901100   1201                * MESH DATA EQUAL TO HOT LEG
11901401   374.4   3
11901402   322.3   4
11901403   296.2   5
* LEFT BOUNDARY DATA
11901501   180010000          0    1      1     2.320      1
11901502   185010000          0    1      1     2.300      2
11901503   190010000          0    1      1     1.410      3
11901504   195010000          0    1      1     3.400      4
* RIGHT BOUNDARY
11901601      -200            0    3120   1     2.320      1
11901602      -200            0    3120   1     2.300      2
11901603      -200            0    3120   1     1.410      3
11901604      -200            0    3120   1     3.400      4
* AXIAL SOURCE
11901701   0    0.0     0.0     0.0     4
* ADDITIONAL LEFT BOUNDARY DATA
11901801   0    0.063   0.063   0.0     4
*
* DOWNCOMER
*
```

```
*           NSTR  NMP   CYL  STDY-Y    LEFT COORD
12201000    7     5     2     1         0.019
12201100    0     1              * MESH LOC & FORMAT
12201101    2     0.'21          * INTERVALS, RIGHT COORD
12201102    2     0.071
12201201    1     2              * COMPOSITION, INTERVALS
12201202    4     4
12201301    0.0   4              * RADIAL SOURCE DISTRIB
12201401    372.1 3              * INITIAL TEMPERATURES
12201402    324.0 4
12201403    296.5 5
* LEFT BOUNDARY DATA
12201501   210010000          0     1     1    1.220      1
12201502   220010000          0     1     1    0.880      2
12201503   220020000      10000     1     1    1.22275    4
12201504   220040000      10000     1     1    1.2830     7
* RIGHT BOUNDARY
12201601      -200            0   3120    1    1.220      1
12201602      -200            0   3120    1    0.880      2
12201603      -200            0   3120    1    1.22275    4
12201604      -200            0   3120    1    1.2830     7
* AXIAL SOURCE
12201701   0    0.0     0.0     0.0     7
* ADDITIONAL LEFT BOUNDARY DATA
12201801   0    0.0380  0.0380  0.0     7
*
*=========================================================
*
* COMPOSITION TABLES
*
*---------------------------------------------------------
* MATERIAL PROPERTIES FOR COMPOSITION 1, CLADDING & CORE SHROUD
*
20100100  TBL/FCTN    1      1
*  THERMAL CONDUCTIVITY
20100101  293.15    14.2
20100102  323.15    15.5
20100103  373.15    16.0
20100104  573.15    18.3
20100105  723.15    21.0
20100106  973.15    24.1   →
20100107 1173.15    27.6
* VOLUMETRIC HEAT CAPACITY
20100151  293.15      3.718E6
20100152  323.15      3.763E6
20100153  373.15      4.069E6
20100154  573.15      4.408E6
20100155  773.15      4.748E6
20100156 1273.15      5.027E6
*
*---------------------------------------------------------
* MATERIAL PROPERTIES OF MGO, COMPOSITION 2
20100200  TBL/FCTN    1      1
*  THERMAL CONDUCTIVITY
20100201  273.15      7.10
20100202  473.15      5.48
20100203  673.15      3.85
20100204  723.15      3.46
20100205  773.15      3.18
20100206  823.15      2.98
20100207  873.15      2.82
20100208  923.15      2.68
20100209  973.15      2.57
*
* VOLUMETRIC HEAT CAPACITY
20100251  273.15      3.300E6
```

```
20100252  293.15      3.300E6
20100253  573.15      3.296E6
20100254  673.15      3.323E6
20100255  723.15      3.314E6
20100256  923.15      3.865E6
20100257  973.15      3.884E6
*
*-----------------------------------------------------------
* PROPERTIES OF COMPOSITION 3, STEAM GENERATOR TUBES, COPPER
*
*         TYPE        COND = TABLE      VOLUM. CP = TABLE
20100300  TBL/FCTN    1                 1
*
* THERMAL CONDUCTIVITY (ASSUMED CONSTANT)
20100301  385.0
*
* VOLUMETRIC HEAT CAPACITY (ASSUMED CONSTANT)
20100351  3.435E6
*
*---------------------------------------------------------------
* COMPOSITION 4  MINERAL WOOL, LEG OUTER INSULATOR
*
20100400  TBL/FCTN    1                 1
* CONDUCTIVITY
20100401  0.16
* VOLUMETRIC HEAT CAPACITY
20100451  2.1E5
*
*==============================================================
*
* GENERAL TABLES: POWERS & LOSS BOUNDARY HEAT TRANSFER COEFFICIENTS
*
* - FUEL RODS
20210000  POWER
20210002  0.0    12.0E3
20210004  1.0E4  12.0E3
*
* - EXTERNAL HEATERS,  5 KW = 13.8 KW/M2
20210100  HTRNRATE
20210102  0.0    -13.8E3
20210104  1.0E4  -13.8E3
*
* UPPER PLENUM & HOT LEG
20211000  HTC-T
20211001  0.0     6.1
20211002  1.0    26.1
20211003  1.0E4  26.1
*
* COLD LEG & DOWNCOMER
20212000  HTC-T
20212001  0.0     6.1
20212002  1.0    26.1
20212003  1.0E4  26.1
*
* ENVIRONMENT TEMPERATURE
20220000  TEMP
20220001  0.0    293.0
20220002  1.0E4  293.0
*
. * ================= = END OF INPUT =================
```

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11. ABSTRACT (200 words or less)

Natural circulation experiments carried out in the REWET-III facility in 1985 have been used for RELAP5/MOD2 assessment. The REWET-III facility is a scaled-down model of VVER-440 type reactors. The facility consists of a pressure vessel in which the downcomer is simulated with an external pipe assembly, hot and cold legs with loop seals and a horizontal steam generator. The volume scaling factor compared to the reference reactor is 1:2333.

The present paper summarizes the experiences gained in the RELAP5/MOD2 calculations of selected REWET-III single- and two-phase natural circulation experiments. The code's ability to represent the main phenomena of experiments in both cases was satisfactory.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)

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