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International Agreement Report

Assessment of RELAP5/MOD2 Cycle 36.04, Against the Loviisa–2 Stuck-Open Turbine By-Pass Valve Transient on September 1, 1981

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Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

March 1992

Prepared as part of
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NOTICE

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I EXECUTIVE SUMMARY

RELAP5/MOD2 simulations have been conducted for an overcooling type transient that occurred at the LOVIISA Unit 2 on September 1, 1981. The objective of this study was to assess the applicability of the RELAP5/MOD2 cycle 36.04 code for a real plant transient analyses.

The code assessment work presented in this report was based on the available plant data that were saved through the normal plant instrumentation into the memory of the plant computer. Because of the limited storage capability only plotted histories from the plant recorders are available for the comparison of the later part of the transient. Although the recorded data are quite comprehensive it must be emphasized that the instrumentation cannot explain all phenomena. Analyses with different codes and the plant training simulator helped to find causes for events not readable from the instrumentation and gave better understanding of the different phenomena. Correct operator involvement during the incident demonstrated their importance in mitigating the consequences of the transient and to bring the plant into stabilized safe conditions.

The RELAP5 results matched well the main measured parameters, in particular if the general trends were examined. The biggest quantitative differences were found between calculated and measured values of the primary pressure and pressurizer water level. The reason for those discrepancies was found in the imprecise nodalization model.

The calculation clarified the behavior of the pressurizer and the pressurizer spray that could not be determined from the information available. The importance of the modelling of the pressurizer vessel wall was demonstrated when condensation on the wall alone was able to stop and turn down the pressure increase.

The wall heat transfer in that pressurizer volume, where both liquid and vapor were present, experienced an anomalous behavior during the fast in-surge period. The vapor in that volume was superheated faster than in the volumes above. The capability to easily print out all terms of the equations involved would greatly help the trace-back of the causes.

An oscillatory behavior of the servo valve model was detected. The real causes for this behavior could not be found, but the reduction of the time step size removed the oscillations. Usually the minor edit and plot time intervals are selected coarser than the time steps in order to prevent an enormous size of the restart file. An unfavorable selection can hide the oscillations of the parameter so that only an envelope is seen and the real behavior is hard to discover.

The calculation with minor changes in initial values pointed out that the calculation result was sensitive to the primary mean temperature. The variation of other main parameter inside the range of measurement uncertainty did not change the results remarkably.

The sensitivity study of the pump stop times stressed the importance of the correctly simulated loop flows in a multi-loop reactor. However, it was not found out whether the dissimilarities in the primary mean temperatures were due to the inability of the one- dimensional code to calculate asymmetric behavior of the multidimensional plant or other possible reasons.

The overall code performance was good, although the CPU- time consumption versus transient time (~10) was rather high due to the one reactor coolant pump running throughout the transient. Time step control did not cause any time step reduction. The requested time step size was slightly less than the minimum Courant limit.

II ABSTRACT

An overcooling type transient that took place in the LOVIISA Unit 2 has been analyzed using the RELAP5/MOD2 code. The code version was cycle 36.04.

The Loviisa Power Plant consists of two Soviet VVER-440 type pressurized water reactors having a net electric output of 445 MWe each. In VVER-440 reactors, the primary circuit comprises six parallel loops, each with a horizontal steam generator, a main circulation pump and main loop isolation gate valves. The reactor has significant differences compared to a typical western PWR, such as loop seals both in the hot and cold leg and horizontal steam generators.

The transient that occurred on September 1, 1981 was initiated from full power by a reactor trip. Incorrect operation of the level gauges in four steam generators caused the trip signal. An associated stuck-open failure of one turbine by-pass valve caused a fast cool-down. The high pressure safety injection started to operate, but was quickly turned off by the operator. The downcomer temperature decreased from 265 °C to 215 °C in fifteen minutes. The cooling down ceased when the operator closed the shut-off valve of the open by-pass line.

Although the plant data are not gathered as comprehensively as those from the extensively instrumented test facilities, the real plant transients are important in order to verify the scaling capability of the current one-dimensional codes to large three-dimensional power plants. The transient data together with the start-up commissioning tests also form a good data base when the applicability of the nodalization model for accident analysis is tested.

This work was performed at the Technical Research Centre of Finland (VTT) in co-operation with the utility Imatran Voima Oy (IVO), which owns and operates these plants. Many people in both organizations have contributed to the work and their support and assistance is acknowledged.

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1. INTRODUCTION

The calculation presented in this report is a Finnish contribution to the International Thermal Hydraulic Code Assessment and Applications Program (ICAP) that is conducted by several countries under coordination of the USNRC /1/. The goal of ICAP is to determine quantitatively the accuracy of the advanced LWR system codes TRAC and RELAP5 and to validate them for accident analyses.

In this report the results of an assessment of the capability of RELAP5/MOD2 to calculate an overcooling transient of a PWR with horizontal steam generators are presented. The overcooling event that occurred at the Loviisa Unit 2 on September 1, 1981 was initiated by a reactor trip followed by an associated stuck-open turbine by-pass valve. The downcomer temperature decreased from 265 °C to 215 °C in fifteen minutes and the high-pressure safety injection was actuated. Version 36.04 of the code was used in the simulation.

The code assessment work is based on the comparison of the calculated results with the plant transient data that were recorded through the normal instrumentation into the memory of the plant computer. Because the data storage capability at the time of the incident was very limited, the comparison of the later part of the transient relies only on the plotted histories of the main parameters. In addition to these the progress report of the transient and the alarm list of the plant computer were available.

Although the plant transient data are quite comprehensive, it should be remembered that the normal instrumentation cannot explain all details of the transient. Therefore both the transient data and boundary conditions of the calculation include uncertainties that must be emphasized in the assessment work.

Analyses of the transient with different codes and with the plant training simulator helped to explain the events that could not directly be read from the plant instruments. Simulation of the operator action showed the importance of the operators in reducing the consequences of the transient and bringing the plant into stabilized safe conditions.

The transient data make also possible the verification of the plant nodalization and detailed study of various components in the calculation model.

The next two chapters describe briefly the Loviisa Unit 2 and the overcooling incident. Chapter 4 presents the code input model including selection of boundary conditions that can change remarkably the results from the later part of the transient.

The assessment study results are described in Chapter 5, following a discussion of the results in Chapter 6. The sensitivity study calculations are discussed in Chapter 7. Run statistics is listed in Chapter 8 and conclusions are drawn in Chapter 9. Appendices A through G include recorded plant variables.

2. LOVIISA UNIT 2 PLANT DESCRIPTION

The Loviisa nuclear plant /2/ consists of two VVER-440 pressurized water reactors having a net electric output of 445 MWe each. The plant is owned and operated by the state-owned power utility Imatran Voima Oy (IVO). Construction of the two units started in 1971 and 1972, respectively, and the first unit was taken into commercial operation in 1978 and the second in 1980.

The primary circuits have six loops with a horizontal steam generator, primary coolant pump and two main gate valves in each loop. The safety containment is quite large, 56 000 m^3, having a Westinghouse type ice condenser. The secondary circuit comprises two turbines with auxiliary equipment. Residual heat is removed through steam generators to the secondary circuit.

2.1 Primary coolant system

The main parts of the primary coolant system are shown in Figure 2.1. The reactor circuit consists of six loops with horizontal steam generators (SG) (YB11, 52, 13, 54, 15, 56). The hot leg nozzles of the pressure vessel are at a higher elevation than the cold leg nozzles. Both hot and cold legs have loop seals and in three loops (no. 2, 5 and 6) those are connected with a by-pass line having a isolation valve, which is closed in normal operation. Each hot and cold leg is also equipped with a main gate valve, which make it possible to isolate a single loop from the rest of the primary system.

The Loviisa 2 reactor core consists of 313 fuel assemblies 37 of which are moving follower assemblies of the control rods. There are also dummy assemblies that replace the 36 outermost fuel assemblies of the original core in order to decrease the neutron exposure on the reactor pressure vessel. The fuel assembly has 126 fuel rods in a triangular lattice surrounded by a hexagonal stainless steel housing. The nominal core power is 1375 MW and the core outlet pressure is 122.4 bar. The total primary system flow rate 40 000 m^3/h is maintained by the six reactor coolant pumps (RCPs) with a rated pump head of 4.4 bar.

2.2 Primary pressure control system

The pressurizer (YP10B01) with a total volume of 37,8 m^3 is connected by two 209 mm diameter surge lines to the hot legs of loops no. 3 and 4. Two parallel pipelines are feeding water from the cold legs of loop no. 3 and 4 to the pressurizer spray valves. Pressurizer spray and electrical heaters are used to maintain the primary pressure stable. The spray capacity is dependent both on the pressure difference between hot and cold leg, i.e. the number of RCPs running, and of the number of open spray valves. The maximum total spray capacity with all 8 valves open is 50 kg/s. There is also an additional spray line from high pressure safety injection system (HPIS) with a nominal capacity of 15 kg/s. The total power of the pressurizer electrical heaters is 1620 kW. They are subdivided into 7 groups and controlled in proportionality to the primary pressure. In the case of fast pressure increase the power operated relief valve (PORV) of the pressurizer and two safety valves protect the primary system from over pressure.

At the time when the incident happened the PORV line was closed due the requirement of the licensing authorities after experience from TMI accident.

2.3 Primary coolant decontamination system

The natural impurities of reactor water, corrosion products and gaseous products of radiolysis and fuel fission are removed by circulating primary water through the primary coolant decontamination system (TC). The system consists of two parallel lines (TC10 and TC50) which usually both are operating. They work under full reactor pressure and the pressure difference between the hot and cold leg is utilized for water circulation in the ion-exchanger.

The six primary loops are connected to the reactor water purification system through three TC-collectors, which are also used for make-up (TK) and high pressure safety (TJ) injections.

The connecting pipes are equipped with gate valves so that each loop can be isolated from other systems. The normal operational position of the valves can be seen in Figure 2.1. Primary water flows from the discharge side of RCPs of loops YA 12, 15 and 16 through TC-collector Z01 to both ion-exchange units TC10 and TC50. Purified water is returned from unit TC10 via TC-collector Z02 to the hot legs of loops YA 11, 13 and 14. Unit TC50 discharges through TC-collector Z03 to the suction side of RCPs YD 11, 13 and 14.

2.4 Primary leak collection and make-up system

The primary water inventory and boron control is carried out by the letdown and make-up water system (TK) and by the allowable and controlled leakage decontamination system (TE).

TK system removes non-condensible gases from controlled leakages and letdown water and feeds make-up water back to the primary circuit. The make-up system is also used for boric acid control. The boric acid concentration in the reactor is raised by feeding concentrated boric acid solution to the make-up water deaerator.

The constant pressurizer level is maintained by three low capacity (1,7 kg/s) piston type make-up pumps (TK51, TK52 and TK53), one of which is operating all the time (adjustable 33 - 100 %). The other two are started from the pressurizer level signals. Make-up water is injected via the cold side of either water purification system TC10 or TC50 to the primary loops.

The TK-system also includes two high capacity (18 kg/s at 132 bar) pumps (TK11 and TK12), which are normally used in fast boron control operations and when all boric acid is removed from primary coolant at the end of burn-up period with the ion-exchanger of the TE-system.

During this incident the operator manually turned on and later switched off the pump TK11. After speeding-up the pump flow rate was regulated by an integrating controller. Figure 2.2 shows the reconstructed total make-up water flow rate curve that includes flows from all low capacity make-up pumps and the high capacity make-up pump TK11.

The TE-system collects all primary controlled leakages and letdown water and purifies them. It has also separate ion-exchange filter for boric acid removal. The function of the TE-system is closely connected to the action of the TK-system.

If the pressurizer liquid level exceeds by 100 mm the normal value, which is a function of reactor power, the letdown valve in cold side of either water purification system TC10 (valve TE11S01) or TC50 (TE51S01) is opened. An orifice through which water flows to the deaerator (back-pressure 1,2 bar) controls the letdown flow rate. Under normal conditions the operators are able to control the pressurizer water level with the one operating make-up pump such that the letdown line opens only about once in a shift.

2.5 Emergency core cooling system (ECCS)

The Loviisa Unit 2 is equipped with a emergency core cooling system (ECCS) consisting of 4 accumulators, 4 high pressure injection (TJ) pumps and 4 low pressure injection (TH) pumps.

During the incident two high pressure injection pumps TJ12 and TJ51 started injecting via the TC-collectors Z01 and Z03 to the cold legs of primary loops YA11, 13 and 14 and to the suction side of RCPs YD11, 13 and 14. The TJ-pumps take water from the TH-tank, where the temperature is 50 °C. The TJ-pump characteristics is shown in Figure 2.3.

2.6 Secondary systems

Secondary feed water and steam flow diagrams are given in Figures 2.4 and 2.5.

All main and emergency feed water pumps are electrical motor-driven. The feed water flow is controlled according to the level measurement of the steam generators. The emergency feed water injection is started when mixture level in a steam generator is 140 mm below the nominal value.

The main feed water stayed on throughout the incident.

The six steam generators (SG) are Soviet horizontal type PGV-4, with a heat transfer area of 2510 m^2. The 5536 tubes with an outer diameter of 16 mm are located in a horizontal vessel of 3,21 m inside diameter. The whole secondary side volume of an SG is 69 m^3. Steam is generated with a nominal capacity of 125 kg/s at a pressure of 44.8 bar. Water is separated from steam by gravity when the two-phase mixture leaves the evaporation surface at low velocity. The chevron type separator at the top of SG secures drying of saturated steam to the design moisture content.

The Loviisa Unit 2 has two turbogenerators. Each SG has its own steam line to the turbine valves. SGs YB11, YB15 and YB13 which are connected to the primary loops no. 1, 5 and 3 are feeding the first turbine and SGs YB54 YB52 and YB56 (similarly connected to loops no. 4, 2 and 6) are feeding the second turbine. Each steam line is equipped with an SG isolation valve and two SG safety valves (opening pressures 56 and 58 bar). All six steam lines between SG isolation valve and turbine valve are connected together via a steam collector, which reduces possible unbalance between different loops. The steam collector also supplies steam to the two secondary atmospheric relief valves and four turbine by-pass valves in a transient situation.

The discharge capacity of one secondary relief valve is 67 kg/s (at 54 bar) and the valve operating range is from 52 to 54 bar. The turbine by-pass valves start to open at 47 bar and the capacity of one line in fully open position at 51 bar is 135 kg/s. Thus the total turbine by-pass capacity is 70 % of the nominal steam generation.

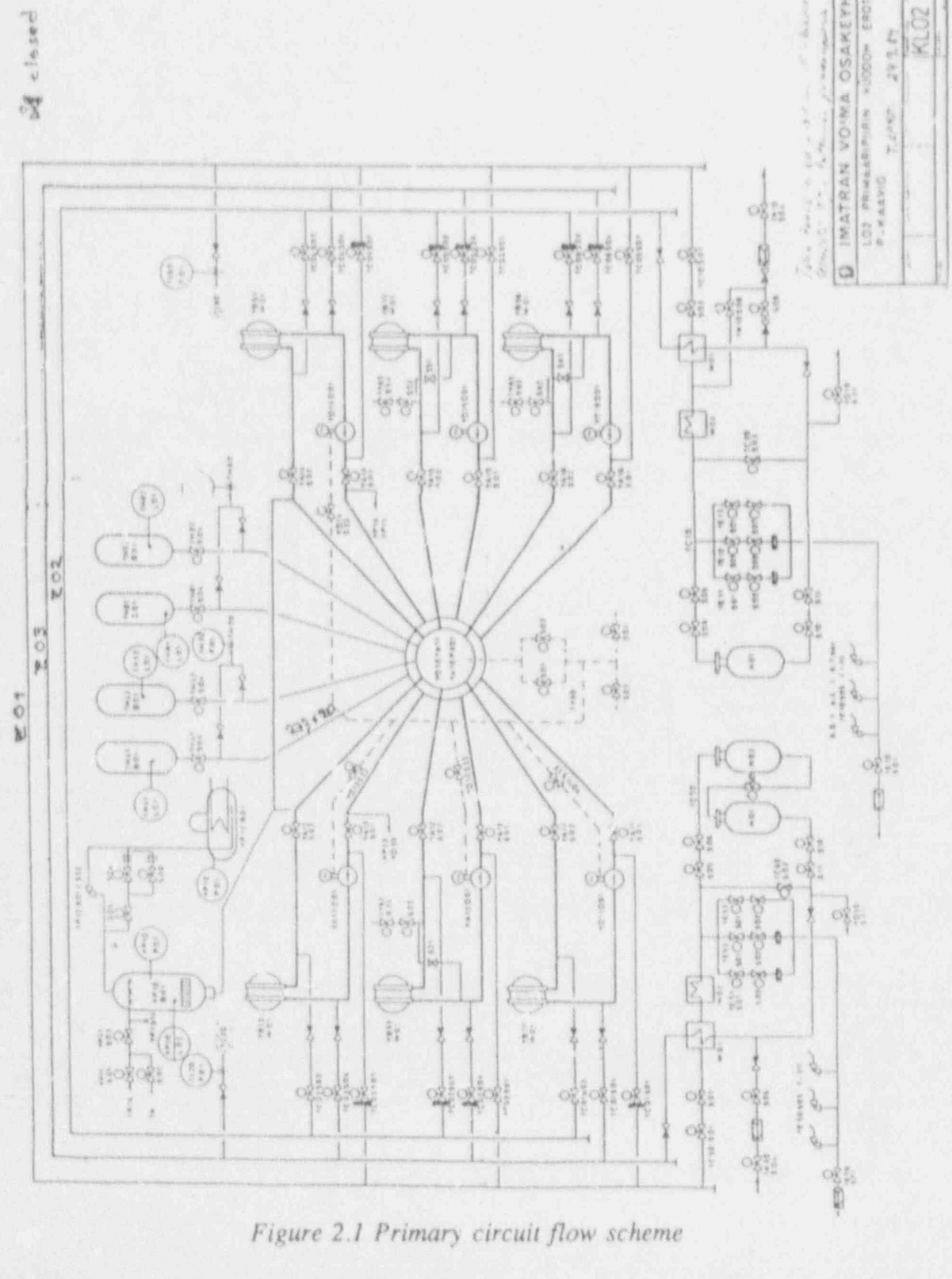


Figure 2.1 Primary circuit flow scheme

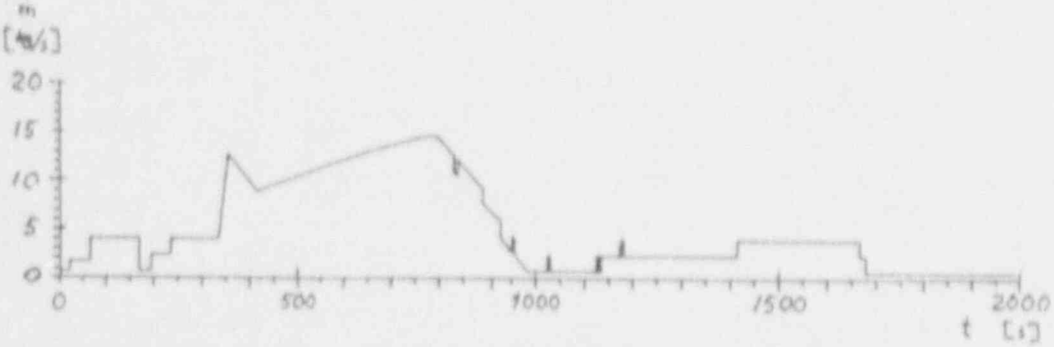


Figure 2.2 Reconstructed total make-up flow rate during the transient

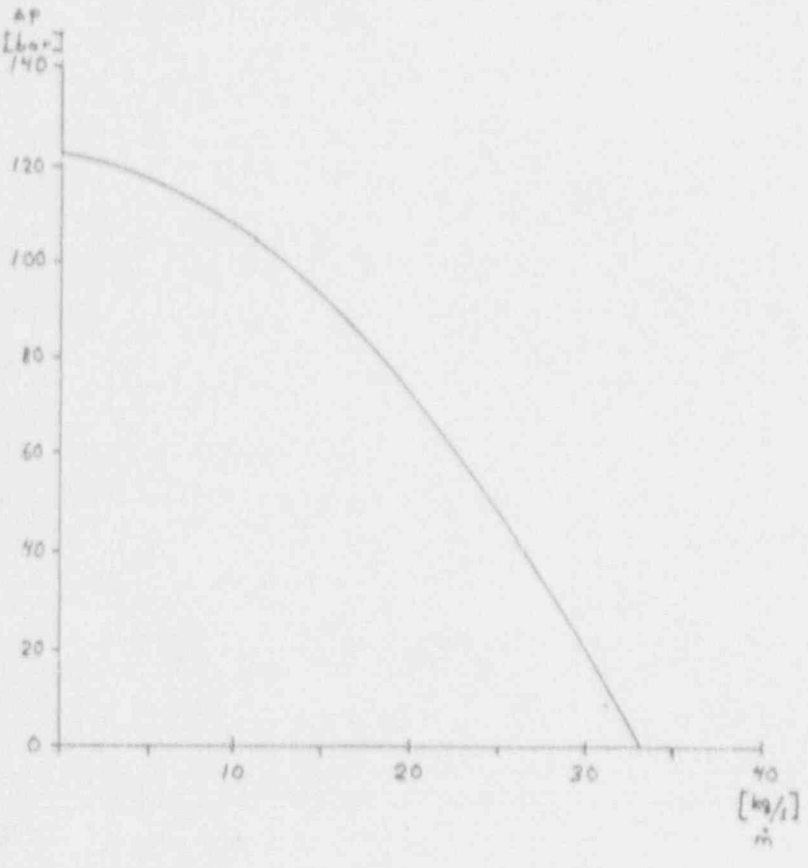


Figure 2.3 High-pressure safety injection pump characteristics

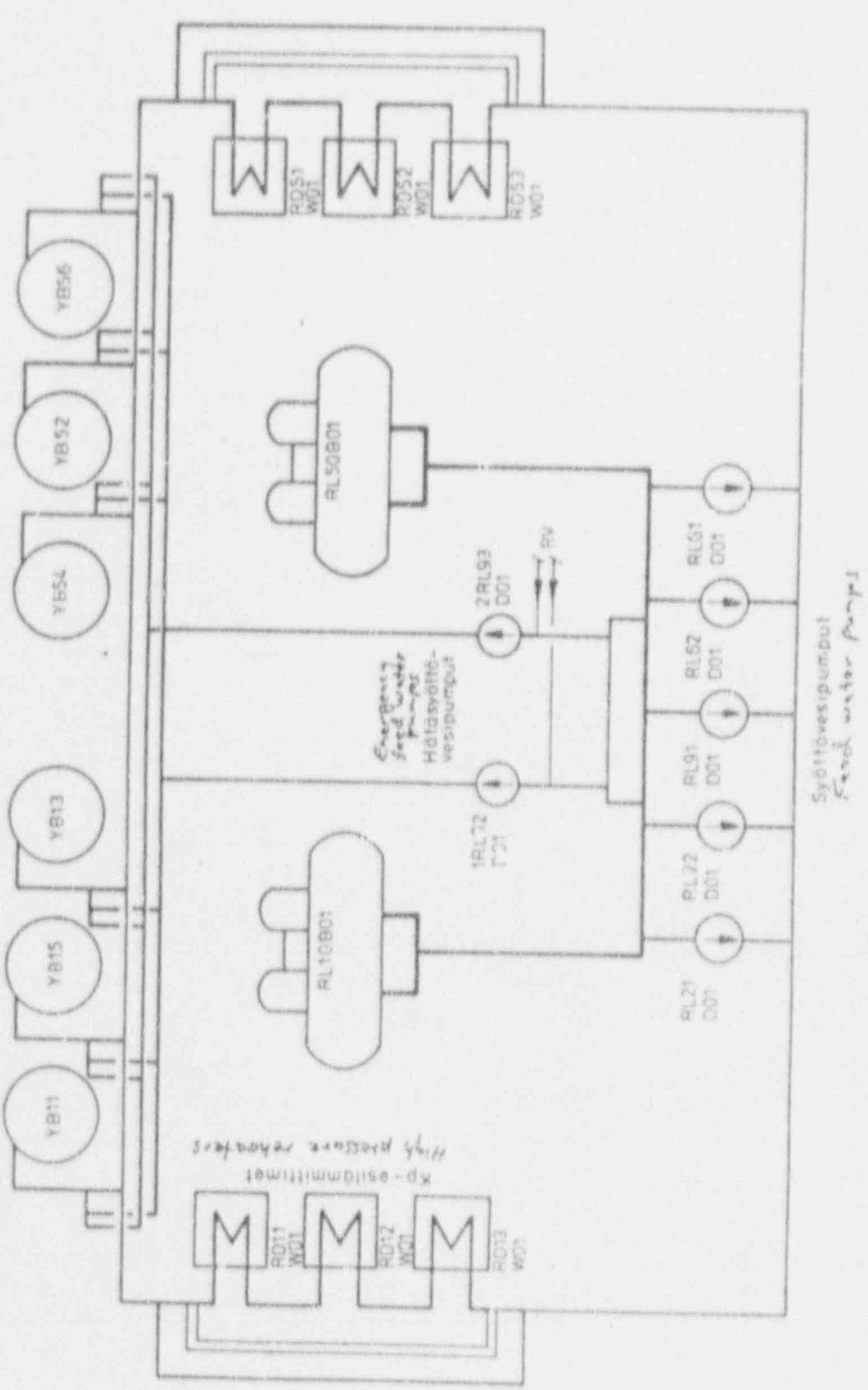


Figure 2.4 Secondary feed water flow scheme

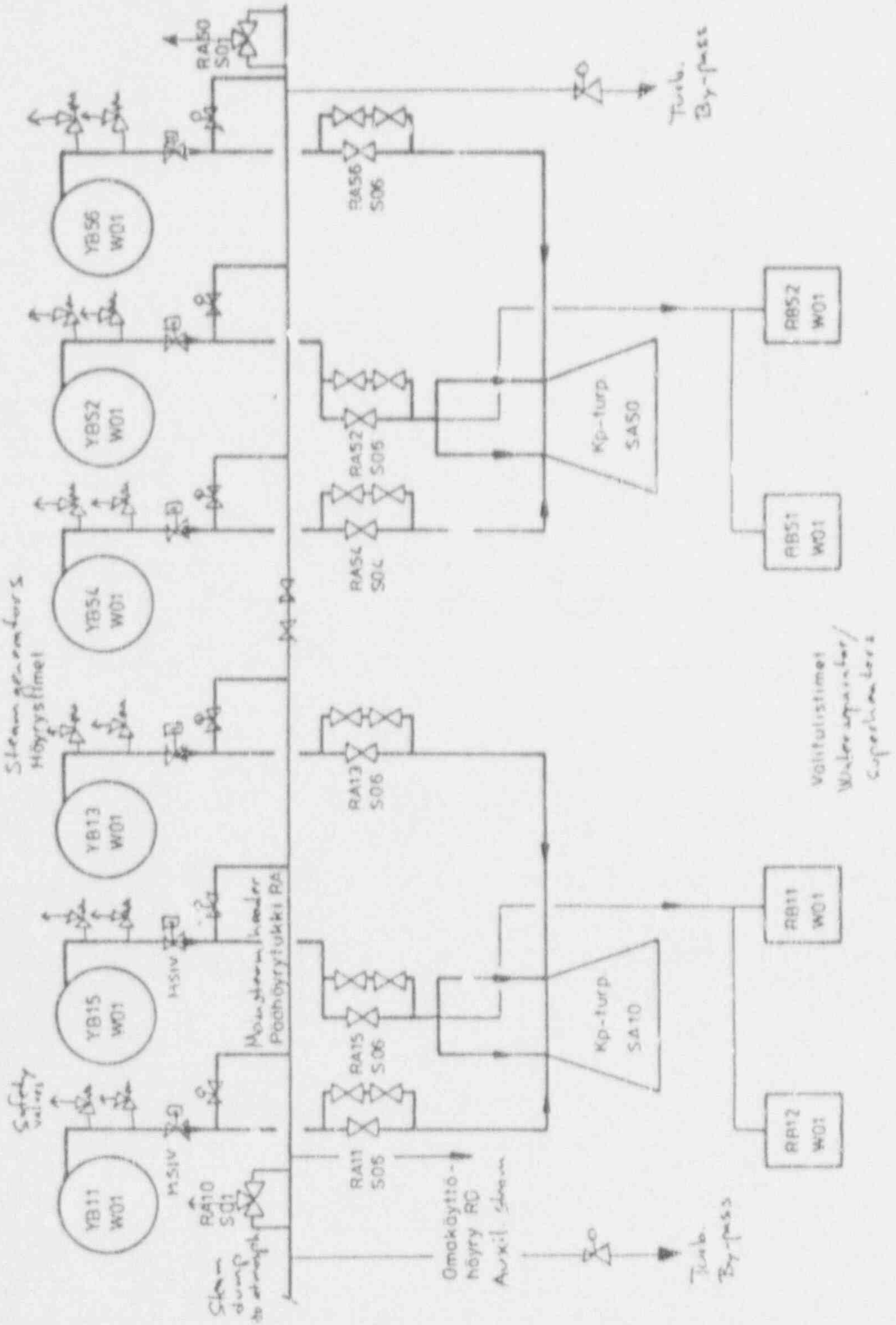


Figure 2.5 Secondary steam flow scheme

3. PLANT TRANSIENT

Information presented here is based on the report of the incident for the Finnish safety authorities, plant recordings, listings of the plant computer and direct information of the personnel in the Loviisa plant and training simulator. Part of the material introduced in this chapter and Chapters 4, 7 and 8 has been presented before at the ANS meeting in Atlanta /3/.

The special report of the incident /4/ is in Finnish and its not appended here but all significant events are listed in Table 3.1. Appendices A through G include the parameters that were saved into the memory of plant computer during the transient. Unfortunately at the time the incident happened the recording capacity of the computer was fairly small and none of the parameters have recorded value throughout the transient. Instead of the missing part of recordings the data from plant plotters, that are presented in Figures 3.1. through 3.8, can be used for the main plan variables. The accuracy of the plots is worse than that of the listings and some engineering judgement is needed to synchronize the plots.

The course of the whole transient can easily be seen in Figure 3.9, where the most important variables are drawn. This figure was constructed from the information of plant computer listings, plant recorder plots and operator actions by Mr. J. Backman, who was the plant operator at the moment of the transient.

Figure 3.10 illustrates the components and systems of the Loviisa 2 related to the transient.

3.1 Initial conditions

Before the incident the plant was operating at full power producing 454 MW electricity /4/. The primary pressure was 123 bar and the hot and cold leg temperatures were 291 ^{0}C and 265 ^{0}C, respectively.

The water level in the pressurizer was 5.6 m from the bottom corresponding to the full power water volume of 24.5 m^3. The level gauge in the plant showed the value of 4.65 m, because the lower tap of the impulse line is located 0.915 m above the pressurizer vessel bottom. The primary water inventory was controlled by the flow rate of the make-up pump TK51. The letdown line was not open.

3.2 Transient initiation

The Loviisa Unit 2 transient initiated at 7.06.46 a.m. when a malfunctioning thermal relay tripped the reactor coolant pump (RCP) in loop no. 4 (YD14). The whole incident sequence is shown in Table 3.1. The automatic reactor power control began to reduce power to the level corresponding to the number of operating RCPs. The trip of one RCP does not actuate the reactor trip in the Loviisa plants.

However, the reactor trip was actuated twelve seconds later by a low level signal in steam generators YB11, 13, 53 and 56. The signal becomes true when the level in two out of the six steam generators is less than 1800 mm. The varying secondary pressure resulted in incorrect SG level readings, owing to some dirt in the flow restrictions of the impulse pipes.

As the turbines were tripped following the reactor trip, the turbine by-pass valves (TBV) were demanded to open. The full capacity of the four TBVs is 70 % of the nominal steam flow rate. Three TBVs opened to the position between 40 and 44 % as they normally do following the turbine trip. One of the TBVs (RC51S03), however, travelled to the fully open position and stuck because of failure in the hydraulic controlling system of the valve.

The incorrect low SG level indications also actuated further four RCP trips (YD11, 12, 13, 16). The RCP in one loop is stopped if the steam generator level in that loop is less than 1600 mm.

3.3 Overcooling period

About 30 seconds after the reactor trip the three operating TBVs were closed. One valve (RC51S03) failed to close and stayed fully open, but this was not notified and the secondary pressure continued to decrease. This resulted in cooling of the primary circuit and lowering of the pressurizer level continued. At the same time five RCPs were coasting down and the operators were mainly concerned with the misleading very low SG level indications.

Four minutes into the transient it was evident that the pressurizer (PRZ) level was decreasing too much. The operator switched on the high capacity make-up pump (TK11D01) at 7.12.08 to compensate for the pressurizer level decrease. The cooling down of the primary system was, however, so rapid that the pressurizer level reached the high pressure safety injection (HPSI) actuation limit 40 seconds later. Two out of the four HPSI pumps received an actuation signal. The safety injection system actuation logic is a two out of three logic. Figure 3.11 helps to explain why only two trains started.

After the measuring channels no. 3 and 4 recorded the low level, the protection signal channels no. 3 and 2 actuated HPSI pumps TJ12 and TJ51, respectively. Two instantaneously starting pumps (TJ12D01 and TJ51D01) were capable of compensating the pressurizer level and channels no. 1 and 4 did not react any more. This behavior is possible as the tolerance of the level measurements is of the order of 50 mm. As a consequence the repressurization was slower than it had been in the case of four operating pumps.

After 40 seconds' injection time the operator switched off the HPSI pumps. The decision was based on the confidence that primary circuit had not experienced a loss-of-integrity, because the pressurizer level stopped lowering, and that thermal shock due to the unnecessary injection of the cold HPSI water should be avoided.

The stuck-open TBV was recognized after nine minutes from the transient initiation. First, the operator tried to close the TBV (RC51S03). As he could not do this, he closed the shut-off motor valve (RC51S01) in the same line (closing time of ~ 142 s).

In one steam generator (YB11) the water level was increasing although the control valve (RL31S02) and the protection valve (RL31S03) were closed. Only after the shut-off valve (RL31S01) was closed and the steam generator was connected together with other one (YB52) via periodically operating drain line the water level in steam generator YB11 started decrease slowly.

The cooling down now ceased. The operator stopped later the high capacity make-up pump (TK11D01). He started another RCP (YD13D01) to make the pressurizer spray more effectively, which caused a rapid drop of the primary pressure. After half an hour from the incident initiation primary pressure and pressurizer level were finally stabilized. The minimum primary coolant temperature was 215 ^{0}C. The overcooling was not severe from the pressure vessel integrity viewpoint. Since at least one RCP was working throughout the transient, thermal stratification of cold HPSI water did not occur in the cold legs.

Three component failures were involved in the overcooling incident: a malfunctioning thermal relay tripped a RCP, a common-cause failure in the level indication of four SGs tripped the reactor and finally a stuck-open TBV initiated overcooling.

The operators acted efficiently in reducing the consequences of the transient. The relatively long time needed to identify the stuck-open TBV was mainly due to misleading SG level information. This made the operator check for the possibility of loss of feed water instead of steam leakage.

Table 3.1 Transient sequence.

Time	Transient time (seconds)	Events
07.06.46	0	RCP in loop no. 4 (YD14D01) trips. Automatic reactor power decrease starts.
07.06.58	12	Reactor trips. Turbines trip.
07.07.01- .03	15- 17	TBVs operate (RC11-,12-,51-,52S03). One TBV (RC51S03) travels to the fully open position. 4 RCPs trip (YD11-,12-,13-,16D01). RCP in loop no. 5 (YD15D01) continues to operate.
07.07.04	18	All pressurizer electrical heaters on.
07.07.26- .32	40- 46	3 TBVs close. 1 TBV remains open (RC51S03).
07.10.20	214	Low pressurizer level alarm.
07.11.25	279	Low secondary pressure alarm. Operator started to close pressure reduction lines.
07.12.18	332	Operator switches on a high capacity make-up pump (TK11D01).
07.12.44	358	All pressurizer electrical heaters off.
07.12.48	362	2 HPSI pumps on (TJ12-, 51D01).
07.13.00	374	All pressurizer electrical heaters on.
07.13.12	386	HPSI actuation signal no more valid.
07.13.29- .31	403- 405	The operator stops the two HPSI pumps (TJ51D01 and TJ12D01).
07.15.21	515	Primary pressure reaches the nominal value.
07.16	~ 550	The operator recognizes the stuck-open TBV (RC52S03). The shut-off valve (RC51S01) in the TBV line is closed with travel time of 142 s.
07.17	~ 610	The operator notices the unusual high level in the steam generator YB11. The shut-off valve (RL31S01) in the feed water line is closed and the steam generator is connected with the steam generator YB52 via the drain line.
07.20	~ 790	Secondary pressure ceases decreasing.
07.20	~ 790	The minimum value of primary average temperature (215 °C).

07.20.26	820	Pressurizer spray valves open.
07.21.24	878	The operator opens shutdown pressure control valves to the spray line.
07.23.11	985	The high capacity make-up pump (TK11D01) is switched off.
07.28.26	1300	RCP in loop no. 3 is switched on to get pressurizer spray on.
07.35	1700	Primary pressure and pressurizer level are stabilized. Primary mean temperature is increasing slowly ~8 °C/h.
07.35.31	1725	Stuck-open TBV (RC51S03) is closed when the hydraulic pumps are switched off.
08.20	4400	Primary temperature is stabilized at value of ~230 °C
09.30	~8600	Water level in the steam generator YB11 has reached the normal value.

3.4 Plant measurement uncertainty

The plant transient data presented in Appendices A through G and in Figures 3.1 through 3.9 is based on the normal plant instrumentation.

3.4.1 Printed plant parameters

The alarm system of the Loviisa plant consists of different groups of plant parameters, which are stored by triggering event in the memory of the process computer. Those groups, which have meaningful variables in order to understand the propagation of the transient, are shown in Appendices A through G.

The first line of each list identifies the group, the date and time when the listing was printed. The next two lines tell the alarm signal that triggered storage and the time of the event. In the following lines the stored variables are identified in the same order as their values are listed below in vertical columns as a function of time. The last value in each identification line presents how often the transducer is recorded. If this column is filled with two asterisks (**), it indicates that the variable is computed from other variables and it is read every tenth second. The scanning frequency should be kept in mind when reading the variables. The value of the plant variable printed at a certain time has a time shift that depends on when the transducer was last scanned.

The printed groups of variables include also measurements that are not important for the evaluation of the transient. In this section only meaningful variables will be discussed. The number in parentheses quotes the ordinal number that specifies the position of the variable in the listed group.

Appendix A illustrates parameters of group 00

- (1): electric power of generator SP10; abbreviation SP10E002
- (2): electric power of generator SP50; abbreviation SP50E002
- (12): mean temperature of hot legs; abbreviation YA10T802
- (13): mean temperature of cold legs; abbreviation YA10T803
- (14): differential pressure over reactor core; transducer YC10P001

The accuracy of the electric power measurements is 1 %. The uncertainty of the calculated temperature value is 0.5 %. The accuracy of the differential pressure measurement is 1 %.

Appendix B includes parameters of group 01

- (1): percentage reactor neutron power; abbreviation YX13X801
- (2): primary pressure; transducer YA10P801
- (3): maximum outlet temperature of group 1 fuel bundles; abbreviation YQ30T801
- (4): maximum outlet temperature of group 2 fuel bundles; abbreviation YQ30T802
- (5): pressurizer level, transducer YP10L002
- (6): pressurizer pressure, transducer YP10P001
- (7): steam generator YB11 pressure; transducer RA11P961
- (8): steam generator YB13 pressure; transducer RA13P961
- (9): steam generator YB15 pressure; transducer RA15P961
- (10): steam generator YB52 pressure; transducer RA52P961
- (11): steam generator YB54 pressure; transducer RA54P961
- (12): steam generator YB56 pressure; transducer RA56P961
- (13): mean loop temperature; abbreviation YA10T902

The accuracy of the reactor power measurement is 1.8 %. The uncertainty of the primary pressure measurement is 1 %, pressurizer pressure 0.8 % and steam generator pressures 1.4 %. The accuracy of all temperature measurements is 0.5 %. The uncertainty of pressure level gauge is 1.5 %.

Appendix C includes parameters of group 02

- (1): steam generator YB11 water level; transducer YB11L005
- (2): steam generator YB13 water level; transducer YB13L005
- (3): steam generator YB15 water level; transducer YB15L005
- (4): steam generator YB52 water level; transducer YB52L005
- (5): steam generator YB54 water level; transducer YB54L005
- (6): steam generator YB56 water level; transducer YB56L005

-(13): secondary pressure in steam collector; transducer RA10P002
-(14): secondary pressure in steam collector; transducer RA50P002

The uncertainty band for the level gauges is 1 %. The accuracy on the pressure measurements is evaluated 0.8 %.

Appendix D includes parameters of group 03

- (6): mass flow rate of high capacity make-up pump TK11, transducer TK11F001
- (9): mass flow rate of letdown line TE50; transducer TE50F001
-(11): back pressure in letdown line TE50; transducer TE50P001
-(14): subcooling in the reactor inlet; abbreviation YA10T817

The uncertainty of the mass flow rate transducers is 1.5 %. The accuracy of pressure measurement is 0.8 %. The uncertainty of the calculated subcooling temperature is 2 %.

Appendix E includes parameters of group 17

- (1): mean pressure in secondary steam collector, abbreviation RA00P901
- (2): mean primary loop temperature; abbreviation YA10T902
- (3): primary pressure; transducer YA10P801

The accuracy of secondary pressure is 0.8 % and primary pressure 1 %. The uncertainty of the temperature measurement is 0.5 %.

Appendix F includes parameters of group 30

- (1): total vapor generation rate of steam generators YB11, 15 and 13; transducer RA10F801
- (2): total vapor generation rate of steam generators YB54, 52 and 56; transducer RA50F801
- (3): opening rate of turbine by-pass valve RC11; transducer RC11S003
- (4): opening rate of turbine by-pass valve RC12; transducer RC12S003
- (5): opening rate of turbine by-pass valve RC51; transducer RC51S003
- (6): opening rate of turbine by-pass valve RC52; transducer RC52S003

The accuracy on the vapor generator rate is 2 %. The uncertainty band for the valve position gauge is 1.5 %.

Appendix G includes parameters of group 32

- (5): secondary pressure in steam line from steam generator YB11; transducer RA11P005
- (6): secondary pressure in steam line from steam generator YB13; transducer RA13P005
- (7): secondary pressure in steam line form steam generator YB15; transducer RA15P005
- (8): secondary pressure in steam line from steam generator YB52; transducer RA52P005
- (9): secondary pressure in steam line from steam generator YB54; transducer RA54P005

-(10): secondary pressure in steam line from steam generator YB56; transducer RA56P005.

The accuracy of the pressure measurements is 0.8 %.

3.4.2 Plotted plant parameters

Figure 3.1 illustrates the recorded reactor neutron flux. It shows the results of the neutron detectors of three levels; power range (YX13X051-56), intermediate range (YX12X051-56) and source range (YX11X051-56).

The estimated accuracy including the recorder uncertainty is 2.2 %.

Figure 3.2 shows the plotted primary pressure (YA10P901) and primary mean loop temperature (YA10T901).

The uncertainty of pressure measurement is 1.5 % and temperature is 1 %.

Figure 3.3 illustrates the recorded temperatures of primary loop hot legs (YA11T003 through YA16T003).

Figure 3.4 shows the recorded temperatures of all primary loop cold legs (YA11T005 through YA16T005).

The accuracy of the temperature sensors is 1 %.

Figure 3.5 shows the measured water levels in all steam generators (YB11L005 through YB16L005).

The uncertainty for the level gauges is 1.5 %.

Figure 3.6 illustrate the recorded secondary pressures of two gauges (RA10P901 and RA50P901) in steam collector.

The accuracy of the pressure measurements is 1.5 %.

Figure 3.7 shows the plotted pressurizer pressure (YP10P001) and temperature (YP10T001).

The accuracy of the pressure measurement is 1.3 % and temperature measurement is 1 %.

Figure 3.8 illustrates the recorded pressurizer water level (YP10L001) and differential pressure across reactor core (YC10P001).

The uncertainty of the plotted level is 1.36 %. The accuracy of the differential pressure measurement is 1.3 %.

When the plotted variables in Figures 3.1 through 3.8 are utilized some tolerance should be added as a reading error. Furthermore the timing is not accurate and engineering judgement is needed for comparison of the plotted and printed variables.

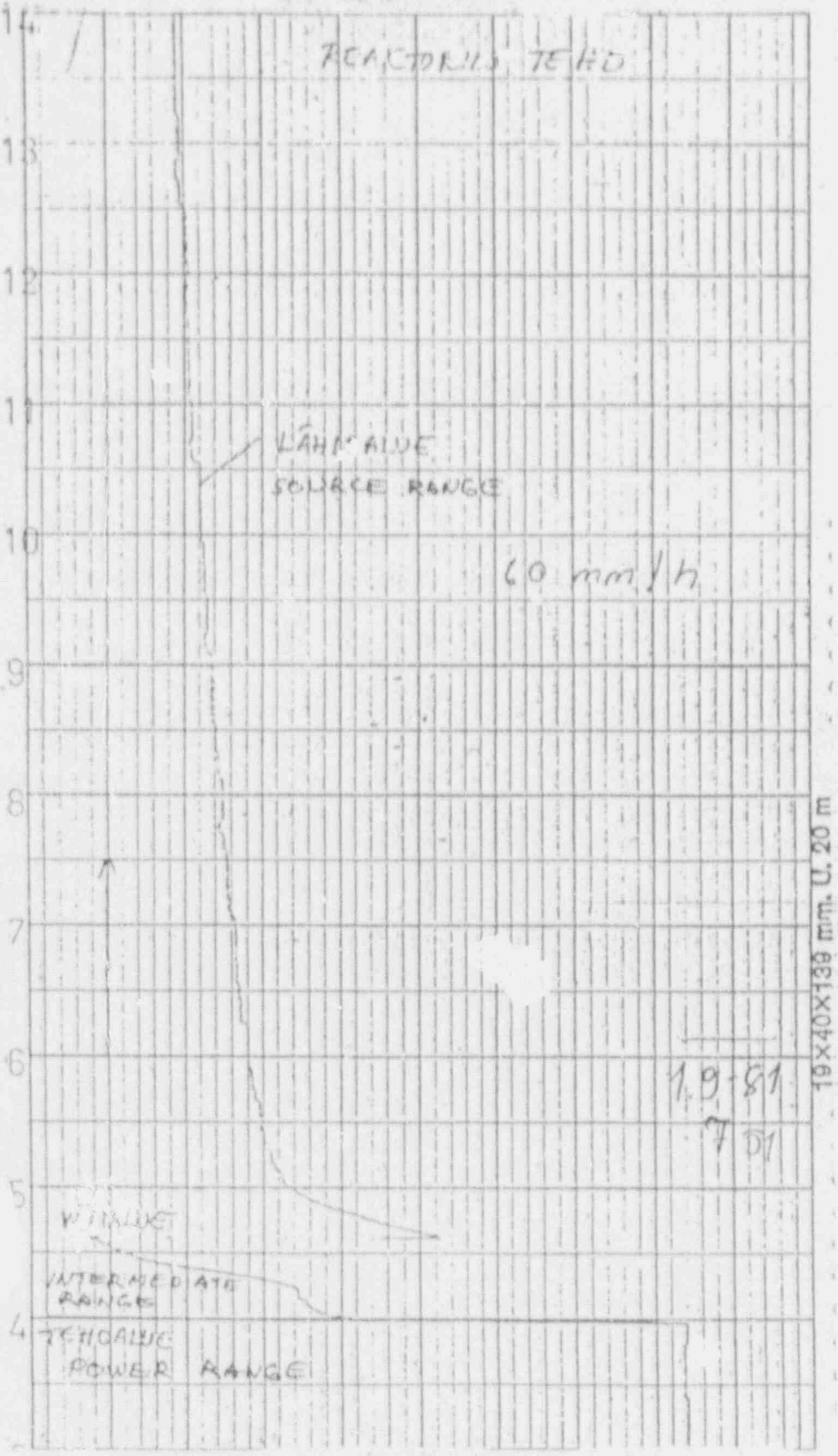


Figure 3.1 Reactor neutron flux.

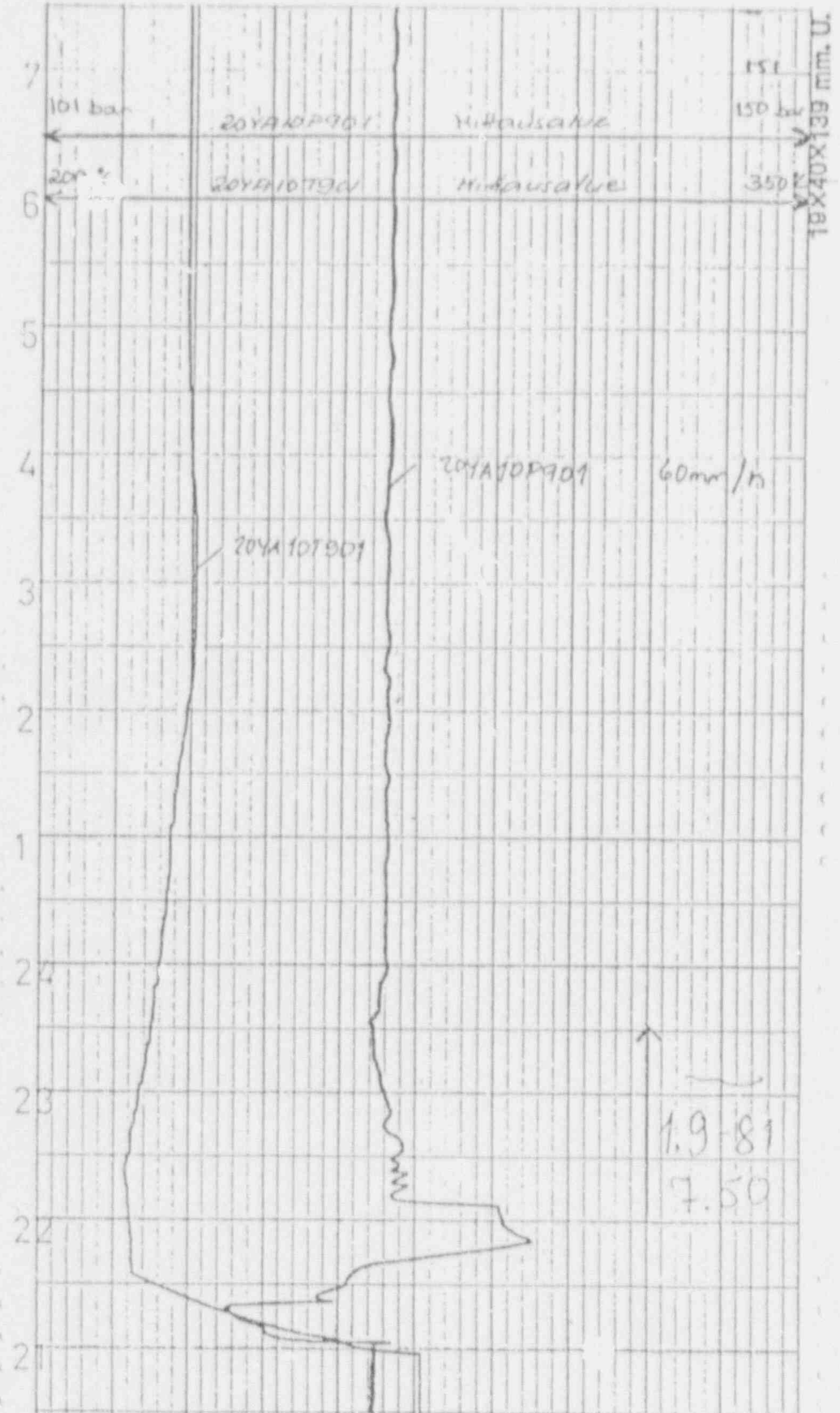


Figure 3.2 Primary pressure (-P901) and mean loop temperature (-T901).

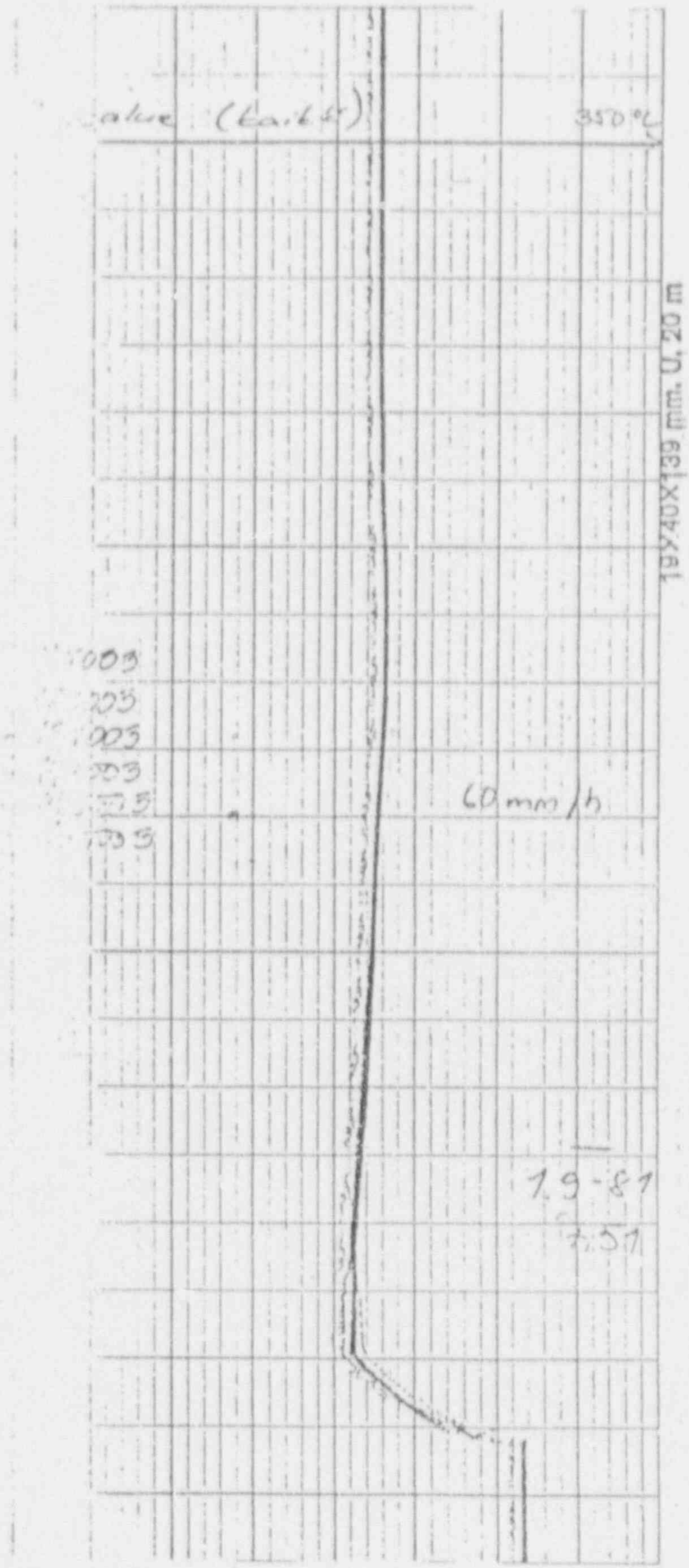


Figure 3.3 Primary loop hot leg temperatures.

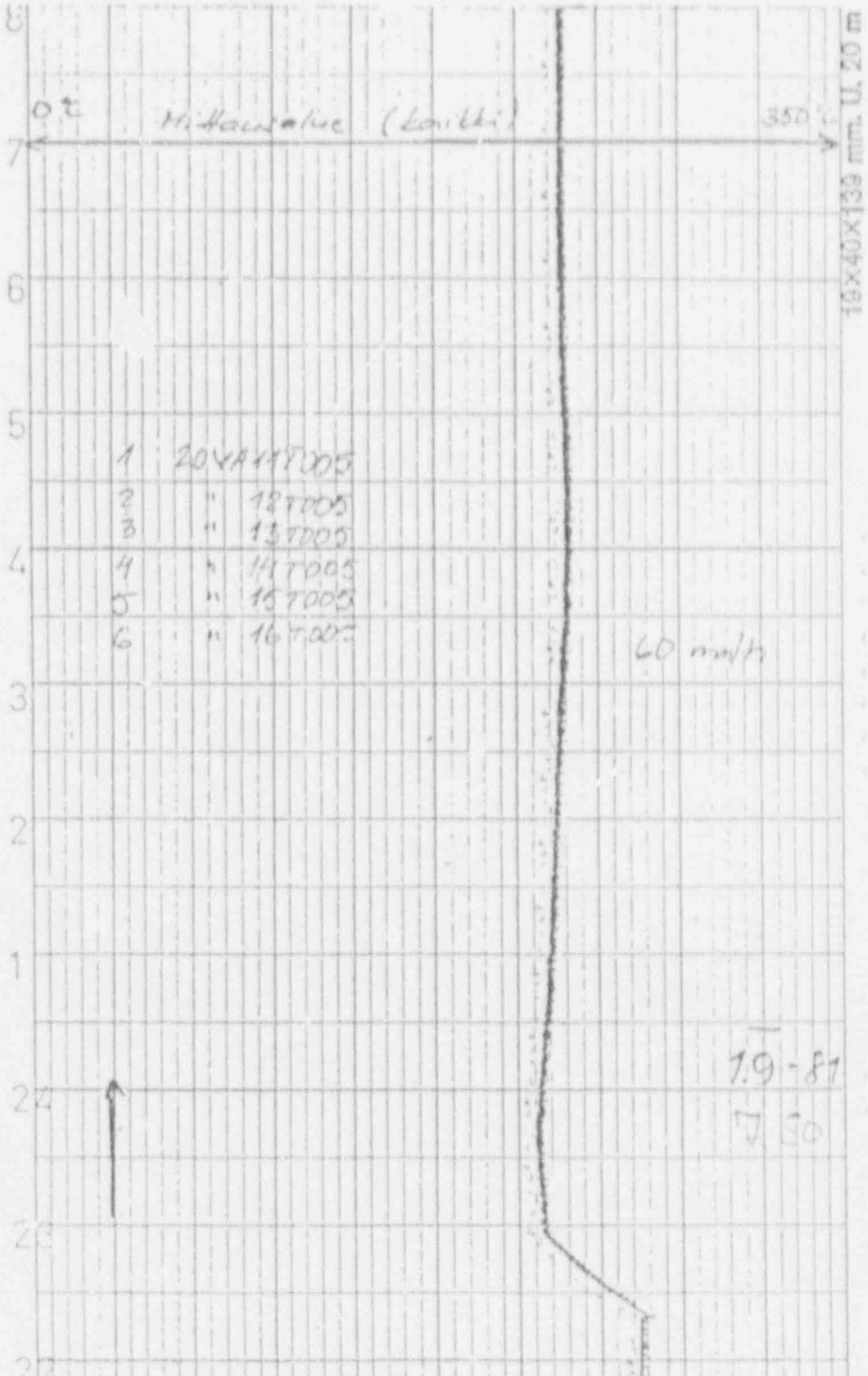


Figure 3.4 Primary loop cold leg temperatures.

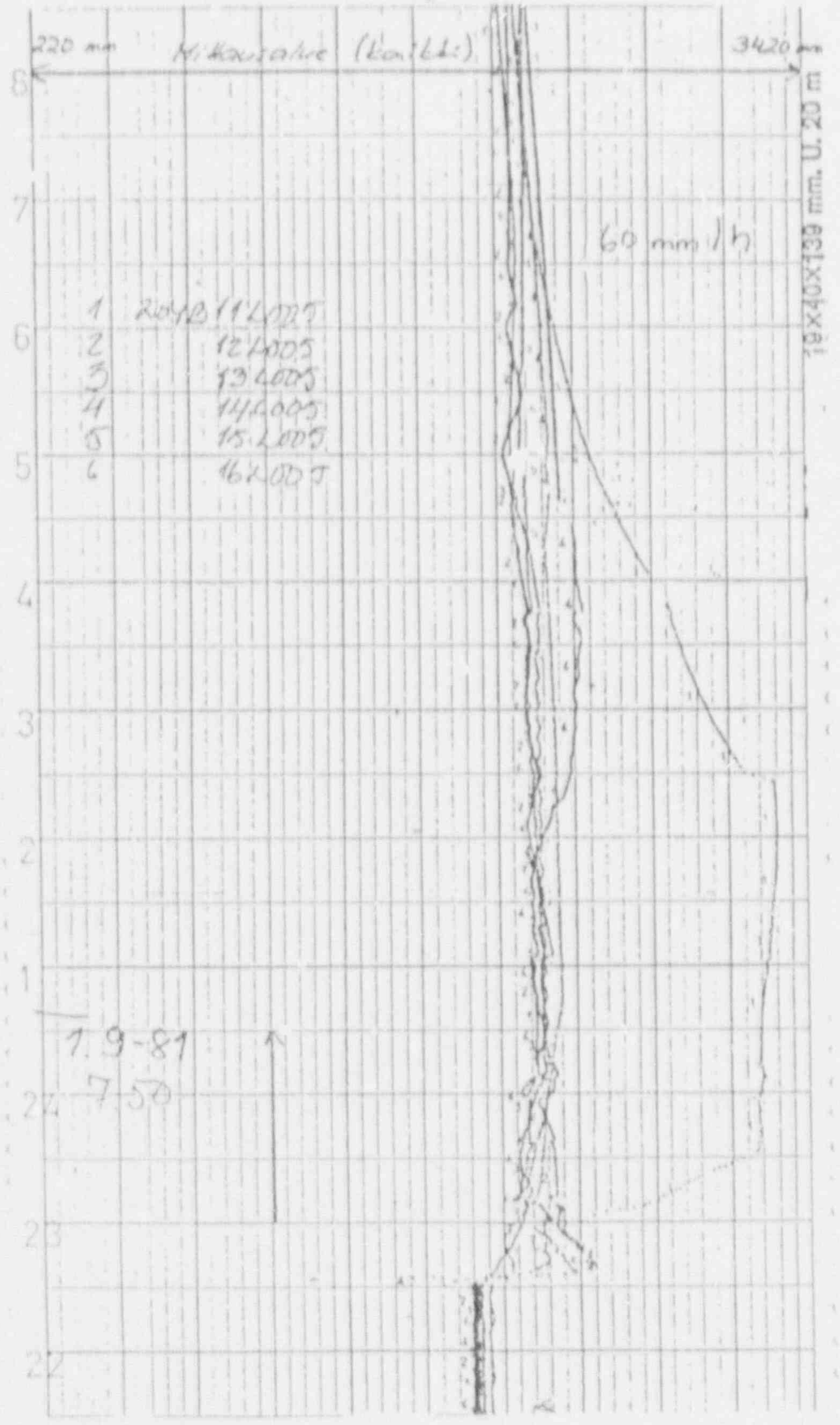


Figure 3.5 Water levels in steam generators.

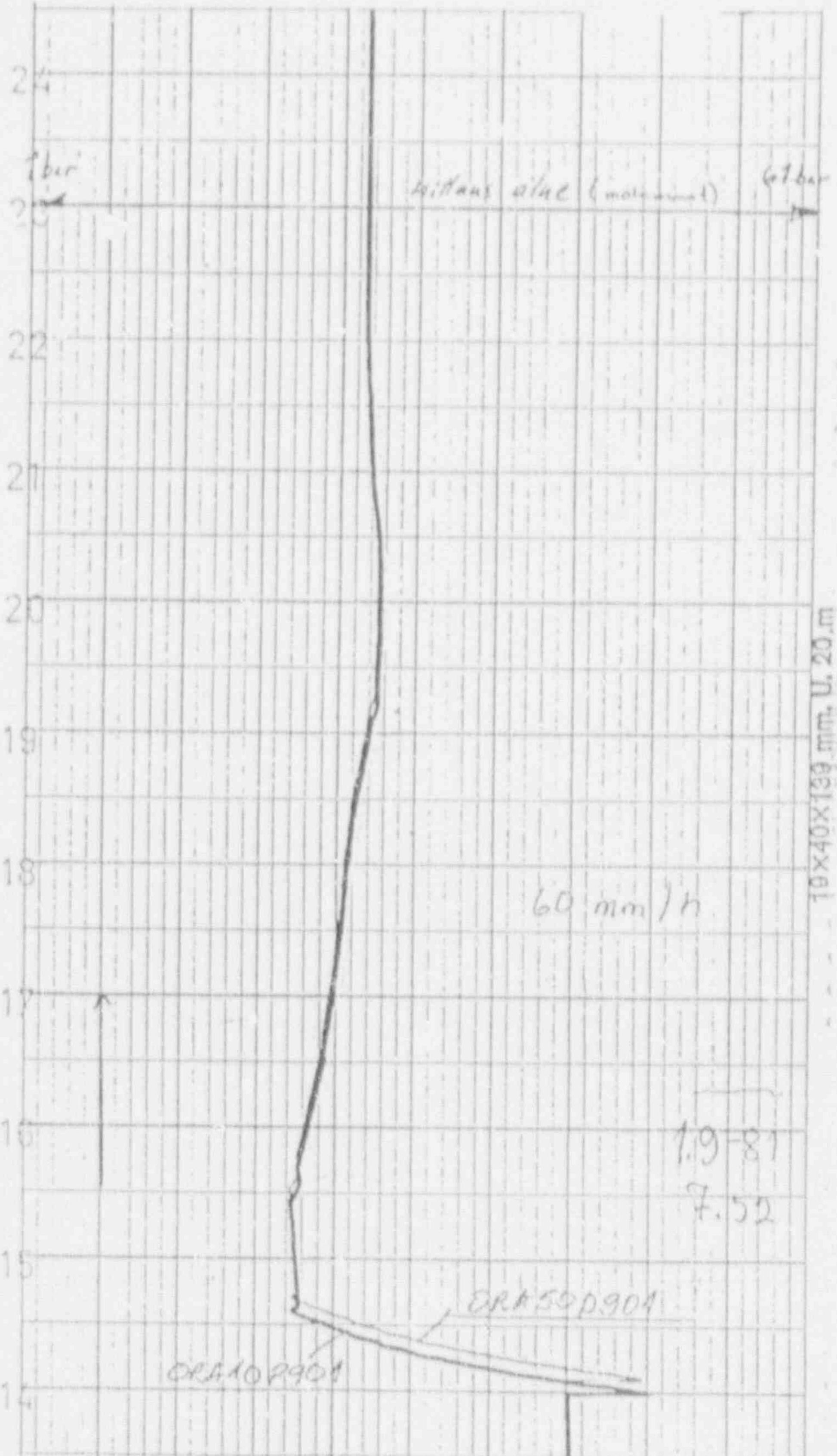


Figure 3.6 Secondary pressure.

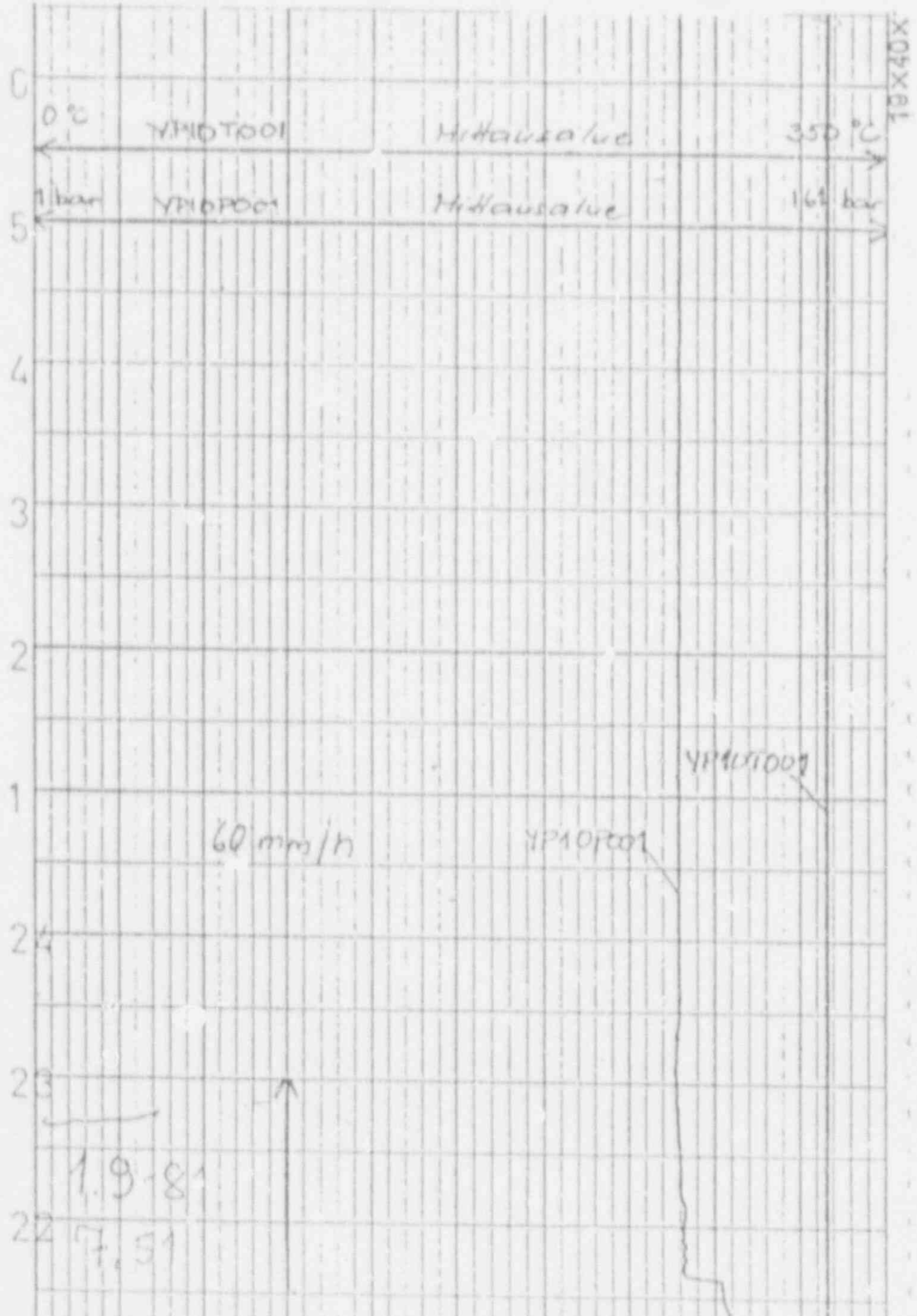


Figure 3.7 Pressurizer pressure (-P001) and temperature (-T001).

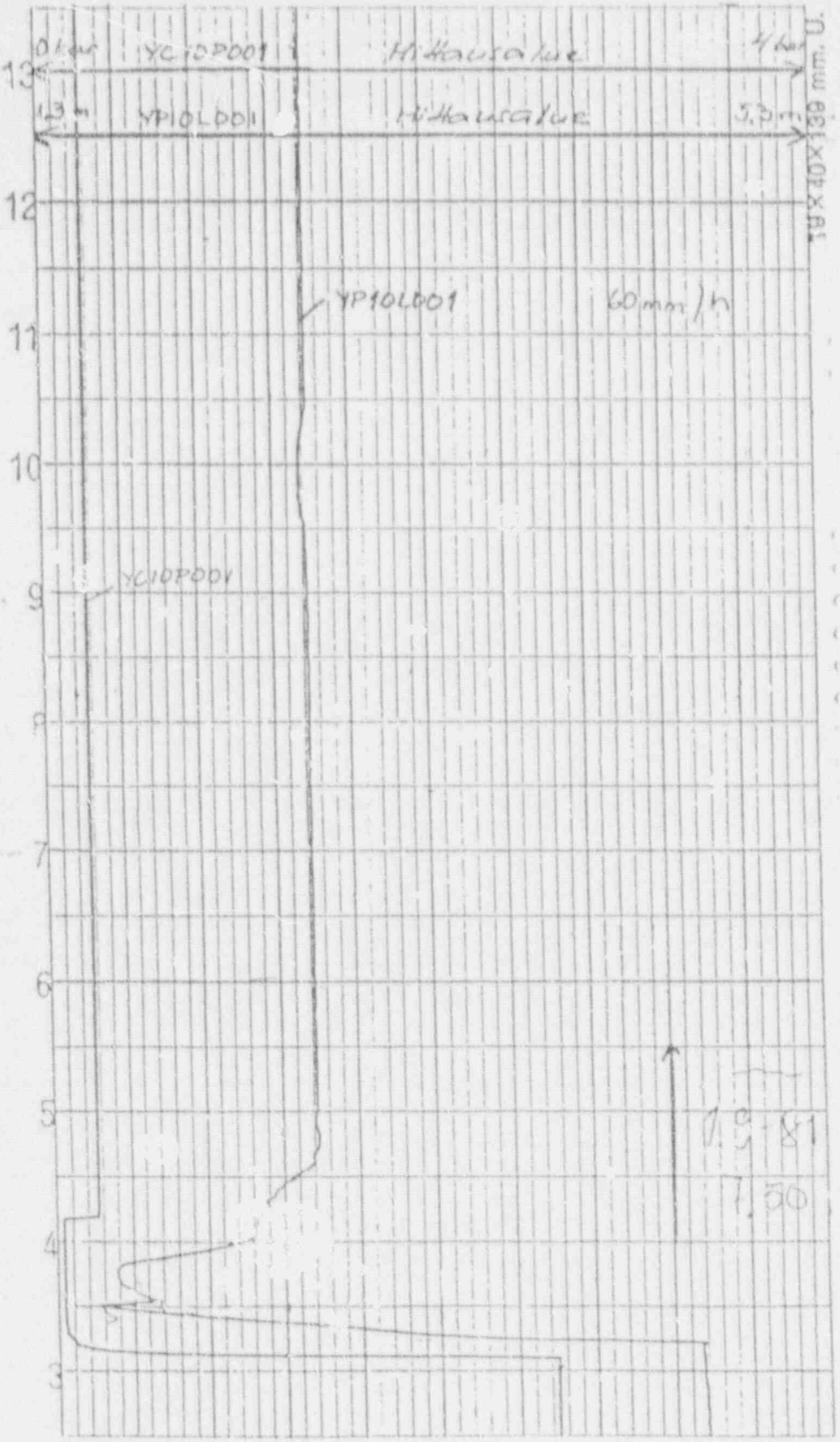


Figure 3.8 Pressurizer water level (-L001) and differential pressure across reactor core (-P001).

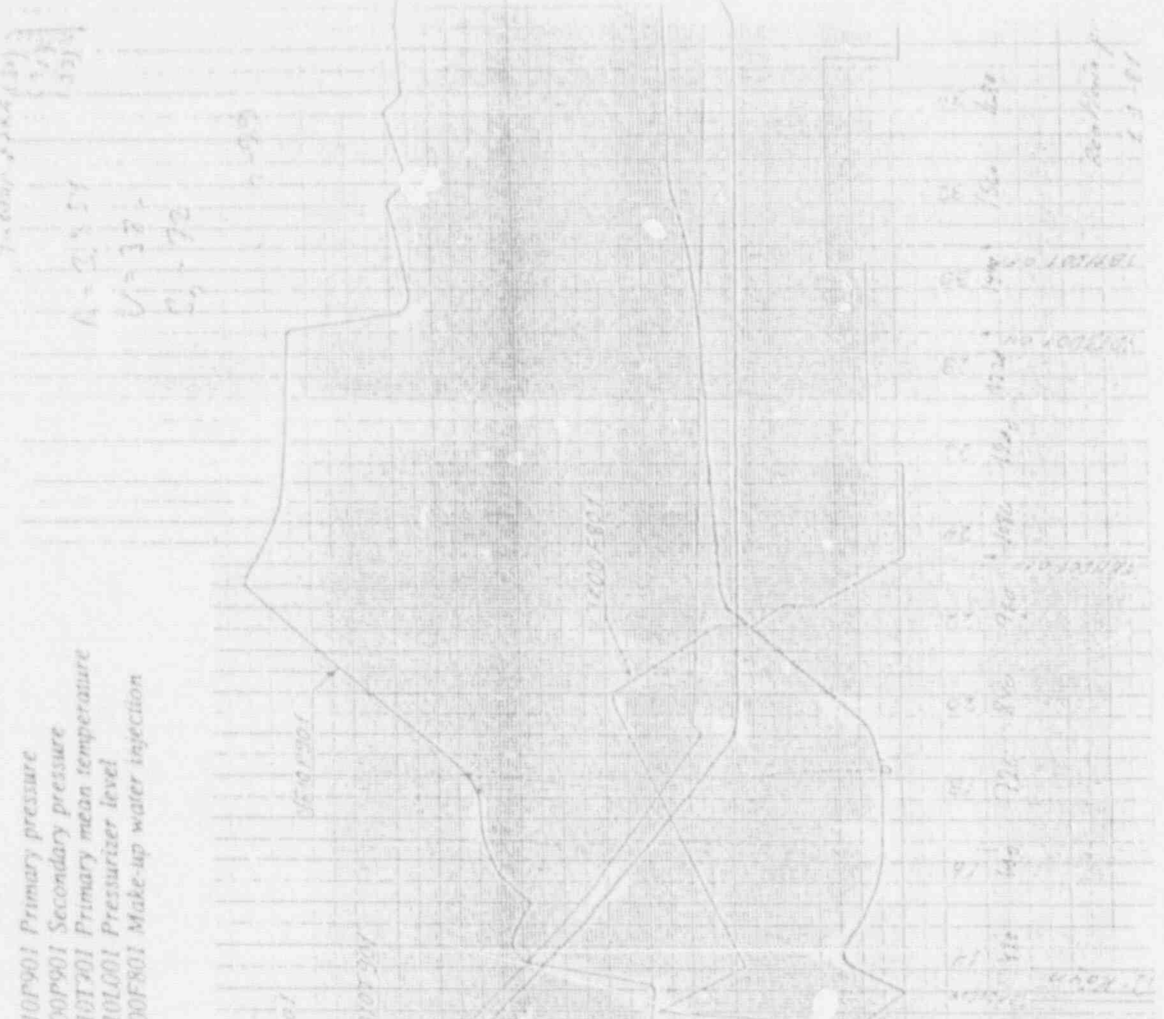


Figure 3.9 Combination plot of most important plant parameters.

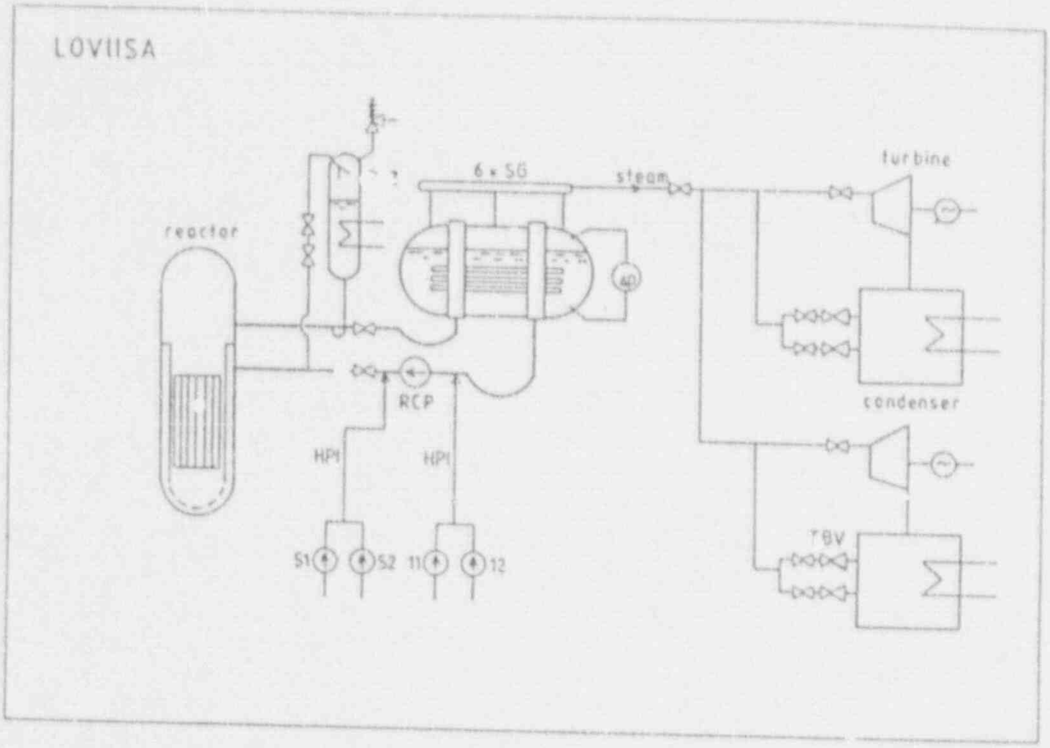


Figure 3.10 Plant systems involved into the transient.

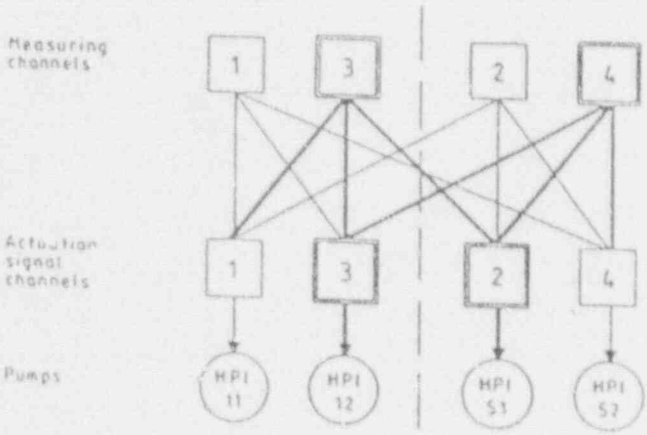


Figure 3.11 The actuation logic circuit of the HPSI- system.

4. CODE AND MODEL DESCRIPTIONS

The code used for the assessment calculation was RELAP5/MOD2 cycle 36.04 and it was implemented on a CDC computer Cyber 180-840.

A quite comprehensive description of the RELAP5/MOD2 code may be found in the code manuals /5/. The code features important for the Loviisa transient calculation are discussed in Chapter 4.1.

The Cyber 180 computer consists of the model 840 CPU with 16 MB central memory (in NOS operating environment only 256 k word (=2 MB) can be utilized) and eight model 855 disk units with approximately 4.8 GB capacity. The speed of the model 180-840 CPU is 1 MFlops (6 MIPS). The operating system was NOS 2.5.2. level 678.

The nodalization model is the usual basic version utilized in accident analysis and it compromises between the size of the model and the costs of computer runs. Details of the input are discussed in Chapter 4.2.

4.1 Code Features

The models and correlations of the RELAP5/MOD2 have been extensively tested against western type pressurized water reactors (PWR) in developmental and independent assessment. Since the Loviisa plants are Soviet type PWRs with certain unique features deviating from most of the western PWR designs, one can ask, whether some important phenomena are missing from the code in a VVER-440 -type reactor simulation.

The most dominating factor of the transient was the cooling-down rate of the secondary side. This was greatly influenced by the primary to secondary heat transfer. The simulation of the horizontal steam generator and its gravitational water separation was fulfilled using the mechanistic separator model of the RELAP5 code. The fallback junction of water required an artificial recirculation flow where the momentum flux was diminished using cross-flow junctions.

Further on, it should be remembered that the capability of the models to describe exactly the real plant behavior under multidimensional flow conditions is limited. On the other hand the normal plant instrumentation cannot explain all details needed for verification of the calculational results.

4.2 Code Input Model

The nodalization used for the calculation included 191 thermal-hydraulic control volumes. The six-loop plant was simulated by a three-loop model. The division was based on the requirement of a typical accident analysis. One single loop is usually needed for the simulation of the broken loop. The double loop represents the two circuits which are connected to the pressurizer. The triple loop consists of those three loops where the hot and cold leg loop seals are connected together via by-pass lines. The HPSI and make-up injections were modelled as boundary conditions. All the contributing control and protection systems were taken into account.

The nodalization scheme with the numbering logic is shown in Figure 4.1.

The first attempts of code calculations showed that injections into the primary circuit had a significant effect on the calculation results. If the injections were assumed to operate according to the actuation signals, small differences in such parameters as pressurizer level could change remarkably the later behavior. In order to diminish the consequences of calculational uncertainties injection rates and times have been given for all calculations as a boundary condition taken from the plant data according to Figure 2.2.

In the nodalization models the pressurizer included 15 stacked volumes. The actuation signals for the pressurizer spray were modelled in the calculation as in the real plant. The spray flow rate is determined by the pressure difference over the spray line being dependent on the number of running RCPs.

In the primary loop forced circulation conditions existed throughout the transient. The temperature differences were quite small. The number of nodes was not very significant except for the short period behavior. The main characteristics of the code nodalization is shown in Table 4.1

The secondary system consisted of the steam generator shell sides and the main steam lines to the turbine throttle valves. The turbine trip is simulated by closing the throttle valves. The turbines and condensers are not included. The feed water system model is replaced with boundary conditions, i.e. time dependent junctions and volumes.

In the horizontal steam generator the recirculation occurs naturally within a vessel having a large liquid cross section. The feed water is injected into the middle of the bundle through nozzles of a long distributor pipe. The two-phase mixture rises up through the bundle and steam is separated above them. Water falls down, owing to the comparatively low velocity of the steam leaving the evaporating surface. The average void

Table 4.1 Main characteristics of the nodalization scheme

	Number of components
Volumes	191
Junctions	203
Heat structures	131
SG tube volumes/loop	5
SG heat structures	5
Cold leg volumes/loop	13
Downcomer volumes	12
Lower plenum volumes	3
Core volumes	5
By-pass volumes	5
Upper plenum volumes	2
Upper head volumes	4
Hot leg volumes/loop	11
Pressurizer volumes	15
Separate loops	3

fraction in the tube bundle is about 0.25. In the RELAP5 calculation the circulation of water was artificially modelled and the water circulation rate was 10 700 kg/s as the steam flow leaving the steam separator was 124 kg/s.

During the transient the feed water flow rate was quite low and the flow was defined in the calculation by a constant level control.

In the secondary side the main boundary condition is the steam flow rate into the turbines and TBVs. In RELAP5 analyses the valve flow area was adjusted to match the real TBV data.

4.2.1 Primary Coolant Loops

The nodalization for the single loop simulating Loviisa loop YA11 is shown in Figure 4.2. The make-up and emergency water injections are connected via the TC-collector Z03 to the cold leg loop seal. Two high pressure injection pumps TJ11 and 12 are feeding through the TC-collector Z03, too. Because the collector Z03 is also connected to the primary loops YA13 and YA14 the injection rates are modelled according the number of loops and equal distribution between the loops was assumed.

One third of the flow rate of the pump TJ12 (started under the incident) is injected into the single loop through the junction no. 721. The high pressure injection water temperature is 58 °C. The TJ- operation was modelled according the signals received from the transient data.

Junction no. 741 is simulating 1/3 of the injections of the make-up pumps TK51, 52 and 53 . The total capacity of each pump is 1.7 kg/s and injection rate is based on the plant data (Figure 2.2). The make-up water temperature is 120 °C.

Also the high capacity make-up pump TK11 feeds through TC-collector Z03. Junction no. 761 represents 1/3 of this flow which is modelled according the recorded injection rates (Figure 2.2). The high capacity make-up water temperature is 50 °C.

The nodalization of the double loop (loops YA13 and 14) that is connected to the pressurizer is presented in Figure 4.3. The model differs from the single loop model only in that the pressurizer surge line attaches to the hot leg and the pressurizer spray line is fed from the cold leg. The TC-collector Z03 is connected to the cold legs of these loops, too. Two thirds of the flow rate from the high pressure pump TJ12, make-up pumps TK51, 52 and 53, and the high capacity make-up pump TK11 are modelled as junctions no. 722, 742 and 762, respectively.

A fine nodalization is chosen for the pressurizer model in order to simulate properly in-surges, spray and thermal non-equilibrium phenomena. Heat slabs are used in order to model the heat transfer between fluid and pressurizer wall. The pressurizer spray is fed from the cold leg by means of four time dependent junctions no. 381, 382, 383 and 384. They are operated according to the primary pressure control program shown in Table 4.2. The spray flow rates correspond, according Table 4.3, to the pressure difference between hot and cold leg, which is dependent on the number of running primary coolant pumps.

There is no measured data of the pressurizer spray flows. In the plant transient report it is stated that the operator opened at 07.21.24 the control valve of the shutdown pressure control system to make spraying more effective. However, based on the documentation of the Loviisa training simulator it is evident that this should not produce any spray when only one reactor coolant pump is running. In the model it was assumed that only the normal spray valves functioned according to Tables 4.2 and 4.3.

The primary pressure control incorporates the pressurizer heaters that were modelled as heat slabs bounding to volumes 370-03 and 370-04. The actuation logic for the heaters is shown in Table 4.4.

The nodalization of triple loop (loops YA12, 15 and 16) is shown in Figure 4.4. The reactor coolant pump discharge side is connected to the TC-collector Z01, which is normally feeding the primary water to the purification system. In case of emergency two high pressure safety injection pumps TJ51 and 52 are injecting water into the primary loops through the TC-collector Z01. Junction no. 723 simulates the injection of HPSI pump TJ51 that came on during the transient. The on and off signals for HPSI are taken from the plant computer data.

The primary model does not have any letdown flow. In normal operation the plant letdown valve is opened very seldom because the operator is maintaining the constant pressurizer level with the adjustable make-up pump.

The reactor coolant pump model was based on the single-phase curves measured by the manufacturer. The pump characteristics were verified against a measured pump stop test during start-up commissioning.

The primary model includes form losses that are chosen to obtain the nominal loop pressure drops corresponding to the plant data.

Figures 4.2 through 4.4 shows the volumes where heat slabs are connected in order to describe the heat exchange between coolant and metal structures.

4.2.2 Reactor vessel and core

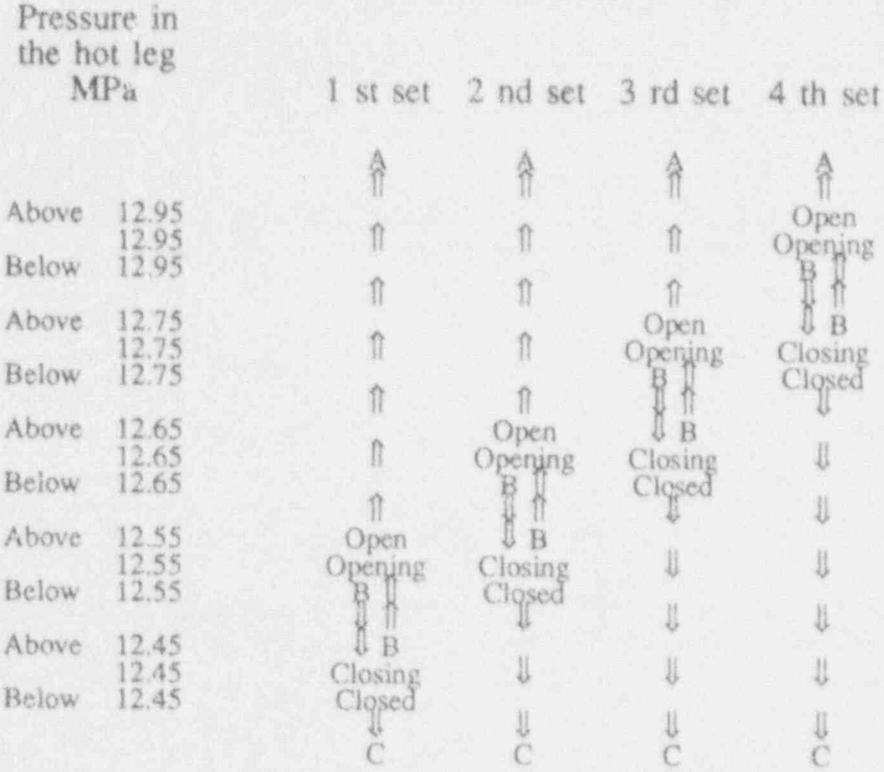
The reactor vessel nodalizadion scheme is introduced in Figure 4.5. The code is not forced to simulate the multi-dimensional flow effects, but both the downcomer and upper plenum are modeled as one-dimensional channels. The cold leg connections to the vessel are cross-flow junctions that were recommended in the code assessment report /6/. The model ignores the small by-pass flow from the downcomer to the upper plenum through the labyrinth seal.

The core region is nodalized as two parallel channels, one representing that channel where the fuel elements are located. The other one includes all by-pass routes including the dummy elements in the outer core. The core is divided into five axial parts.

The vessel upper head includes a large volume between the protective tubes and supporting plates of the control rods. In this volume the recirculation of the fluid was assumed to be small due the supporting plates, and the by-pass flow from lower plenum through the guide tubes of the control elements was also ignored. The three uppermost nodes of the vessel simulates this volume, wherefrom the fluid interacts with the upper plenum through small holes with a total area of 1,77 m^2.

The heat slabs shown in Figure 4.5 includes all major vessel and internal structures.

Table 4.2 Pressurizer spray actuation logic



A When pressure is above opening set point valves are open

B Between opening and closing pressure range the closed valve is closed until the opening pressure is reached and the valve once opened stays open as long as pressure is above closing pressure

C When pressure is below closing set point valve is closed

Each set contains 2 valves in which the flow rate is modelled according to the Table 4.3.

Table 4.3 Pressurizer spray mass flow rate depending on pressure difference between hot and cold leg

Pressure difference kPa	Capacity of spray injection valve sets			
	1 st set	2 nd set	3 rd set	4 th set
80	0.0	0.0	0.0	0.0
98	3.56	3.54	3.12	2.45
155	7.35	6.90	6.34	5.06
215	9.91	9.30	8.67	6.82
270	14.28	13.39	12.50	9.83

Each set consists of two valves that are opened according the Table 4.2.

Table 4.4 Pressurizer heater actuation logic

Pressure in the hot leg		Pressurizer heater group						
		1 st group	2 nd group	3 rd group	4 th group	5 th group	6 th group	7 th group
	MPa	90 kW	90 kW	90 kW	90 kW	180kW	360kW	720kW
Above	12.40	A ⇑	A ⇑	A ⇑	A ⇑	A ⇑	A ⇑	A ⇑
	12.40	off						
Below	12.40	B ⇑						
Above	12.38	⇓ B	⇑					
	12.38	on	off					
Below	12.38	⇓	B ⇑					
Above	12.35		⇓ B					
	12.35		on					
Below	12.35		⇓					
Above	12.24			⇑				
	12.24			off				
Below	12.24			B ⇑				
Above	12.15				⇑			
	12.15				off			
Below	12.15				B ⇑			
Above	12.14			⇓ B		⇑		
	12.14			on		off		
Below	12.14			⇓		B ⇑		
Above	12.12				⇓ B		⇑	
	12.12				on		off	
Below	12.12				⇓		B ⇑	
Above	12.10					⇓ B		⇑
	12.10					on		off
Below	12.10					⇓		B ⇑
Above	12.06						⇓ B	
	12.06						on	
Below	12.06						⇓	
Above	12.00							⇓ B
	12.00							on
Below	12.00	⇓ C	⇓ C	⇓ C	⇓ C	⇓ C	⇓ C	⇓ C

A	Above disconnection pressure heater group is off.
B	Between disconnection and connection pressure values the connected heater is on until the shut off pressure is reached. The heater once disconnected stays off as long as pressure is above connection pressure.
C	Below connection pressure heater group is on.

4.2.3 Secondary side

The secondary side nodalization scheme is shown in Figure 4.6.

The steam generator shell side nodalization is similar in single, double and triple loops. Only the volume of the nodes is twice and three times greater in the two later loops, respectively. The nodalization is based on the usage of the mechanistic separator model of the RELAP5 code although the water separation in the horizontal steam generator is due the gravitational force.

The steam generator shell side is divided into four volumes. One of them represents the volume where all tubes are located. The heat is transferred from five primary side pipe nodes via heat slabs to this boiler node. The two-phase mixture flows to the separator node wherefrom the liquid is returned via two nodes representing the volume between tube bundles and steam generator vessel to the boiler node. The cross-flow junctions are utilized in the model to decrease the momentum flux of the recirculation flow. Heat transfer between SG pressure vessel and mixture of steam and water is also modeled.

The Loviisa plant has a separate steam line from each steam generator to the turbine throttle valves. Steam lines are connected to a collector that reduces the possible unbalance of the system. The turbine by-pass lines are connected to the steam collector. The properly operating three turbine by-pass valves and the stuck open valve are simulated by valve junctions. The areas of the junctions are adjusted to a value of nominal capacity of each valve.

The feed water injection is modeled to keep the level constant. This discards the increase of the secondary side water level in some of the steam generators that was seen in the recorded data (Figure 3.5) due the incorrect operation of the feed water controllers.

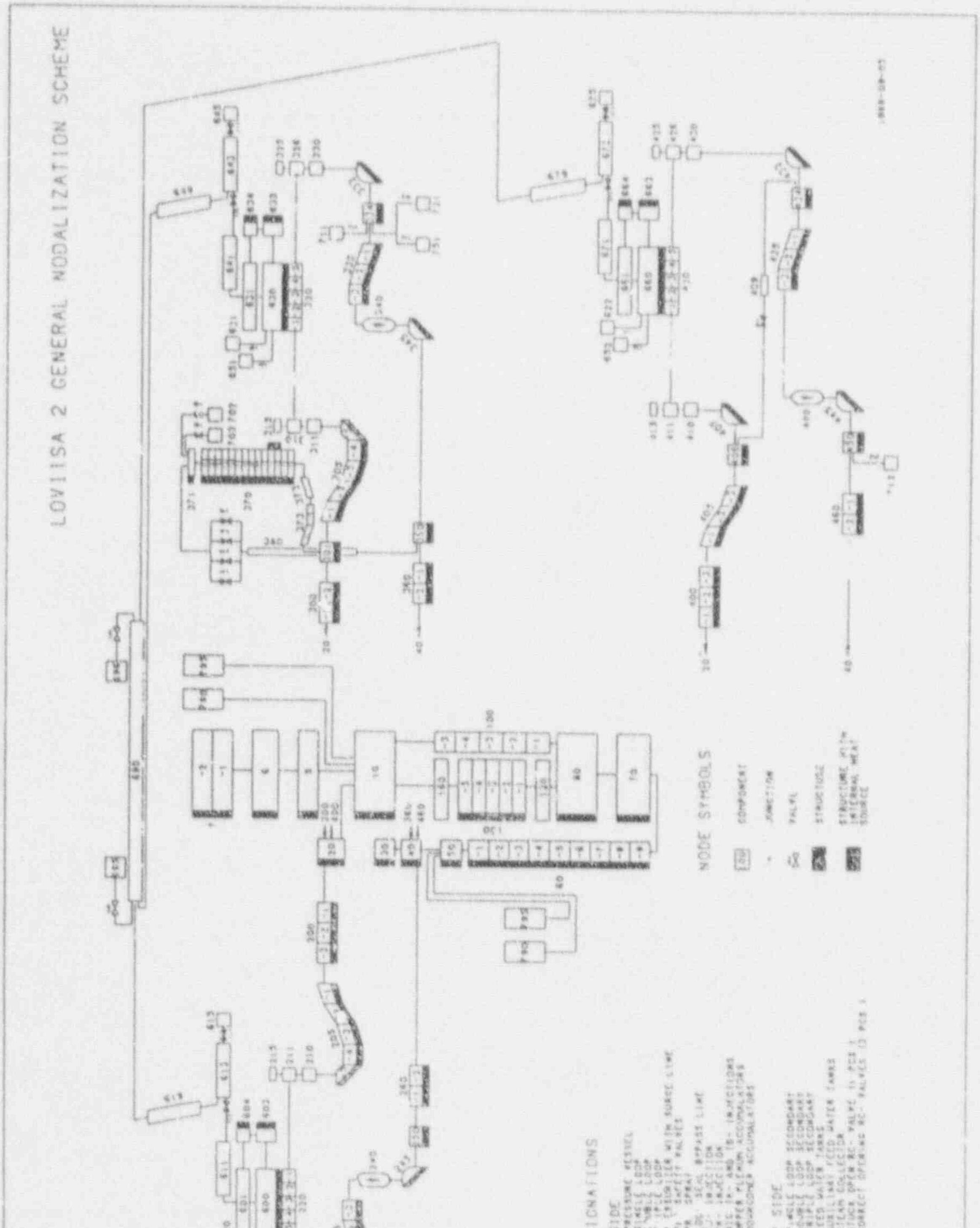


Figure 4.1 General nodalization scheme.

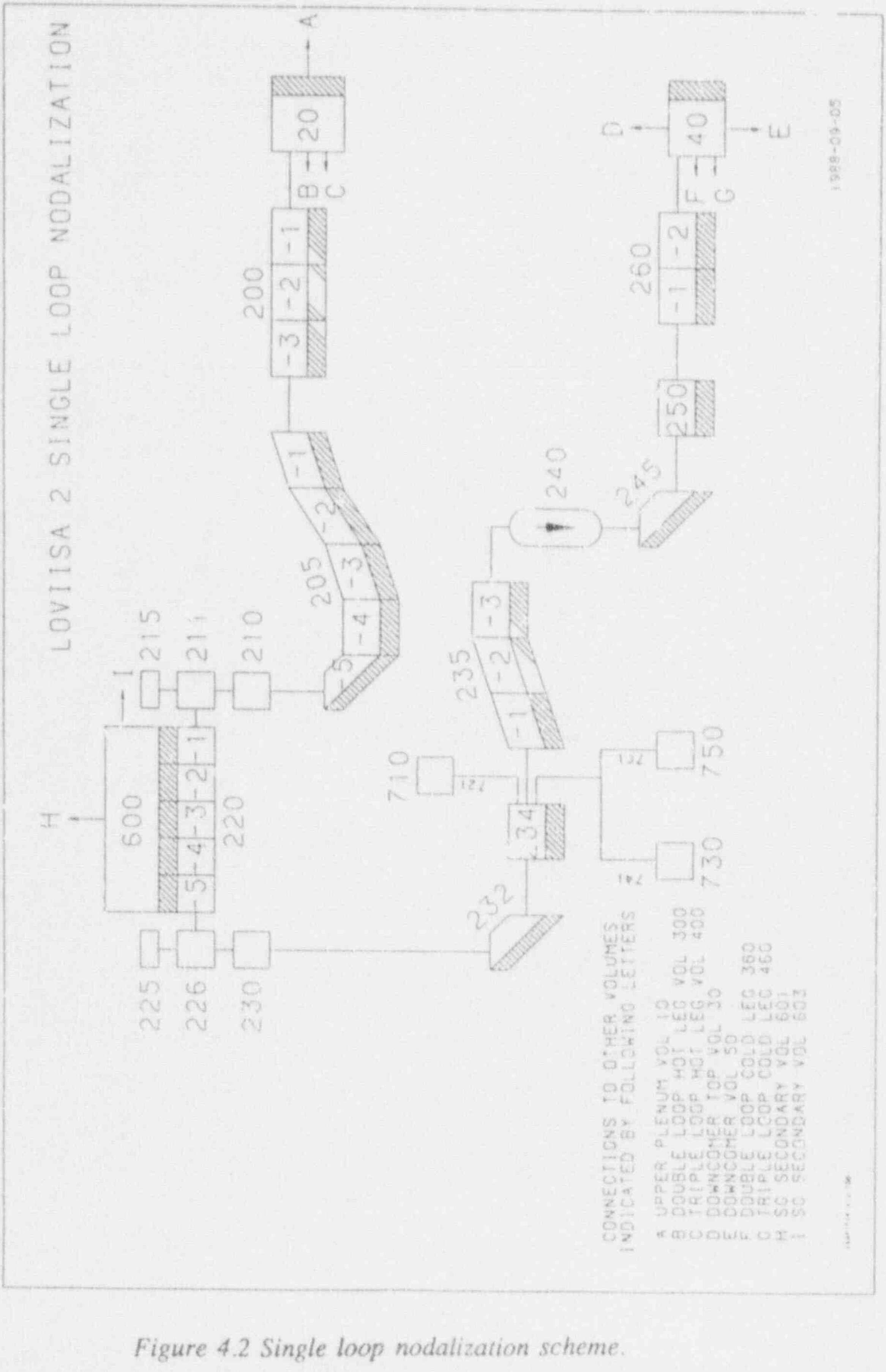


Figure 4.2 Single loop nodalization scheme.

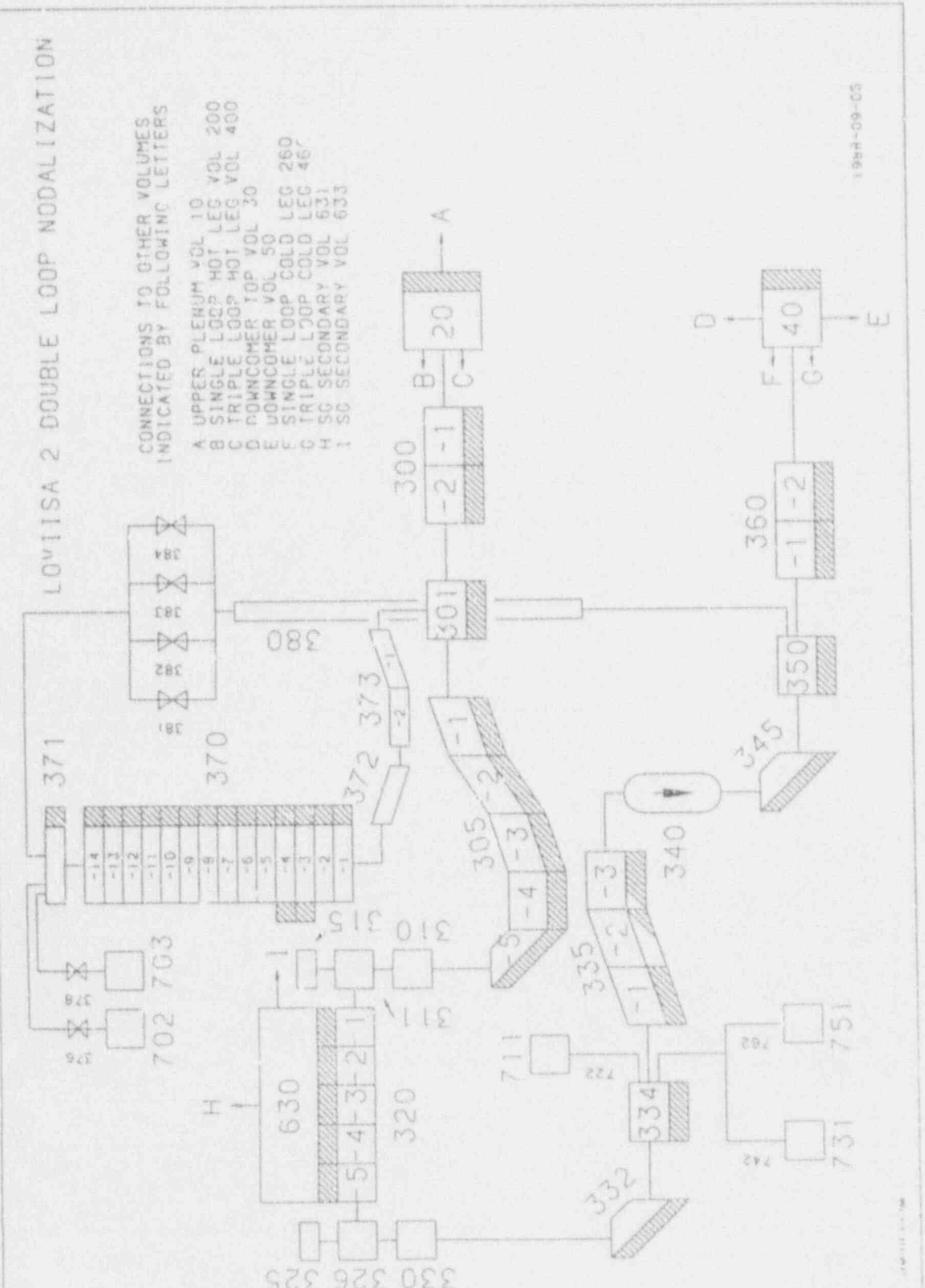


Figure 4.3 Double loop nodalization scheme.

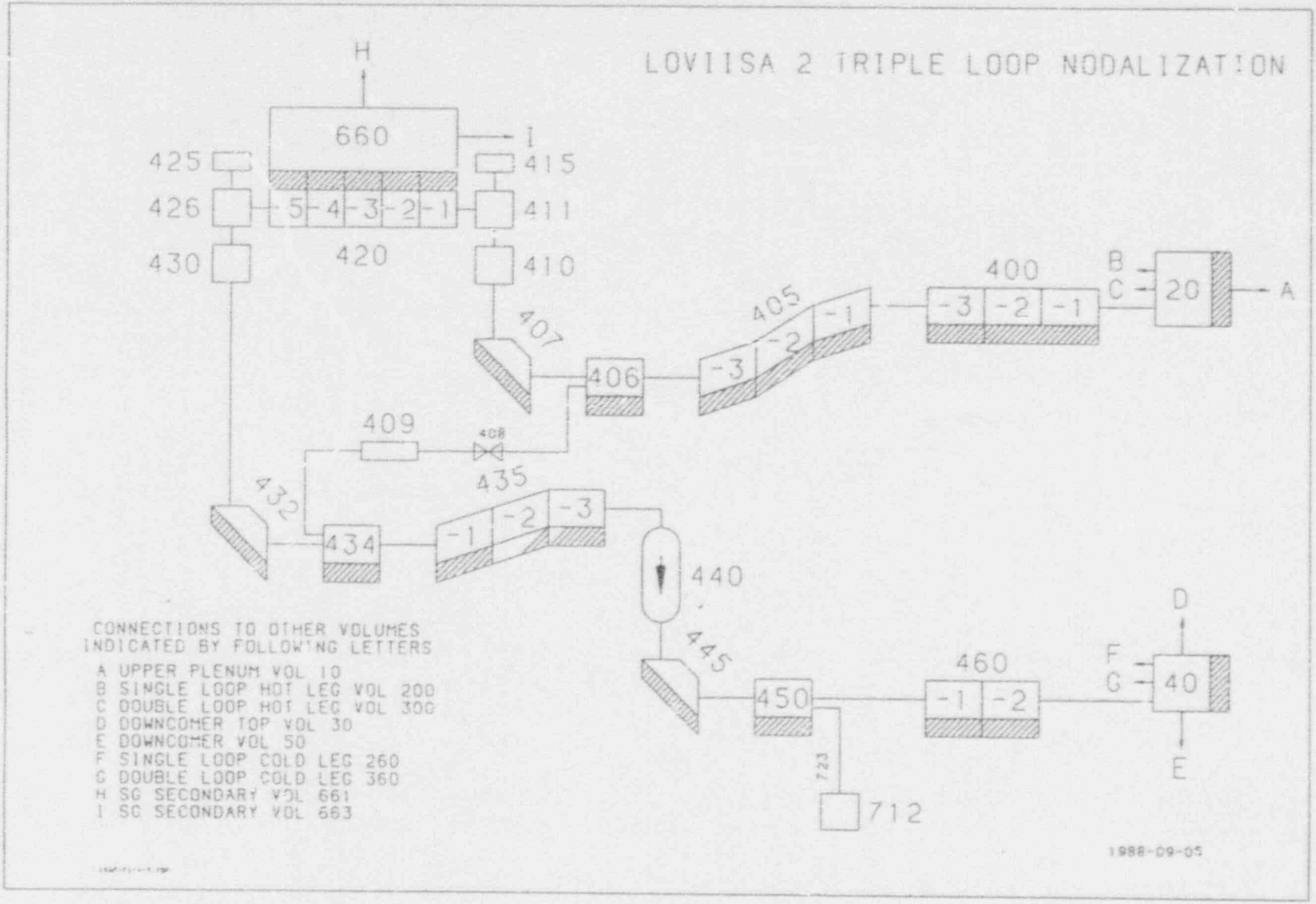


Figure 4.4 Triple loop nodalization scheme.

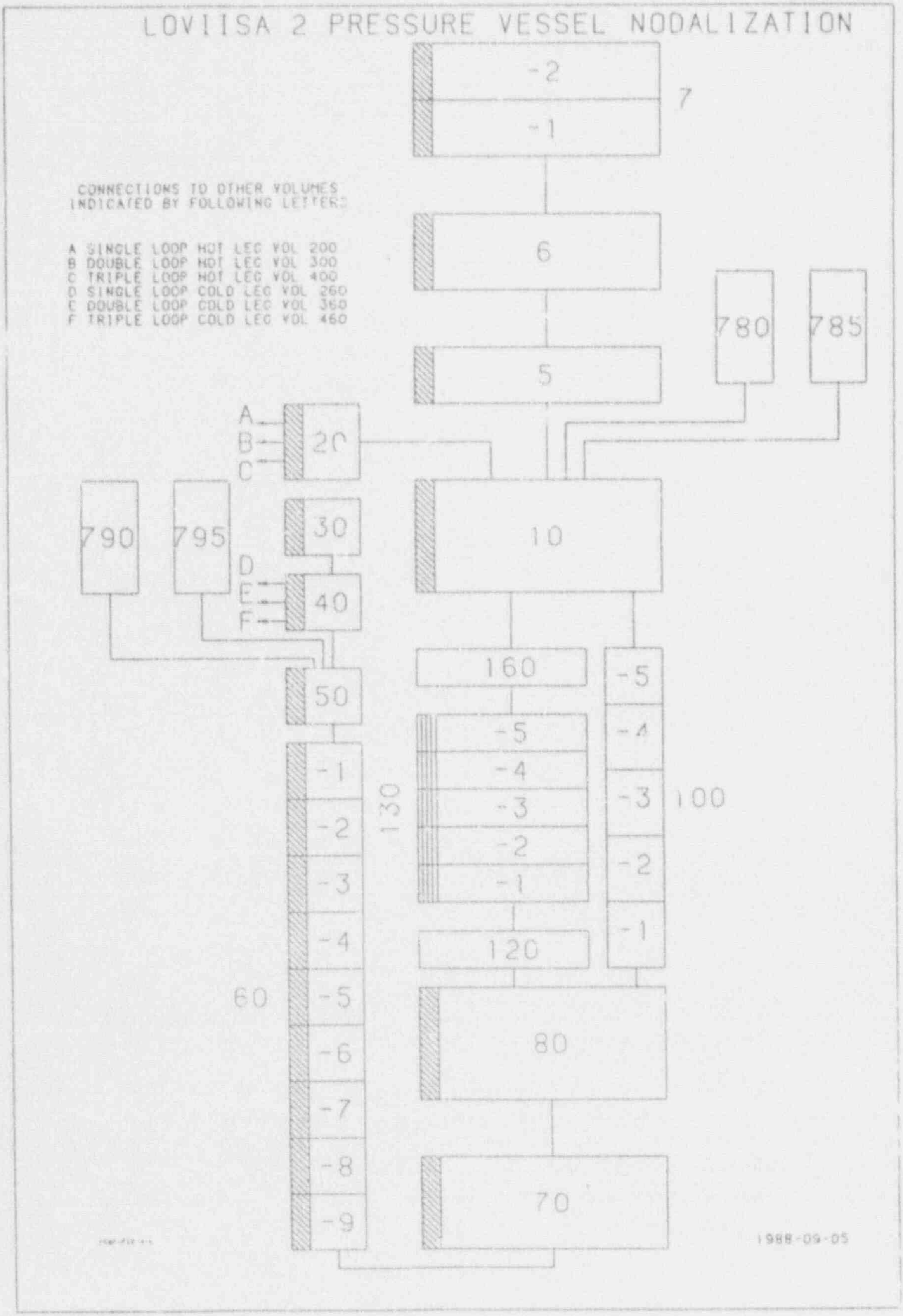


Figure 4.5 Reactor vessel nodalization scheme.

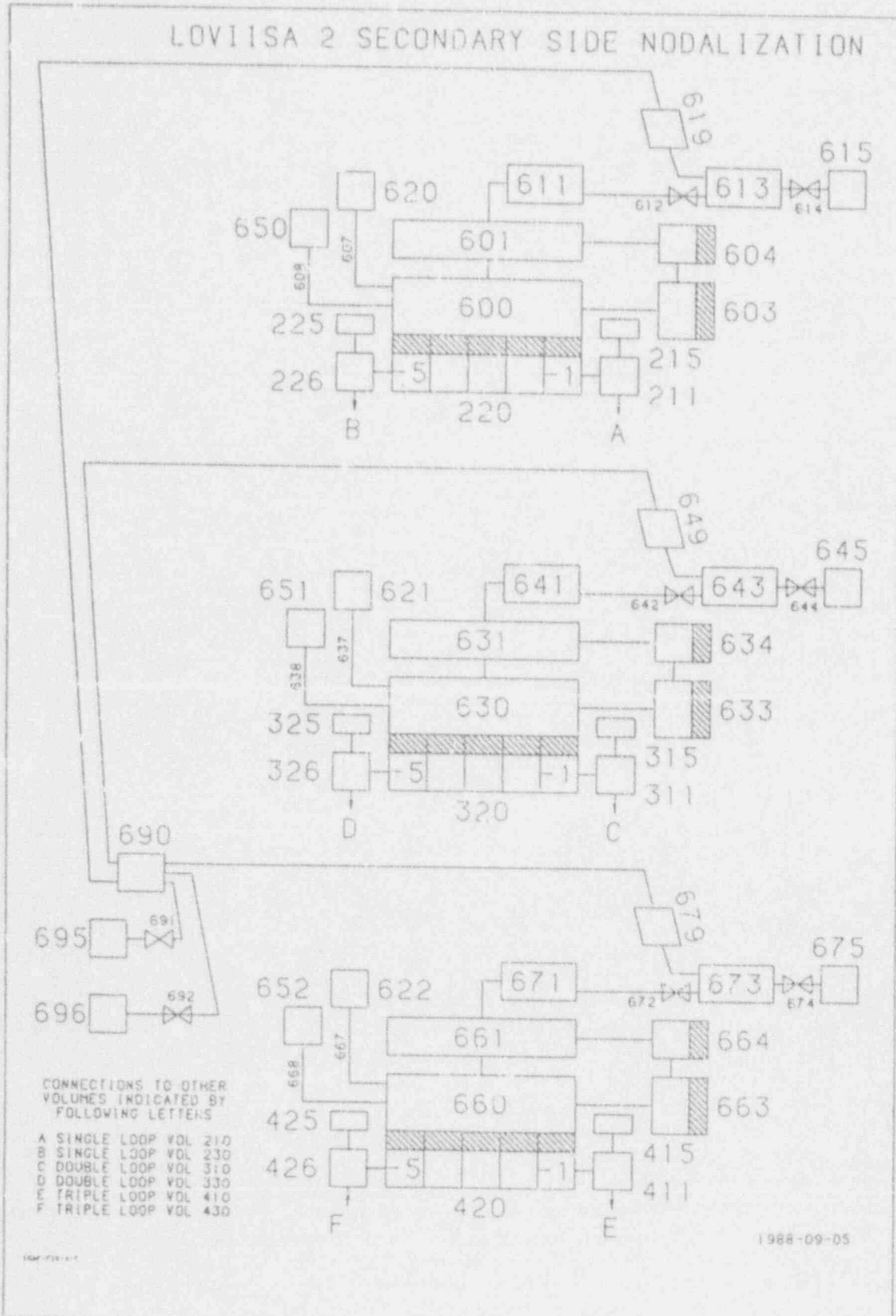


Figure 4.6 Secondary side nodalization scheme.

5. BASE CASE RESULTS

5.1 Steady state calculation

The calculation model presented in the previous chapter was the same as supplied in several accident analyses of the Loviisa Units 1 and 2. Thus no adjustment of the loss coefficients to the plant data were needed. A steady state search run was repeated to reproduce the measured initial conditions that were slightly different from nominal steady state quantities. Table 5.1 compares the measured plant data before initiation of the transient with the calculated values of the steady state run.

The steady state initiation model included some additional components to regulate the primary and secondary conditions. To keep the primary pressure constant a time dependent steam volume was connected to the top of pressurizer. The water level in the pressurizer was kept constant by mean of a time dependent junction which was connected to the reactor vessel lower plenum and was regulated by the pressurizer level. Also the secondary side pressure was maintained by connecting an auxiliary time dependent volume to the steam collectors.

The initiation search run was performed using the RELAP5/MOD2 steady-state option. The code terminated the run after 60 seconds with an announcement of the achievement of the steady state. The run was restarted for 10 seconds in order to reduce still flows from boundary junctions. After a check run without boundary volumes these steady state results were accepted although non-zero flows remained in the junctions of regulating volumes.

The steady state calculation showed that the nodalization of the primary side of steam generator tubes was too coarse. In order to achieve the correct primary fluid temperature the heat transfer rate from primary to secondary had to artificially be improved.This was achieved by decreasing the hydraulic diameter on the primary side of steam generator tubes in the heat transfer calculations. A proper method would be dividing the primary side into more nodes in which the temperature difference approximation would follow closer the real temperature excursion. This could not be done due to the limitation of the computer resources that established the limit on the number of volumes.

5.2 Transient calculation

The transient calculation was based on the initial conditions from the above mentioned steady state calculation. The calculation was performed as a restart problem with a transient calculation option. All the boundary conditions required to regulate the steady state initialization were deleted.

Table 5.1 Comparison of the steady-state calculation results with the plant data

	Plant nominal value	Initial value	Calculated steady-state value
Pressures:			
Primary:			
Pressurizer top	-	123 bar	123 bar
Core outlet	122.4 bar	-	124.3 bar
Hot leg	-	121.8-123.4 bar[1]	123.3 bar
DP across reactor core	2.1 bar	2.69 bar	2.1 bar
Secondary:			
Steam generator	44.8 bar	43.4-44.0 bar[2]	43.9-44.1 bar[3]
Steam collector	-	43.0-43.4 bar[4]	43.0 bar
Temperatures:			
Core outlet	-	299 ° C = 572 K	570.2 K
Hot leg	-	291 °C = 564 K	566.2 K
Cold leg	264 °C	262 °C = 535 K	534.9 K
Mean primary loop	-	273 °C = 549 K	550.5 K
Mass flow rate:			
Downcomer	8500 kg/s[5]	-	8502 kg/s
Core	7480 kg/s	-	7507 kg/s
Core bypass	1020 kg/s[6]	-	995 kg/s
Steam to turbines	750 kg/s	791 kg/s	754 kg/s
Pressurizer water level	4.59 + 0.915[7] = 5.505 m	4.7 + 0.915 = 5.615 m	5.565 m
Reactor power	1375 MW	1375 MW	

---

[1] Variation between different measurements.

[2] Variation between different steam generators.

[3] Variation between different steam generator.

[4] Variation between different measurements.

[5] Based on the nominal volume flow rate of 39000 m³/h.

[6] Total core bypass of 11 % plus 1 % of flow through dummy elements.

[7] Reference level of the plant measurement is 0.915 m from the pressurizer bottom.

The transient calculation was done without any severe failures as can be seen from the comparison of elapsed CPU-time versus calculated time in Figure 8.1. The reactor coolant pump which was running throughout the transient forced to use relative short time steps. Between 15 and 50 seconds the user specified maximum time step was halved due the anomalous behavior of the servo valve model (see Chapter 7.3).

5.3 Base case calculation results

The most important calculated parameters, for which also plant comparison data have been recorded, are shown in Figures 5.1 through 5.5. The calculation matches measurements qualitatively well. The quantitative agreement is also satisfactory.

Secondary circuit

The dominating factor of the transient was the cooling-down rate of the secondary circuit. As can be seen in Figure 5.3 the calculated secondary pressure agreed well with the measured pressure during the first repressurization and the following depressurization period (up to 700 s). This demonstrated that the operation of the turbine by-pass valves (as the boundary conditions) were correctly modeled. The discrepancy between calculated and measured secondary pressure after closure of the stuck open turbine by-pass valve was due to imprecise modeling rather than code errors. When the input deck was prepared the data from Figure 3.9 was supplied to simulate the operator intervention in secondary pressure control. Figure 5.3 shows that this data overestimates slightly the secondary pressure when compared to the plotter recording. The exact timing of the stuck-open turbine by-pass line closure is not known. It was also reconstructed using the secondary pressure data of Figure 3.9. The timing deviated slightly from the plotter data shown in Figure 5.3. Even if the discrepancies between calculated and measured pressure after 740 seconds are almost within uncertainty bands of plotter records, it should be remembered that these discrepancies will affect the primary side variables.

Primary circuit

The thermal hydraulic conditions on the primary side until 350 seconds were mainly controlled by heat transfer from the core and through steam generator tubes to the secondary side. Figure 5.13 shows the calculated heat transfer from the fuel rods to the primary coolant compared with the heat transfer from the primary coolant to the secondary side. The slow decrease in both curves before reactor scram was due the pump stop in the double loop. When the core flow decreased the increasing water temperature caused the reactor kinetic model to decrease power. The reactor power in the plant was also decreased, but for another reason. The power controller (ROM) was adjusting the reactor power to the level corresponding for the number of running primary coolant pumps. The calculated heat exchange through steam generators in different loops is plotted in Figure 5.12. Even though the heat transfer in other steam generators increased the decrease of about 200 MW in the double loop heat transfer rate due to the flow changes (Figure 5.11) in the primary loops was enough to change primary heat balance. This was directly responded by the increase of the primary pressure, Figure 5.1 and 5.2, and the primary mean temperature, Figure 5.4.

Pressurizer behavior during the rapid cooldown

When the triple loop pump was stopped at 16 s the heat transfer rate in the triple loop steam generator also began to decrease. At the same time the reactor was scrammed which caused a rapid cooling in the reactor core, upper plenum and hot legs, Figure 5.6. As a consequence the volume of the primary coolant decreased and forced water from pressurizer to flow to the hot leg of the double loop. Pressurizer response during the rapid cooldown was very good. Both the calculated pressures, Figures 5.1 and 5.2, and pressurizer water level, Figure 5.5, followed exactly the measured values.

Primary circuit temperatures

The agreement between the calculated and the measured primary mean temperatures from 12 s to 200 s was less satisfactory, Figure 5.4. This period was characterized by the reactor power decrease and the reversals of flows in the double and triple loops. Although the calculated average temperature of the loops was in the beginning one or two degrees higher indicating the difficulties of matching the steady state heat transfer through steam generators, the calculated mean temperature decreased too rapidly after reactor scram. Some of the difference might have been due to a time shift in the sampling rate of the measurement. When the core power had reached the decay level, Figure 5.13, the fast decrease of the calculated mean temperature ceased. The calculated curve in Figure 5.4 even showed heat-up when the reversed flow in double loop brought hot water from the pressurizer to the reactor vessel side of the hot leg. The measured values did not show any heat-up but a short plateau a little later than in the calculation. The time difference will be further discussed in the sensitivity study. Later from 200 s on when the triple loop flow was also reversed and all temperatures had reached new levels the calculated primary average temperature followed closely the measurement. After closure of the turbine by-pass line at about 740 s the difference is due the incorrect boundary values of the calculation model.

Effect of the selected nodalization on the pressurizer response

After reaching the reactor decay power level the calculated water level in the pressurizer, Figure 5.5, indicated a considerable slower cooling of the primary circuit than the measured value. This was not consistent for the primary loop mean temperature calculation which agreed nicely with the measurement from 200 s on. At 250 s the calculated and measured pressurizer water levels deviated by 0.47 m, which corresponded to a volume of 2 m^3. When the nodalization model and the water temperatures in different volumes during calculation were examined more closely, it was noted that the temperatures in the upper head volumes, Figure 5.14, were not changed. The total volume of volumes no. 5, 6, 7-1 and 7-2, where the hot initial temperature remained is 21 m^3. If it is assumed that the liquid in those volumes had also cooled down from 570 K to 530 K as the core outlet volumes show in Figure 5.15 this would give a reduction in coolant volume of 2 m^3. Based on these indications the observed inconsistency in calculated water level of the pressurizer must be regarded to result from the imprecise nodalization model. Comparison of Figures 5.14, 5.[illegible] and 5.5 further showed that up to 750 s the difference between the calculated and measured water levels gradually increased, similarly as the temperature difference between the upper head and upper plenum volumes. The nodalization of the upper head was based on the assumption that the recirculation flow through upper head is minimal. There is no measured data from the plant as well as not information from the vendor about the flows in the upper head. This calculation indicates that the model should be changed allowing some flow from the core through the guide tubes of control rods via the upper head to the upper plenum.

Primary pressure

The primary pressure, Figure 5.2, followed during the first part of the transient the cooling rate. Like the pressurizer water level the primary pressure was first in a good agreement with the measurement. The pressurizer pressure, Figure 5.1, however, was during the initial repressurization slightly overestimated. This caused even the spray valves to open, Figure 5.8, which had not happened in the plant. Later, when the water level in the pressurizer was not lowering fast enough it prevented the steam from expanding and reaching the measured depressurization.

In the calculation the heat released from the pressurizer vessel walls delayed also the progress of the primary pressure decrease. Figures 5.16 through 5.21 illustrates fluid and wall temperatures at different elevations of the pressurizer. In the top volumes, no. 370-11... -14 and 371-01, initially full of steam, the walls remained at higher steady state temperatures transferring heat to the steam. The inside wall temperatures in the middle volumes, no. 370-7... -10, were first following the saturation temperature. When liquid disappeared, the recovering heat as a result of conduction started to increase the inner wall temperature. Although the temperature difference between wall and steam and the heat transfer coefficient were low the increasing heat transfer area due the lowering liquid level enlarged slowly heat release to the steam. From about 250 seconds on this turned off the primary pressure decrease, Figure 5.1 and 5.2, regardless of the fact that the primary side was continuously cooling down and the pressurizer level was still decreasing. At 250 seconds the difference between calculated and measured primary pressure was 1.5 bar.

One hundred seconds later the difference had been doubled. When the operator first started the high capacity make-up pump TK11 and later the two high pressure safety injection pumps TJ12 and TJ51 were automatically started. The primary injection flow rate, Figure 5.9, began to dominate the primary pressure evolution and pressurizer level. After closure of the turbine by-pass line at 750 second the effect of the reduced cooling through steam generators was clearly seen as a fast repressurization rate. The repressurization rate slowed down in the calculation already before the stop of the high capacity make-up pump, which caused the measured pressure to decrease. The earlier turn in pressure is based on the wall condensation, as can be seen from Figures 5.22 and 5.23 where heat fluxes from heat structures are presented. The primary pressure and pressurizer level agreed qualitatively well with measured values. The main reason for the quantitative disagreement may be explained by the imprecise nodalization of the upper head, which was discussed earlier.

Temperature curves in Figures 5.16 and 5.17 show that after pressurizer spray actuation at about 1350 seconds the pressurizer wall temperature in the steam volumes remained higher than the steam temperature. The heat release from the walls caused faster repressurization and faster periodic operation of the spray than was measured, Figure 5.1 and 5.2.

The depressurization during the spray injection was faster than at the plant. Some of this may be explained by the larger spray flow rate. In the calculation model it was not possible to restart only one recirculation pump, as the operator did, in order to enforce the pressurizer spray. The start-up of the double loop pump at 1300 seconds raised the pressure difference over loops and made the depressurization more effective.

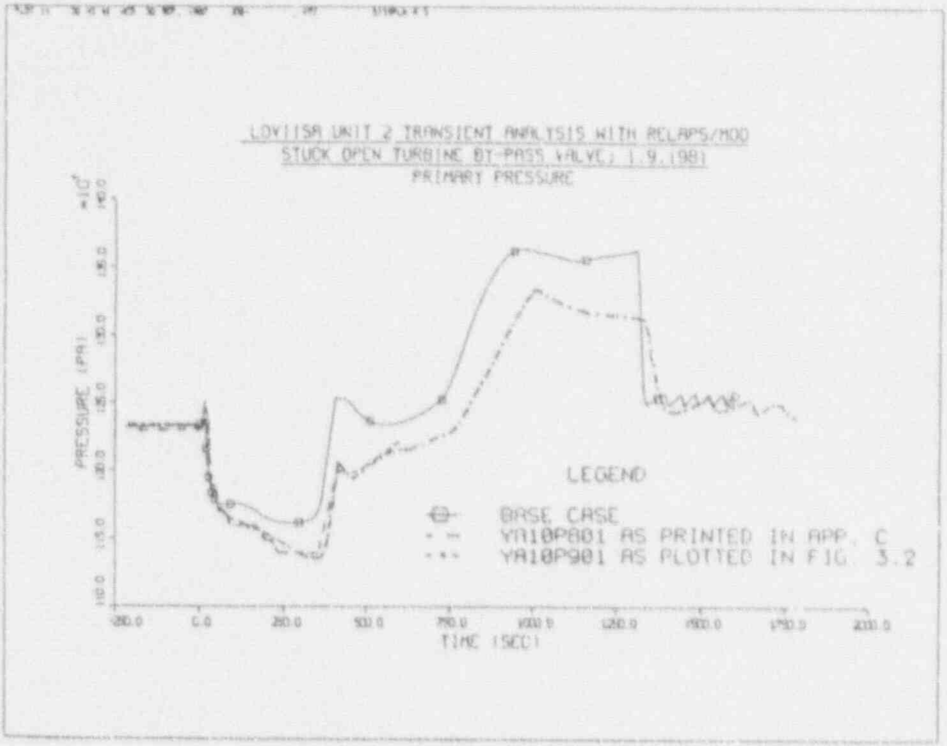


Figure 5.1 Primary pressure.

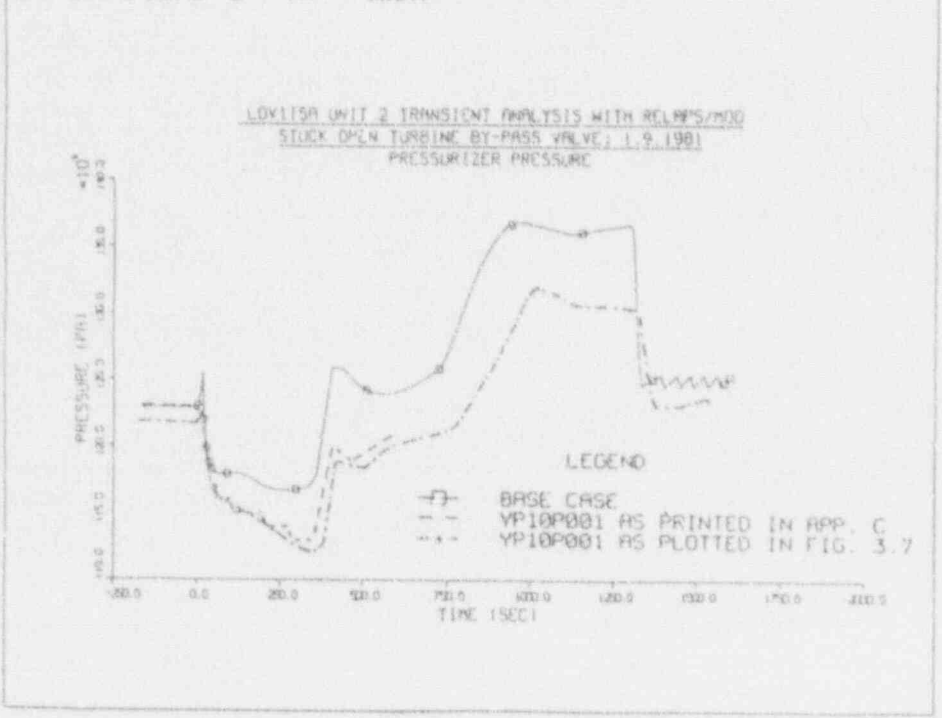


Figure 5.2 Pressurizer pressure.

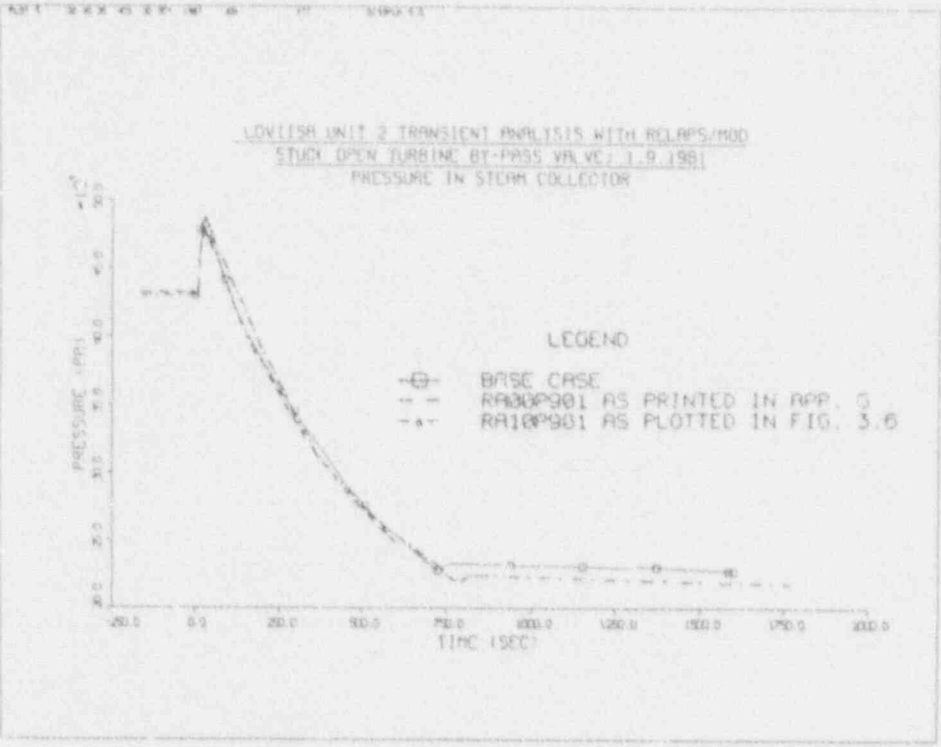


Figure 5.3 Secondary pressure.

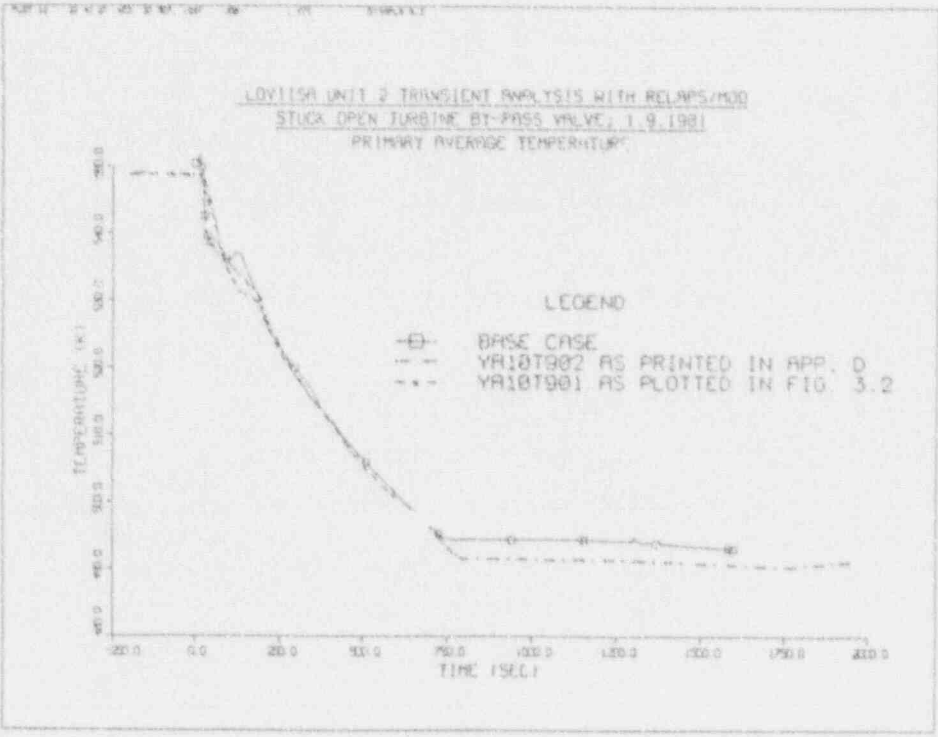


Figure 5.4 Mean temperature of primary loops.

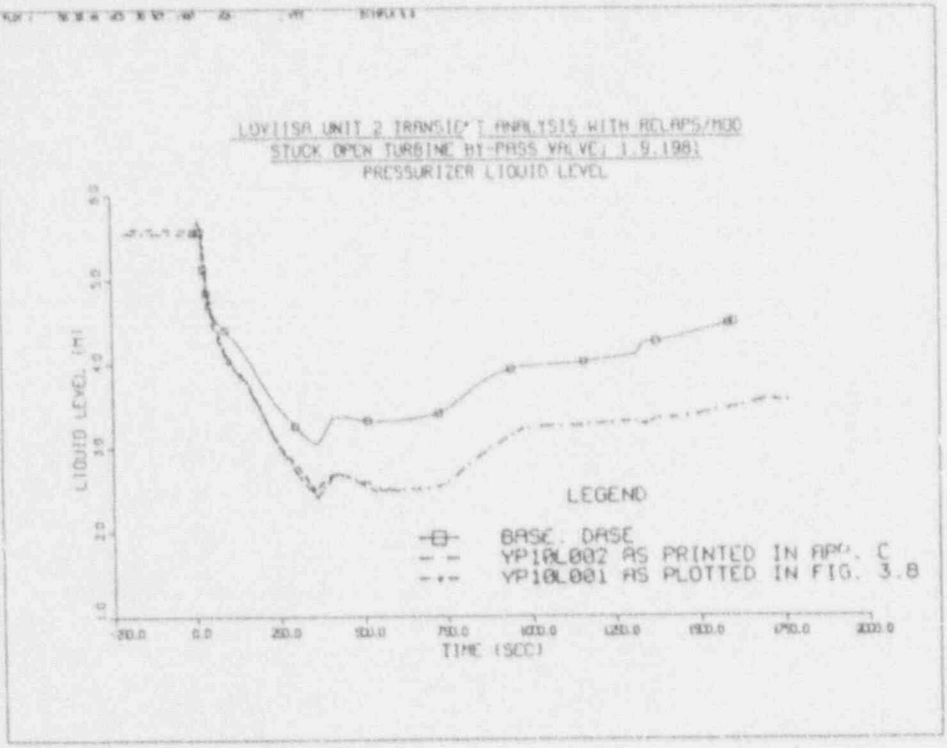


Figure 5.5 Pressurizer water level.

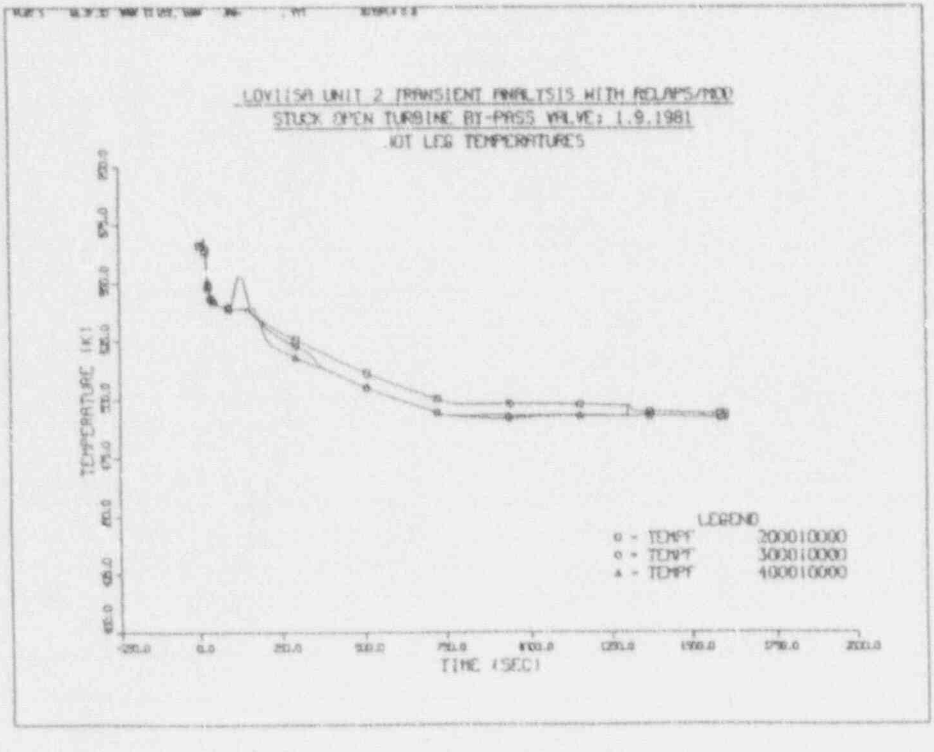


Figure 5.6 Hot leg temperatures of primary loops.

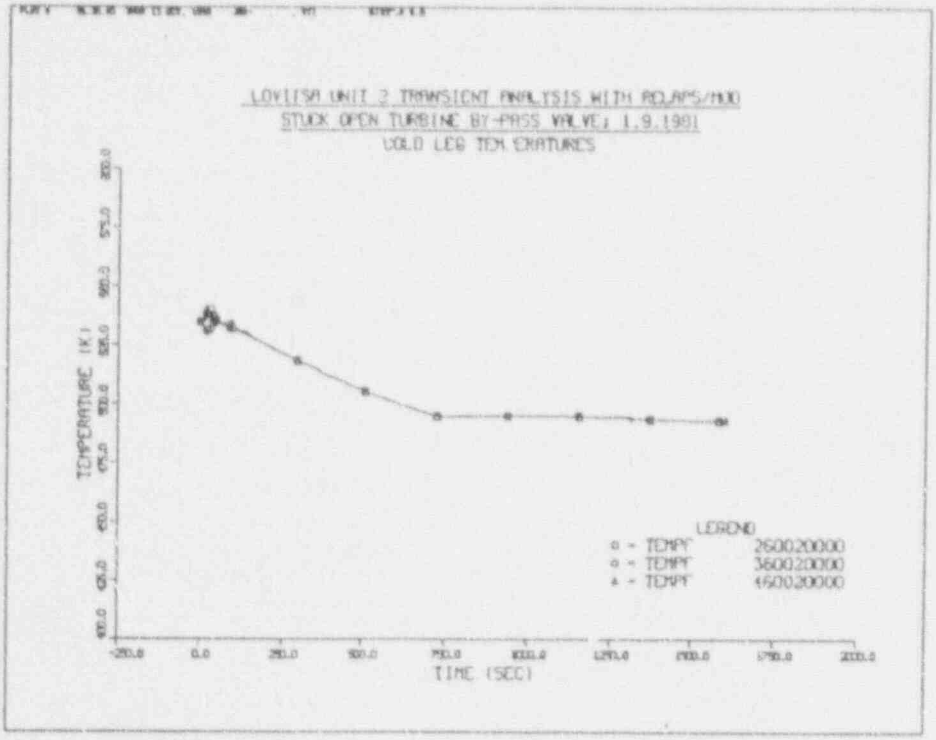


Figure 5.7 Cold leg temperatures of primary loops.

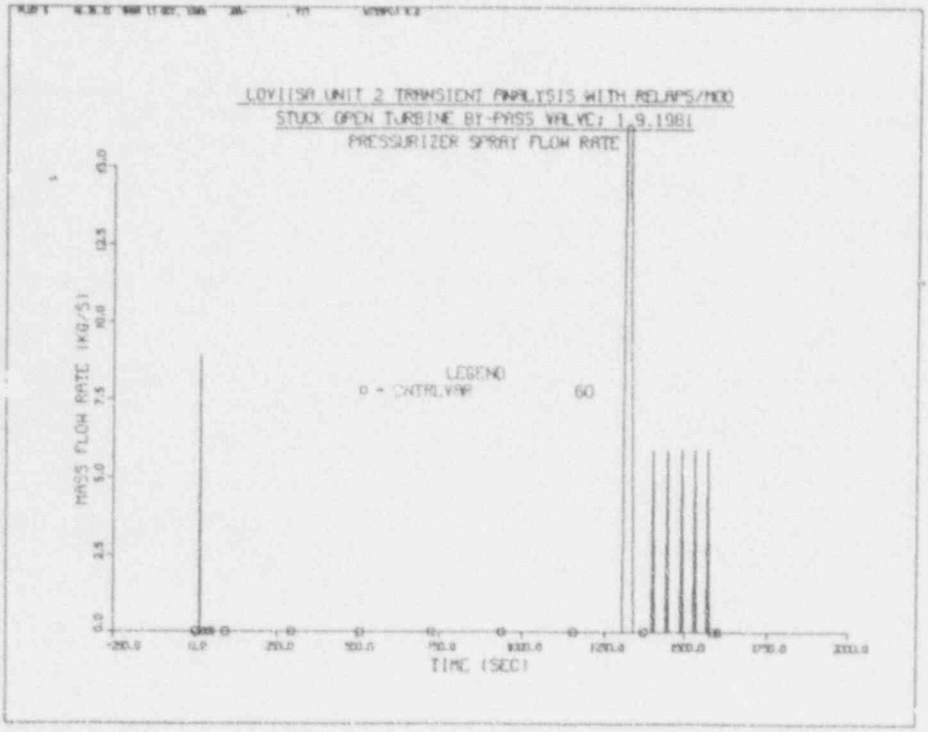


Figure 5.8 Pressurizer spray mass flow rate.

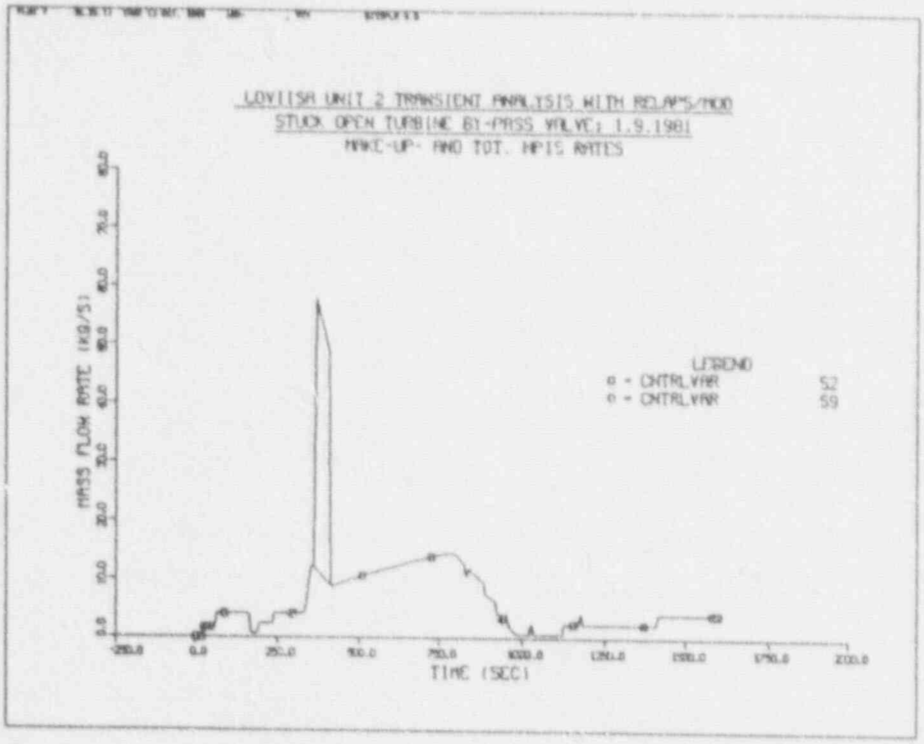


Figure 5.9 Make-up and safety system injection mass flow rates.

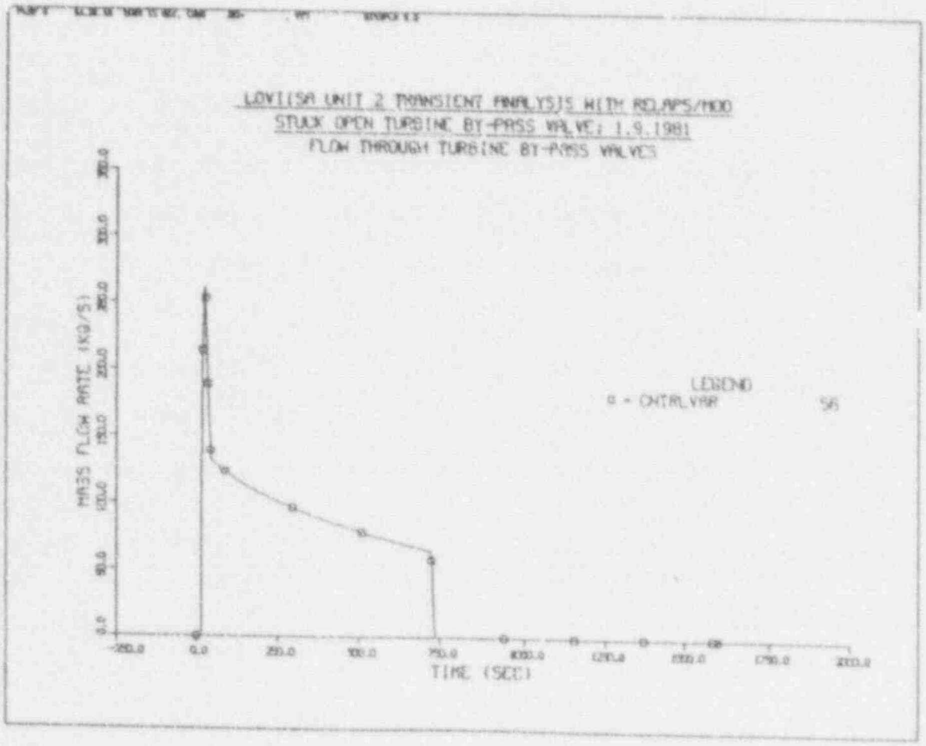


Figure 5.10 Mass flow rate through turbine by-pass valves.

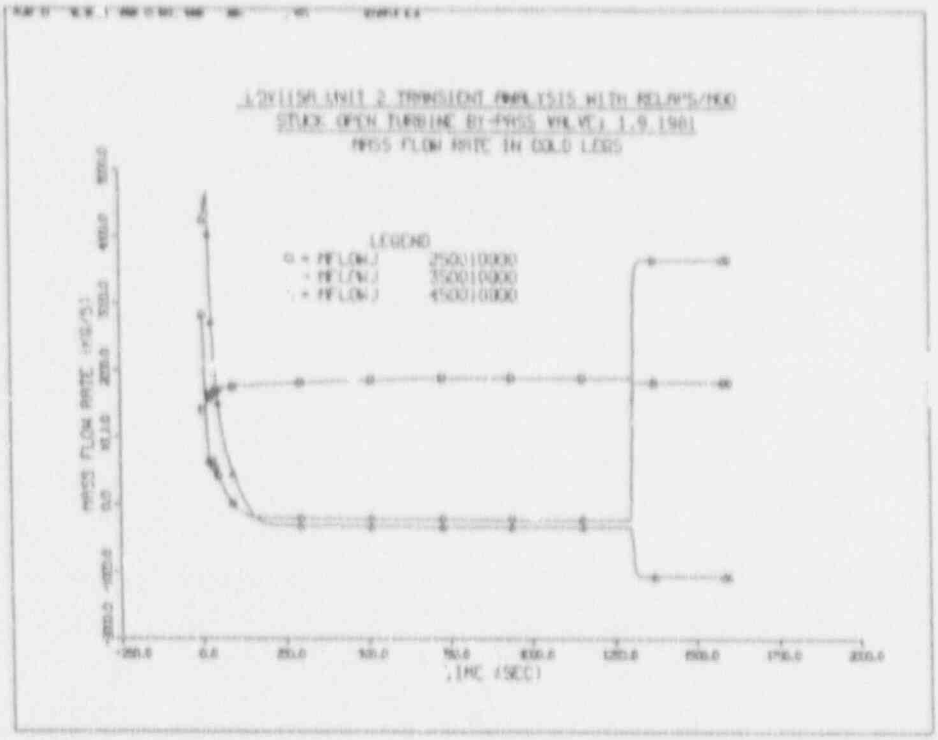


Figure 5.11 Primary loop cold leg mass flow rates.

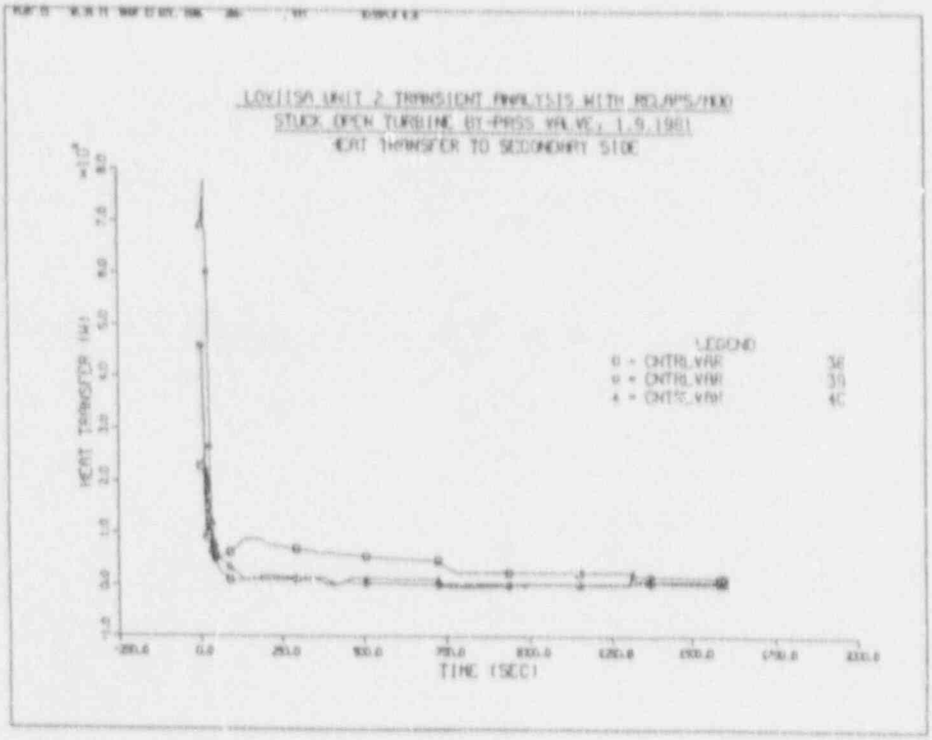


Figure 5.12 Heat transfer through steam generators in different loops.

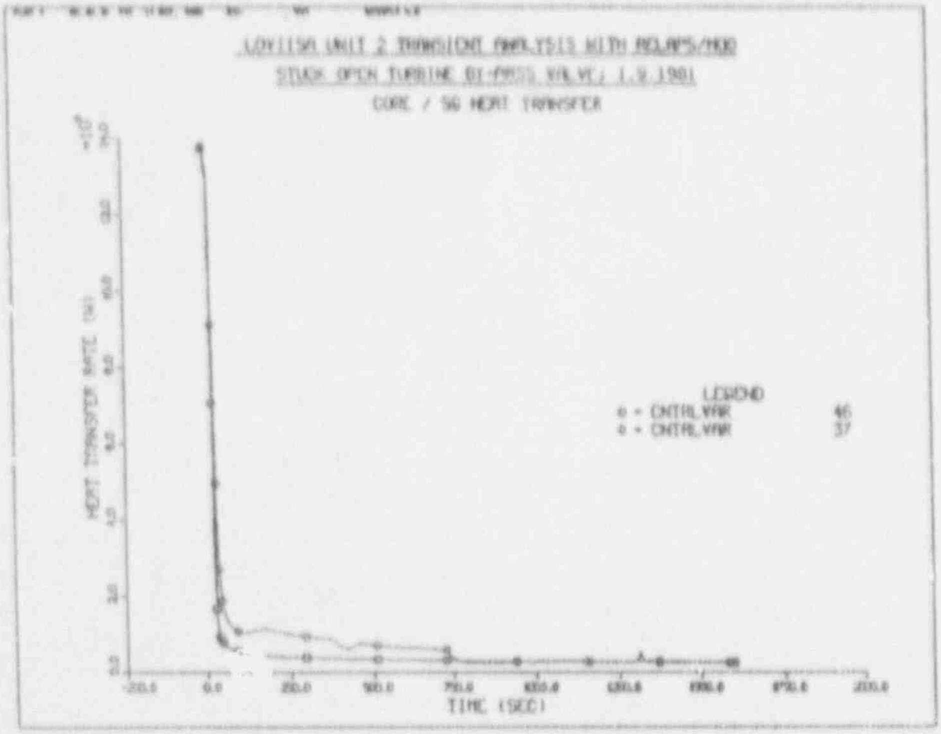


Figure 5.13 Core heat release compared to heat transfer from primary to secondary.

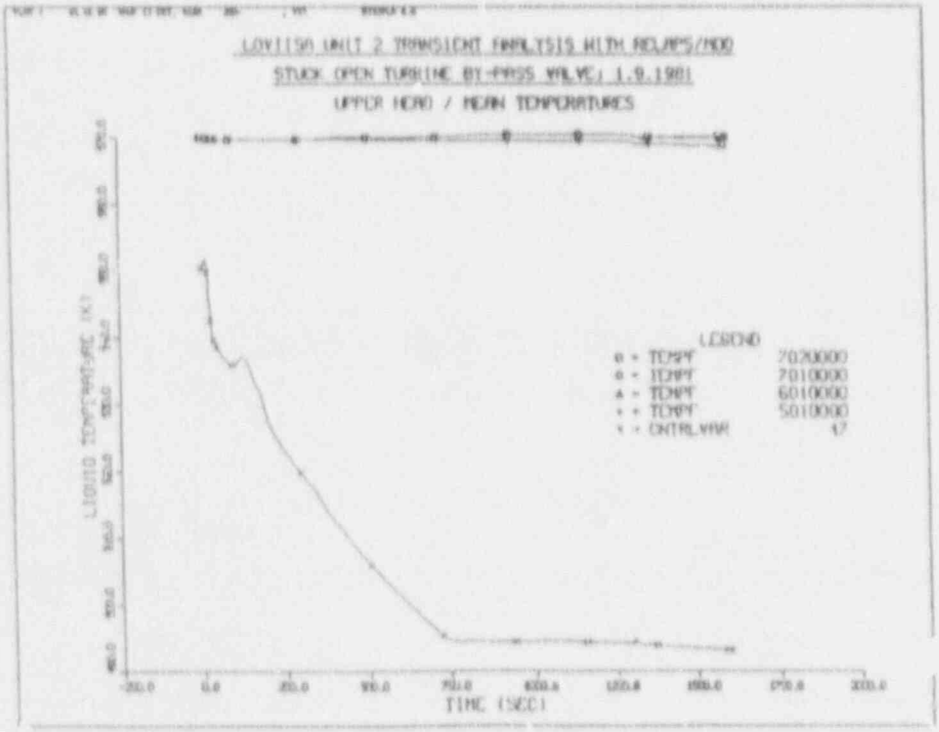


Figure 5.14 Upper head temperatures compared to mean loop temperature.

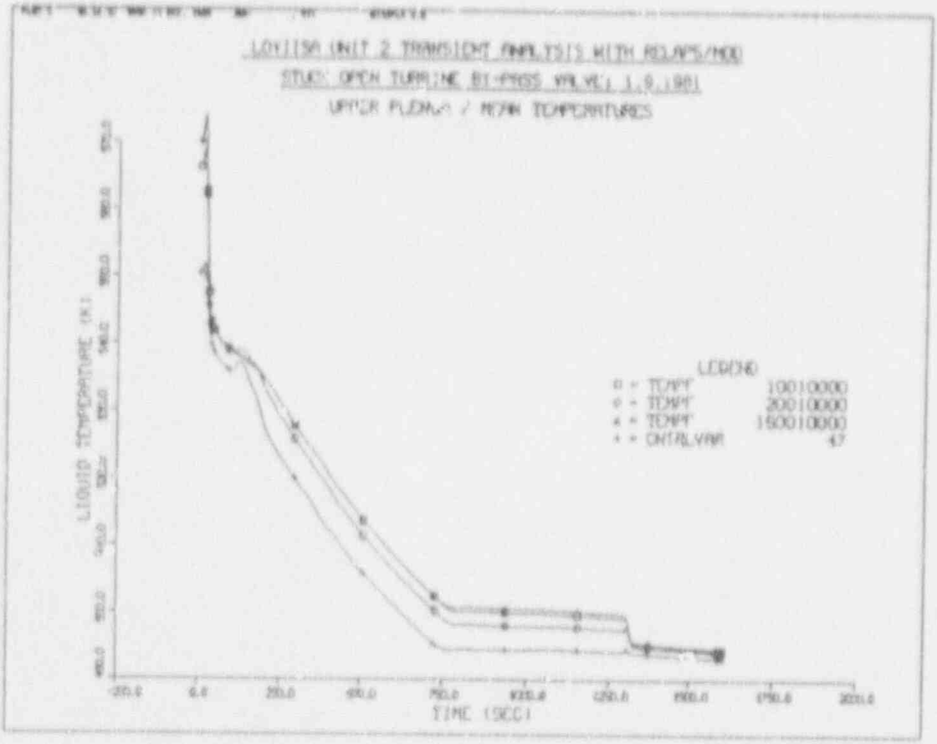


Figure 5.15 Upper plenum temperatures compared to mean loop temperature.

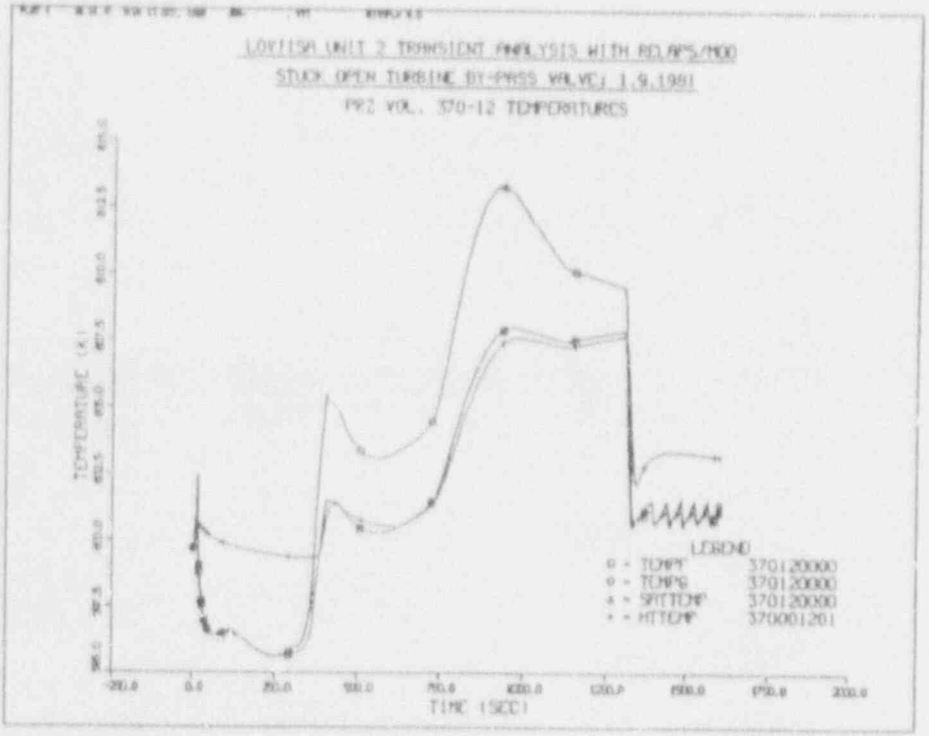


Figure 5.16 Fluids, saturation and wall temperatures in pressurizer volume 370-12.

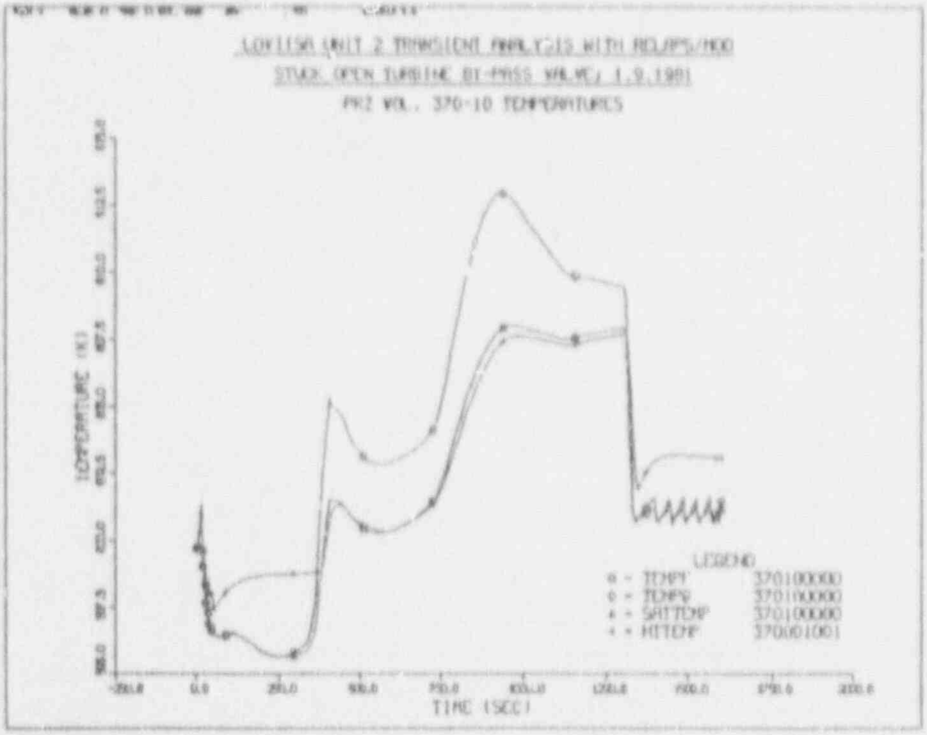


Figure 5.17 Fluids, saturation and wall temperatures in pressurizer volume 370-10.

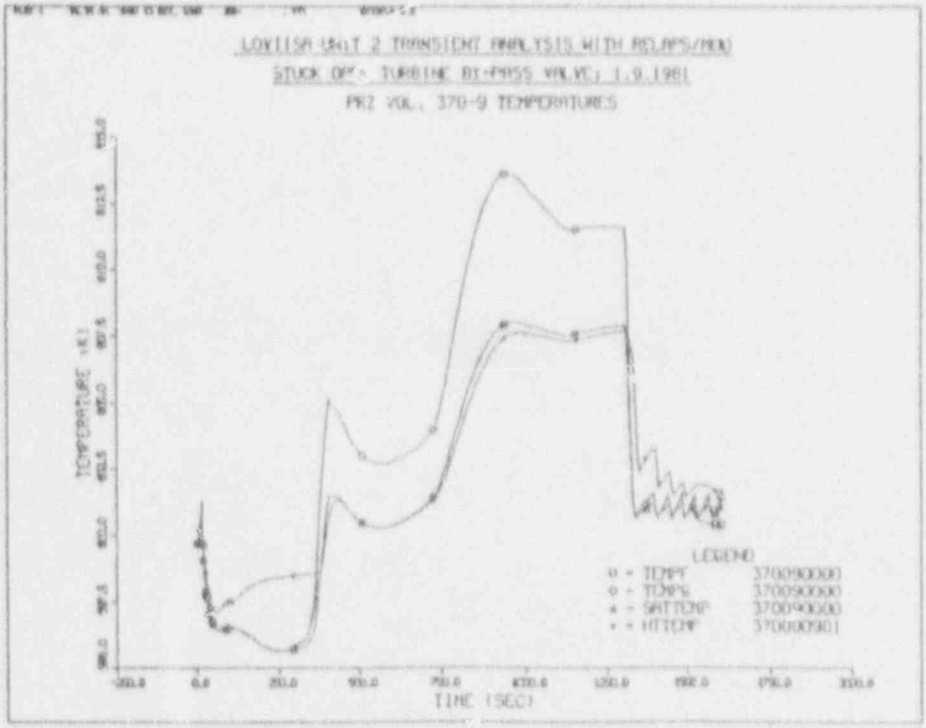


Figure 5.18 Fluids, saturation and wall temperatures in pressurizer volume 370-09.

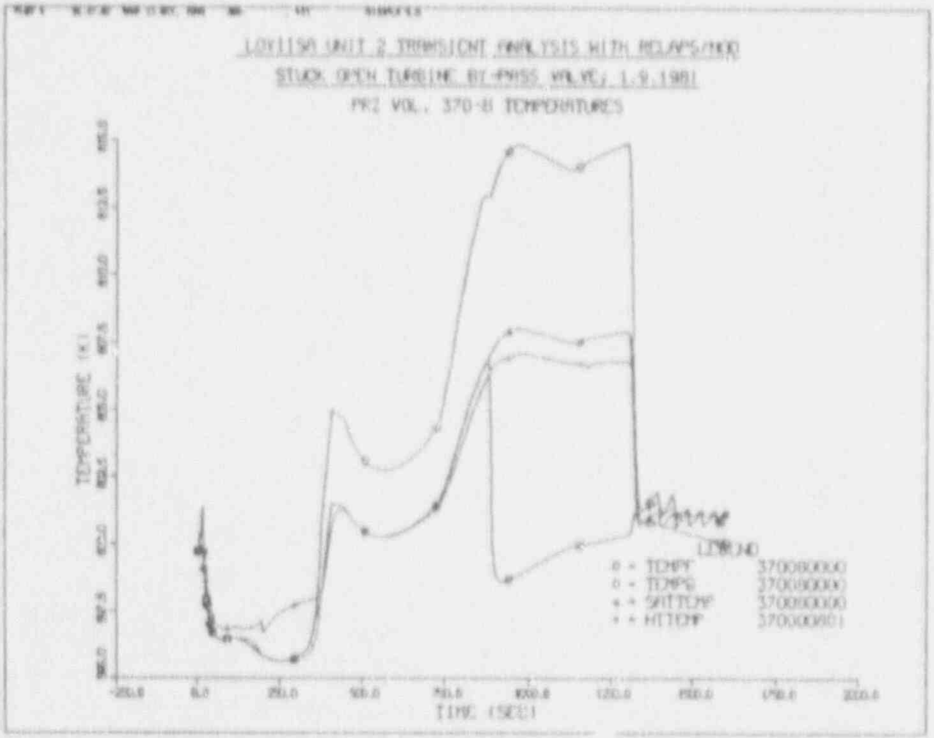


Figure 5.19 Fluids, saturation and wall temperatures in pressurizer volume 370-08.

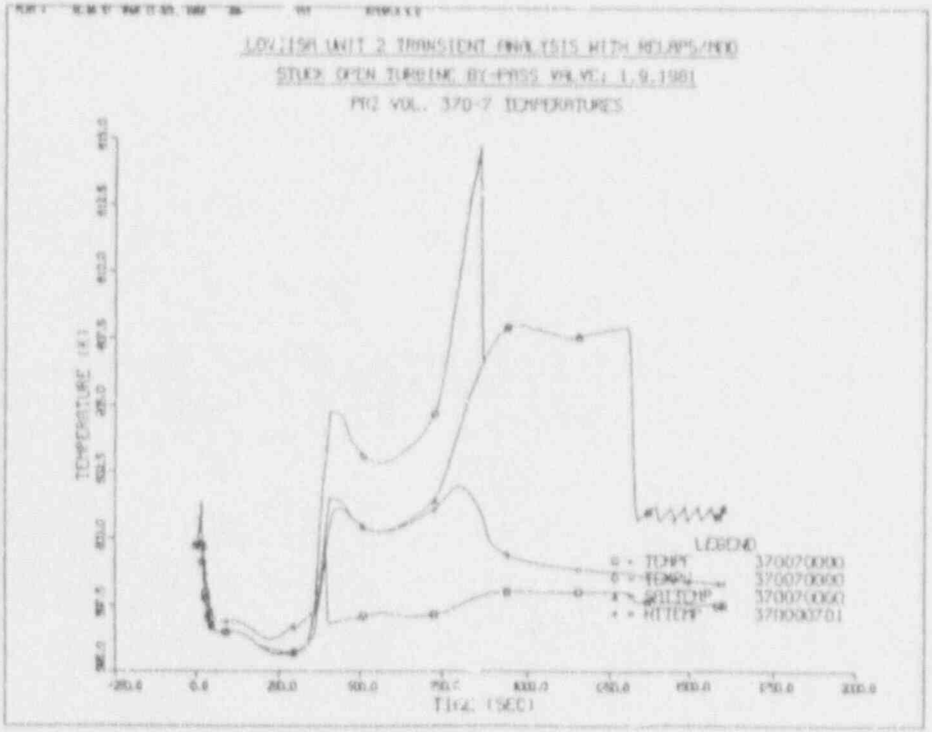


Figure 5.20 Fluids, saturation and wall temperatures in pressurizer volume 370-07.

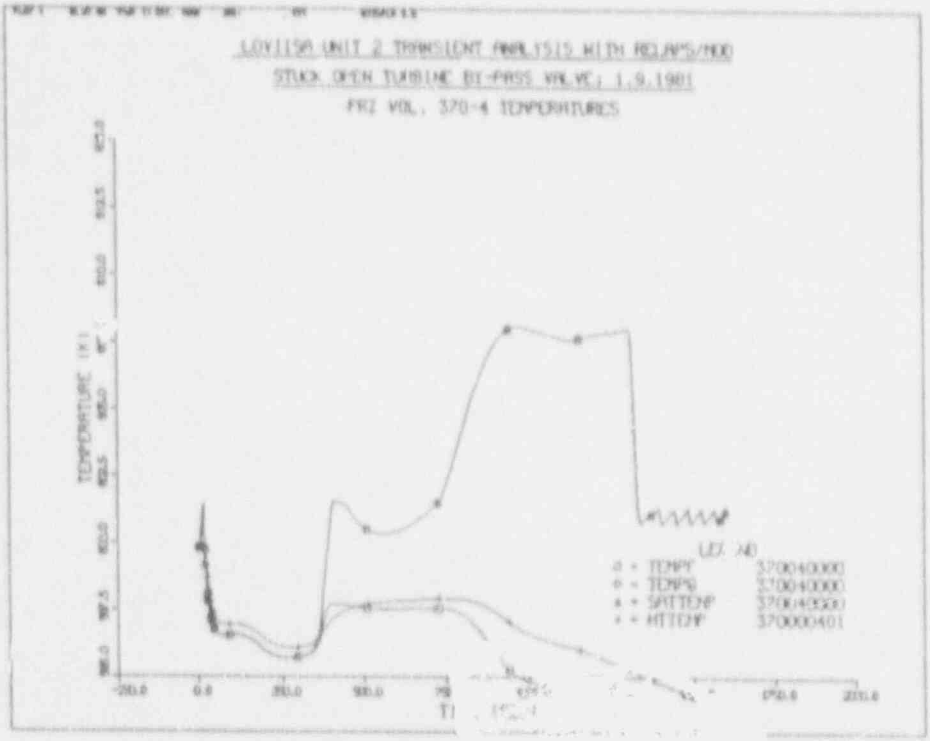


Figure 5.21 Fluids, saturation and wall temperatures in pressurizer volume 370-04.

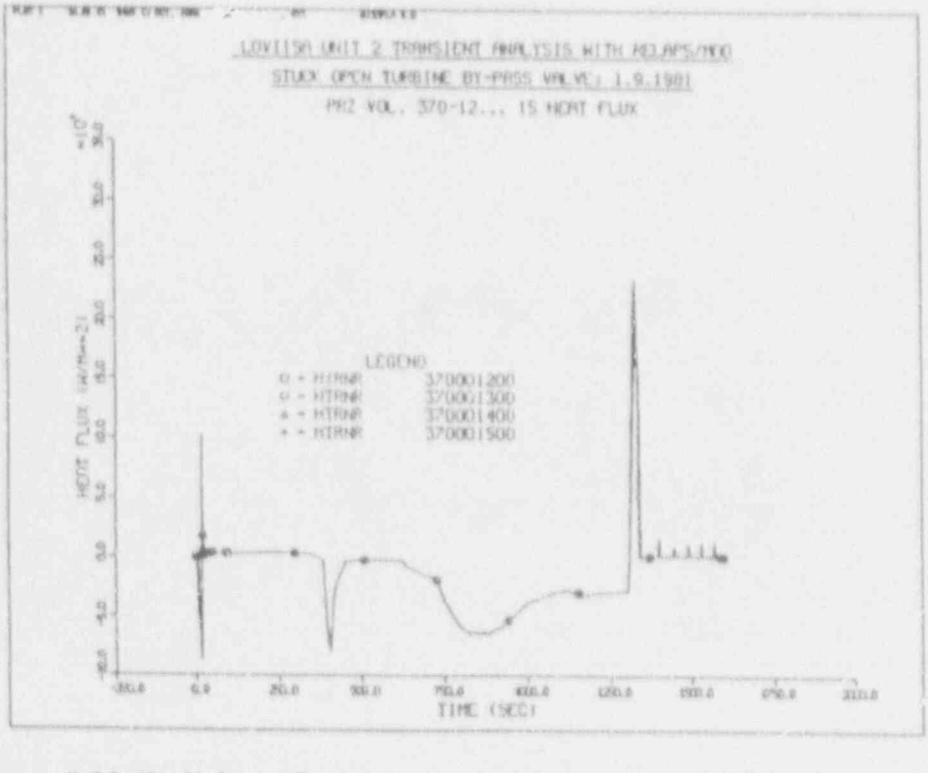


Figure 5.22 Wall heat fluxes in pressurizer volumes 370-12...371-01.

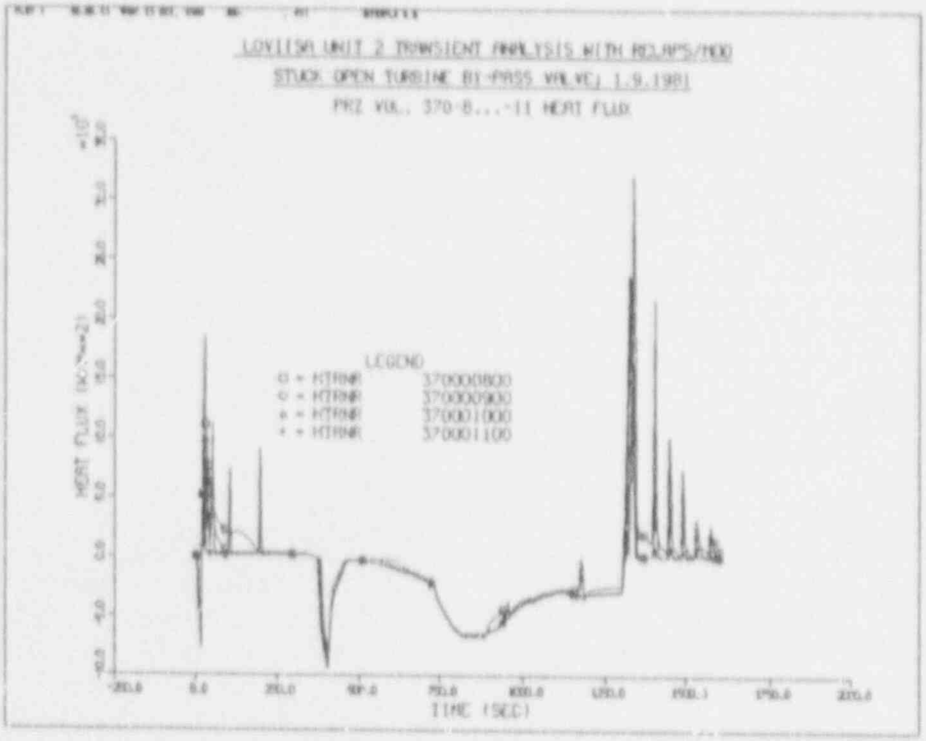


Figure 5.23 Wall heat fluxes in pressurizer volumes 370-08...-11.

6. DISCUSSION OF THE BASE CASE RESULTS

The base case calculation agreed well with the main parameters of the available plant data, in particular if the general tendencies were examined. Quantitatively the biggest differences were in the pressurizer water level and the primary pressure. The reason for those discrepancies originated from the imprecise nodalization model as described in the previous chapter.

The calculation clarified the behavior of the pressurizer and the pressurizer spray line that cannot be determined completely from the available information of the plant data. It has been speculated if water was injected into the pressurizer causing the stop of the repressurization at about 1000 s. Although the spray line valves were open there should not have been any spray as only one primary coolant pump was running. On the other hand some water may have been left in the lines, leaking out after opening manually the closed pressure control valve. This might have disturbed the stratified layer and caused stronger condensation in the pressurizer. The calculation verified that the condensation at the pressurizer walls was alone enough to cease the primary repressurization and no spray was needed. This expresses the importance of the modelling of the pressurizer vessel wall as heat structures in order to correctly simulate the pressurizer behavior.

A closer examination of the RELAP5 simulation showed that the temperature of vapor in that pressurizer volume, where both liquid and vapor were present, experienced anomalous behavior. During the fast insurge the whole steam bubble was superheated and the steam temperatures in all volumes containing steam stayed above saturation temperature until the spray was actuated. The vapor in the volume, where water level was situated, was superheated faster than in the volumes above it, as shown in Figure 6.1. Between 1000 and 1300 seconds steam temperature in the volume 370-08 was higher than in the volume 370-12, even though the amount of heat extracted from the steam phase of the volume 370-08 exceeded considerable that of the volume 370-12, Figure 6.2.

Thus the higher superheating in the volume 370-08 cannot be understood otherwise than whether the energy equation of the steam phase or the interfacial heat transfer between phases was misinterpreted and heat was transferred from a lower temperature to a higher temperature. Based on the calculated velocity data it is evident that the volume should also have been met the vertical stratification conditions. However, the plotted values of the calculated volume flow regimes in Figure 6.3 do not show any indication of stratified flow. The vertical stratification, when experienced, should also have its effect on both the interfacial and wall heat transfer coefficients. The calculated vapor void fractions of the volumes discussed are shown in Figure 6.4.

When the results of the comparison study are analyzed for qualitative and quantitative assessment one should still remember that some of the actuation control logic in the input model was replaced with actuation signals measured during the incident at the Loviisa plant. This was based on the judgement that the effect of the threshold phenomena, which could change remarkably the later behavior, should be minimized.

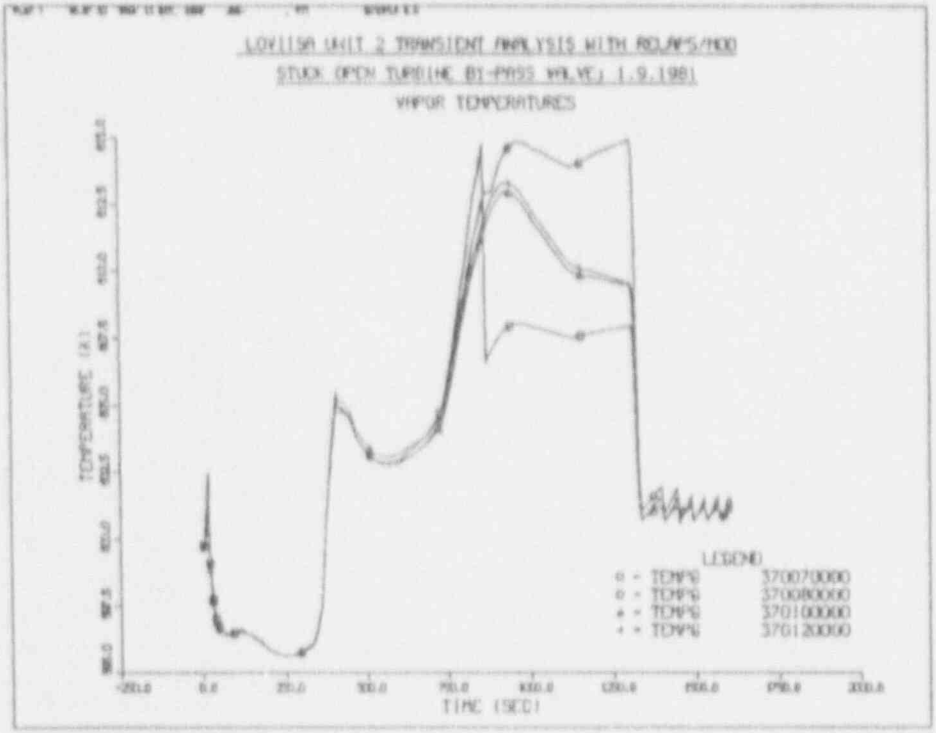


Figure 6.1 Steam temperatures in pressurizer volumes 370-07, -08, -10 and -12.

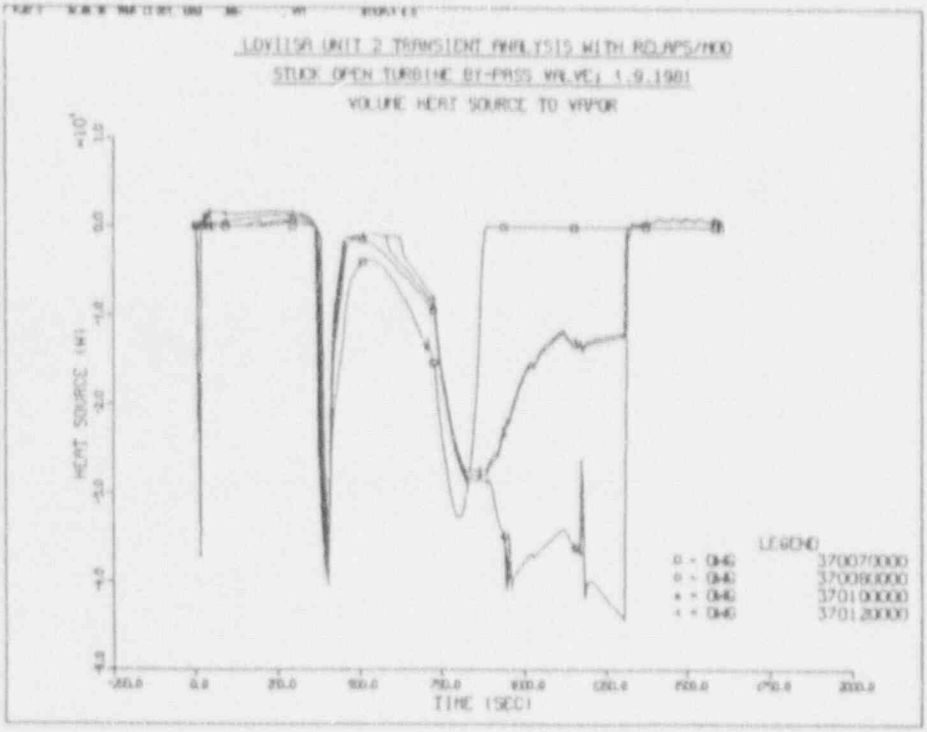


Figure 6.2 Heat source to vapor in pressurizer volumes 370-07, -08, -10 and -12.

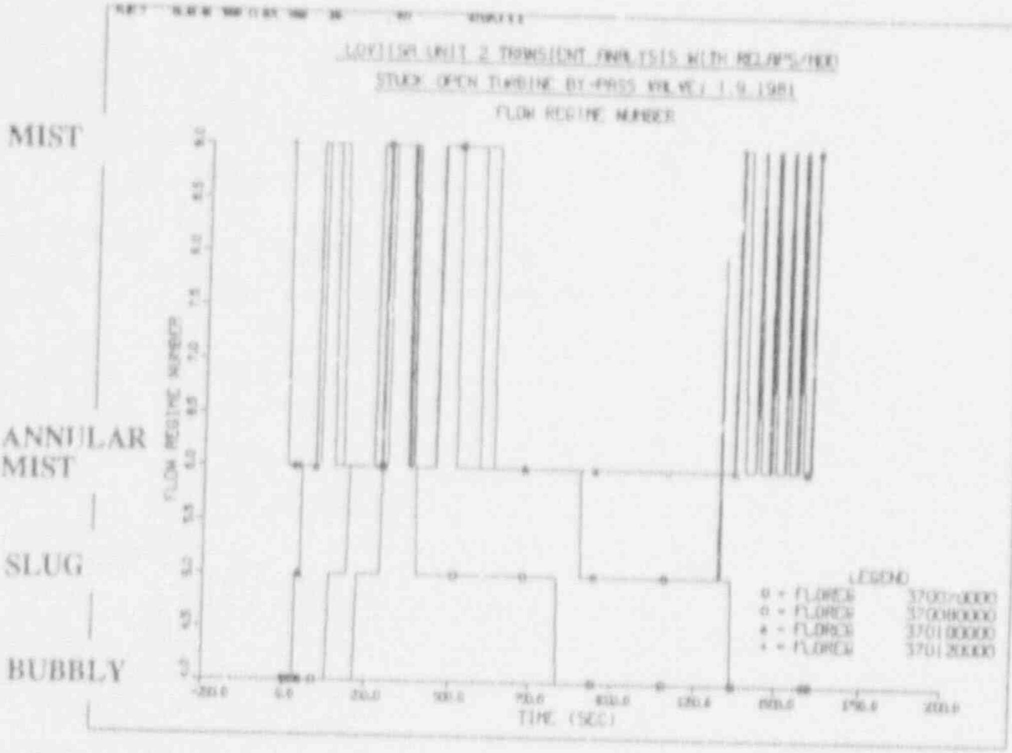


Figure 6.3 Flow regimes in pressurizer volumes 370-07, -08, -10 and -12.

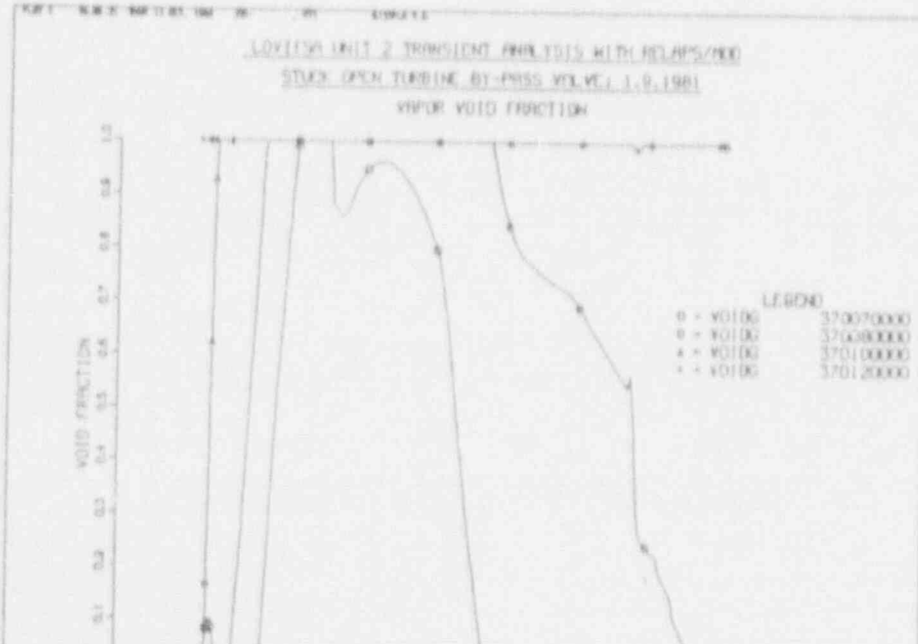


Figure 6.4 Vapor void fractions in pressurizer volumes 370-07, -08, -10 and -12.

7. SENSITIVITY STUDY RESULTS

Although the base case calculation matched qualitatively well the transient data a better prediction was desired. Before the nodalization deficiency, which is believed to cause most of the differences as reported in the chapter 5.3, was discovered some sensitivity studies were performed. In this chapter two of them having a wider interest for code assessment are discussed. Also a description of the incomplete function of the servo valve model is included.

7.1 Sensitivity of initial conditions

The initial conditions of the plant are a source of uncertainty regarding the calculation. Although the nuclear power plants are usually generating the base load and they are operating in steady conditions these may vary from the nominal conditions. Also the plant may initially be in a slight transient. More assumptions have to be made in a real plant transient calculation than in a calculation of plentiful instrumented test facilities.

When the incident started at the LOVIISA Unit 2 it was operating at conditions slightly different from nominal ones which are usually supplied for accident analysis. Thus a comparison run with nominal values was done in order to determine the effect of differences in initial conditions.

Figures 7.1.1 through 7.1.4 show the comparison of the calculated main parameters with measurements. The overall course of all these hydraulic quantities is very similar to the base case calculation.

The calculated primary hot leg pressure, Figure 7.1.1, underrates the measured value between 50 and 350 seconds, partly due to the too low initial value of the primary pressure. However, during the rapid cooldown period, after the reactor trip, pressure decreased a little faster than in the base case calculation. The difference of pressure between the sensitivity study and the base case calculation, which initially was 1.75 bar, increased to 3 bar. This is explained by the higher initial mean temperature of the primary system in the sensitivity study.

After the reactor trip the mean primary temperature started to decrease towards the secondary saturation temperature. The cooling rate was controlled by the primary to secondary heat transfer. Because one reactor coolant pump was running all the time cooling was effective and new temperature levels were achieved quickly. In spite of the different initial values the secondary pressure excursion was almost equal in both calculations (Figure 7.1.2). Thus the primary mean temperature approached the similar course of the secondary saturation temperature as in the base calculation that can be seen in Figure 7.1.3. The deeper cooldown until 50 seconds due to the higher initial mean temperature decreased more the volume of the primary liquid, which was responded by the pressurizer water level (Figure 7.1.4). Therefore the pressurizer level gave better comparison with the measurement than the basic calculation, but for the wrong reason.

7.2 Sensitivity of primary loop flow rates.

Similar differences between the measured and calculated primary fluid mean temperature were seen both in the base case, Figure 5.4, and in the previous calculation, Figure 7.1.3. The calculated mean temperature showed a clear heat-up period after the initial cooldown due to the reactor trip, but there was no sign of reheating in the measured primary mean temperature. It experienced a short discontinuity between the initial and later cooling periods, but somewhat later than the calculated heat-up. Because the behavior of the calculated mean temperature could not be explained solely by the possible differences between the places where temperatures are measured and calculated the loop flows were examined more closely.

During the incident one primary coolant pump was tripped immediately and four others 16 seconds later. The code nodalization model used did not allow the true simulation of the pump stops. In the base calculation the double loop pump was stopped in the beginning and triple loop pump 16 seconds later. In order to see the effect of this difference a comparison run was done, where both the double and triple loop pumps were stopped 16 seconds from the beginning. The single loop pump was running all the time as in the base case. The results are shown in Figures 7.2.1 through 7.2.4.

The comparison did not show a far better agreement than the base case calculation. The heat-up period of the calculated primary mean temperature was moved forwards, but the spike still remained as shown in Figure 7.2.3. The immediate cooling rate after the reactor scram was also too fast, as in the base case. Several reasons may have been involved. One was the initially too high primary mean temperature, which resulted from the difficulties in the steam generator modelling. When the flows in five loops were settled also the temperature difference between primary and secondary diminished. As a result from the higher initial mean temperature the decrease to the final value was larger. A probably more obvious reason was too fast slowdown of the primary coolant pumps. The input deck preparation had included a comparison run with the pump stop start-up commissioning test, but in this test all pumps were stopped at the same time. Also one source may be the hot water that remained unmixed with the core outlet water in the upper head volumes as discussed in the chapter 5.3. One should not forget, that the three-dimensional flow conditions, which obviously become more important when asymmetrical loop flows are experienced cannot hardly be modelled with one-dimensional codes.

The overall course of pressures, Figures 7.2.1 and 7.2.2, and pressurizer water level, Figure 7.2.4, were exactly the same as in the base case. Only the short spikes due to the decrease of heat transfer in the double loop steam generator seen in the curves of the base calculation were missing.

7.3 Sensitivity of servo valve model on the time step size.

When the calculations were run an abnormal behavior of the servo valve model and the attached control variable was discovered. The servo valve was used to simulate the three turbine by-pass valves that operated correctly during the transient.

In the standard set of plots the anomaly was first observed in Figure 7.3.1 by a considerable higher mass flow rate out from the secondary. However, the secondary pressure in Figure 7.3.2 seemed only slightly exceed the opening pressure of the turbine by-pass valves, which should correspond to a net mass flow rate of only somewhat more than the capacity of the one stuck open valve. In order to save the file space and to prevent the possible abortion of the computer run due the file overflow all calculated points can usually not be saved. When the calculation was rerun with values of each time step stored it was found out that the points plotted in Figures 7.3.1 and 7.3.2 were only envelopes of the real behavior. Figures 7.3.3 and 7.3.4 show the short term plots of the servo valve mass flow rate and the secondary pressure, where sharp oscillations can be seen.

No real explanation for the oscillations were found. Some runs were done with changes in the geometry and the numbering of the nearby secondary volumes, but without any change in valve model operation. Only modification of the time step size was noticed to alter the behavior of the servo valve model. The calculation shown in Figures 7.3.3 and 7.3.4 used a requested maximum time step of 0.1 second. In Figures 7.3.5 and 7.3.6 the same variables from a run with the requested time step halved are presented. The reduction of the time step size made the oscillations to disappear. However, there were earlier runs only with slightly different initial values where the valve model seemed to function properly when longer time steps were used throughout the transient. The correct valve operation could not be assured, because not all calculated points were recorded in the earlier runs.

The base case calculation described in chapter 5.3 was done with reduced requested maximum time step (0.05 s) between 15 and 50 seconds in order to guarantee the correct function of the servo valve model. The material Courant limit between this period was just over 0.1 second that would have allowed the use of maximum time step of 0.1 second.

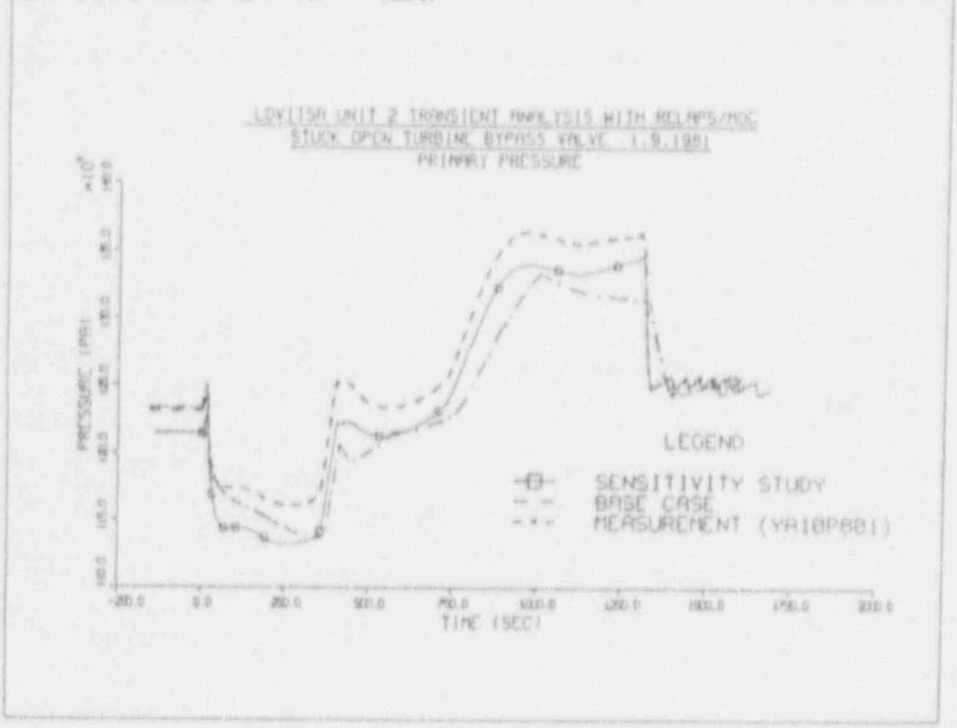


Figure 7.1.1 Primary pressure.

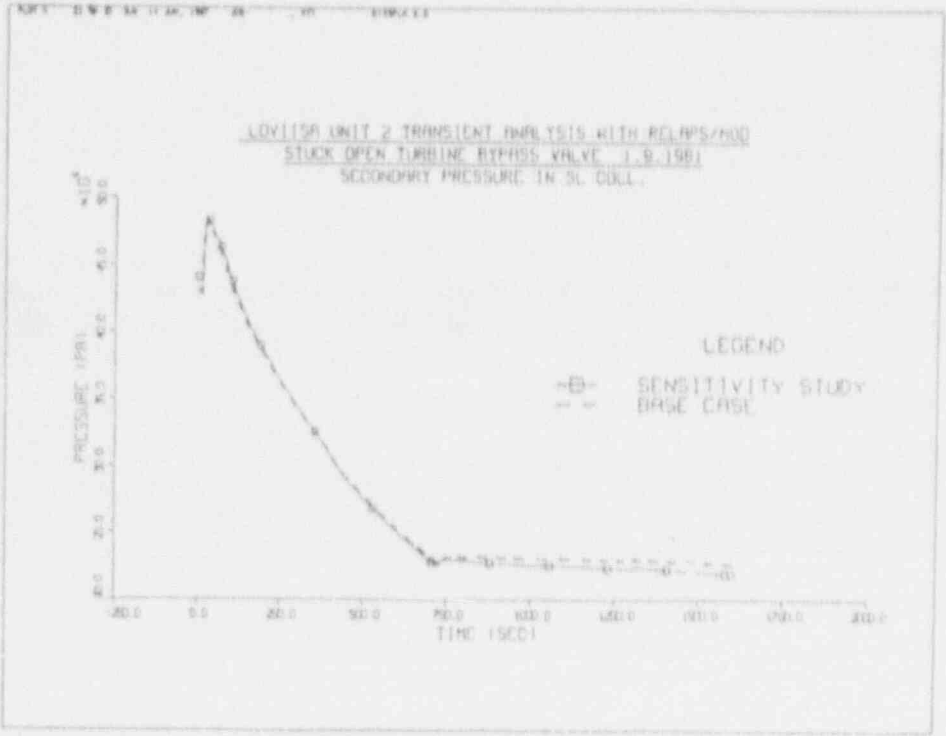


Figure 7.1.2 Secondary pressure.

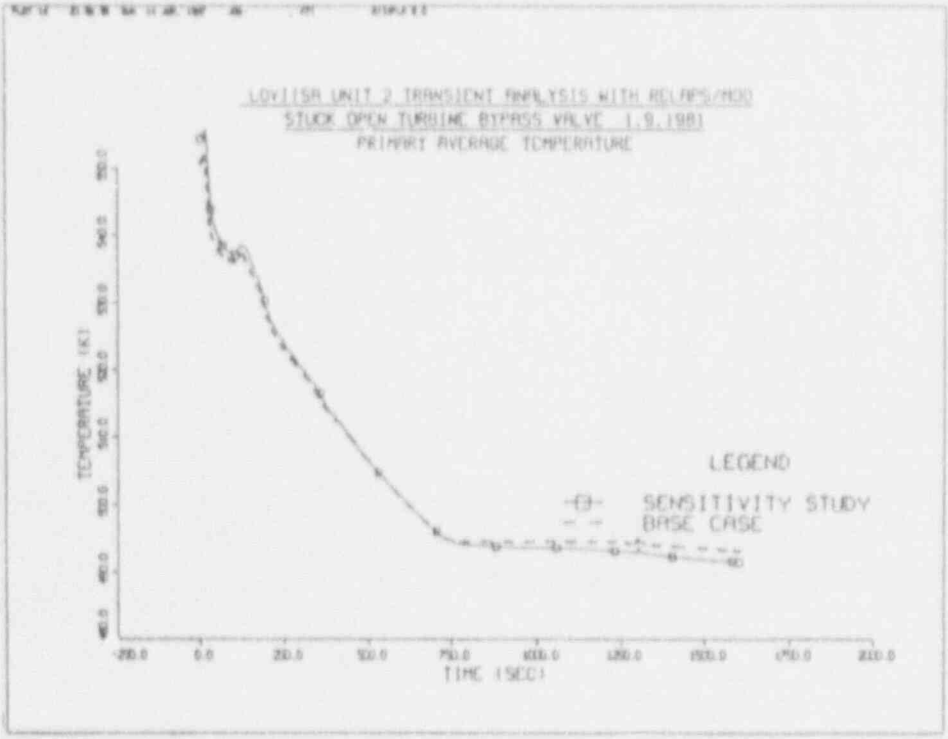


Figure 7.1.3 Primary loop mean temperature.

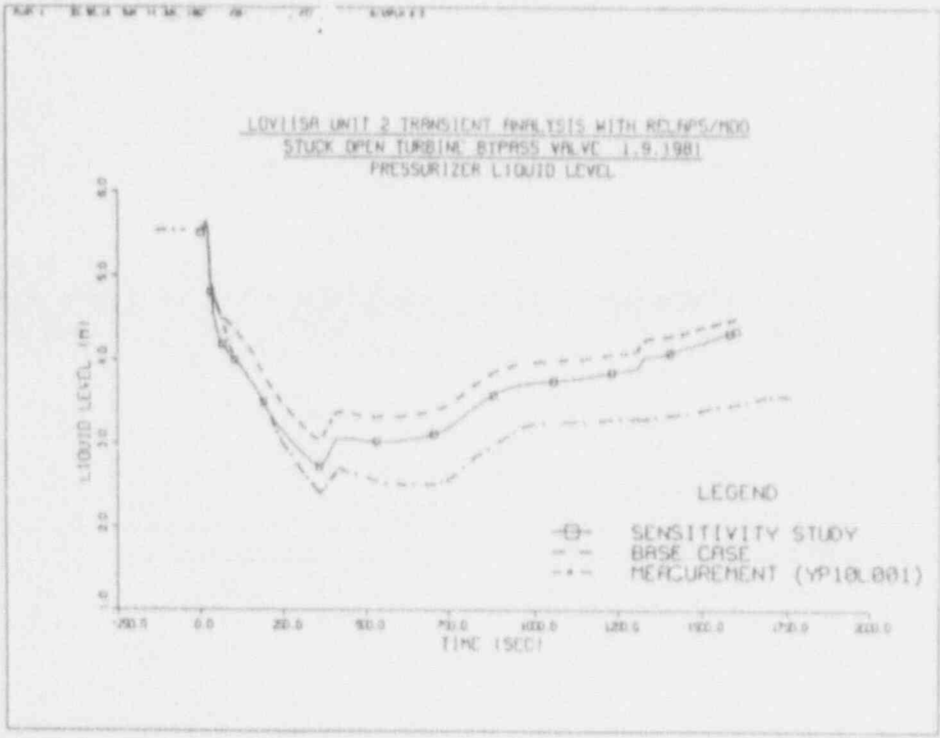


Figure 7.1.4 Pressurizer water level.

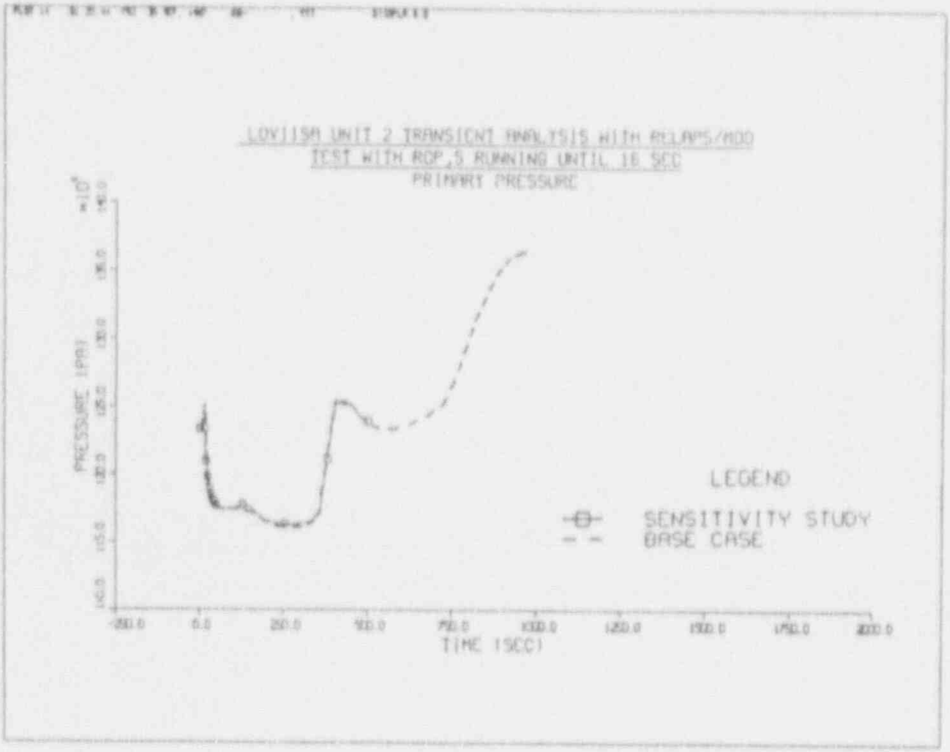


Figure 7.2.1 Primary pressure.

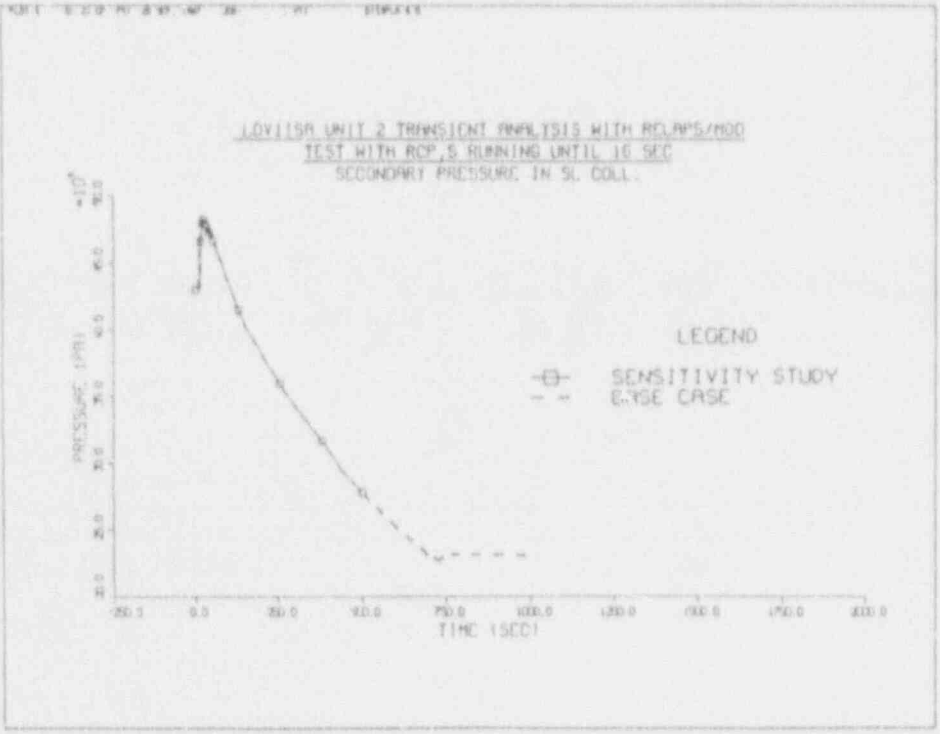


Figure 7.2.2 Secondary pressure.

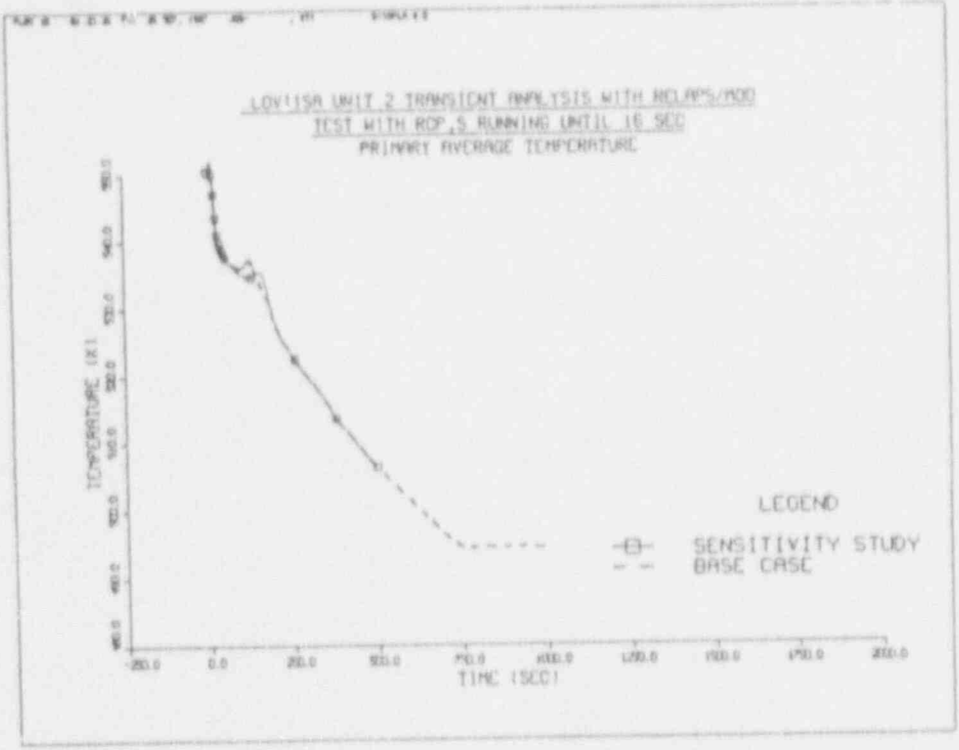


Figure 7.2.3 Primary loop mean temperature.

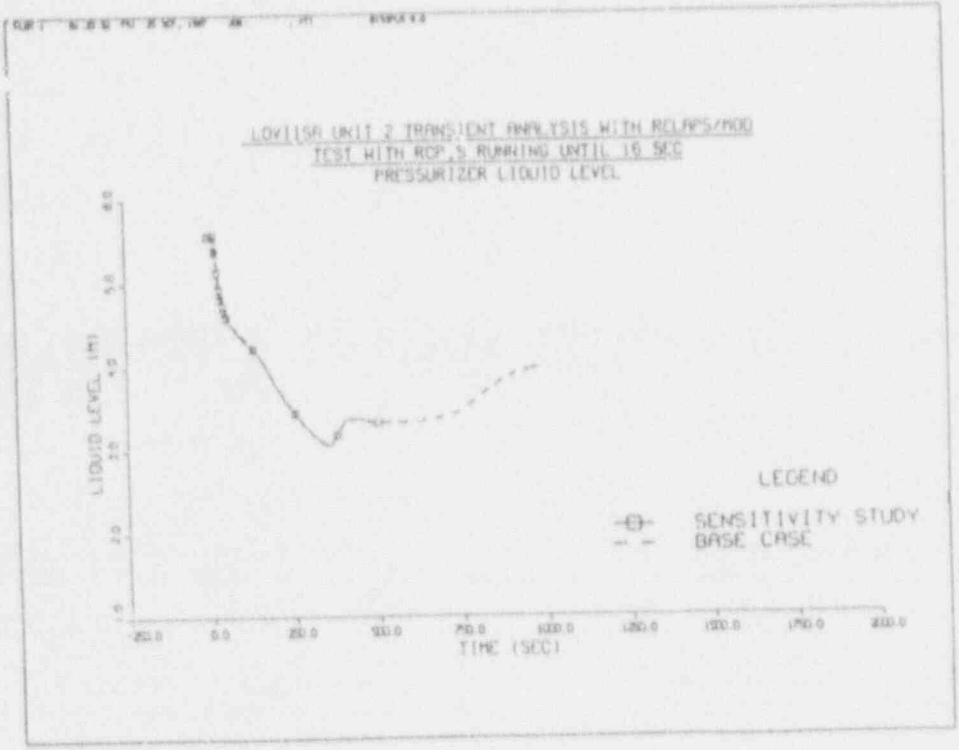


Figure 7.2.4 Pressurizer water level.

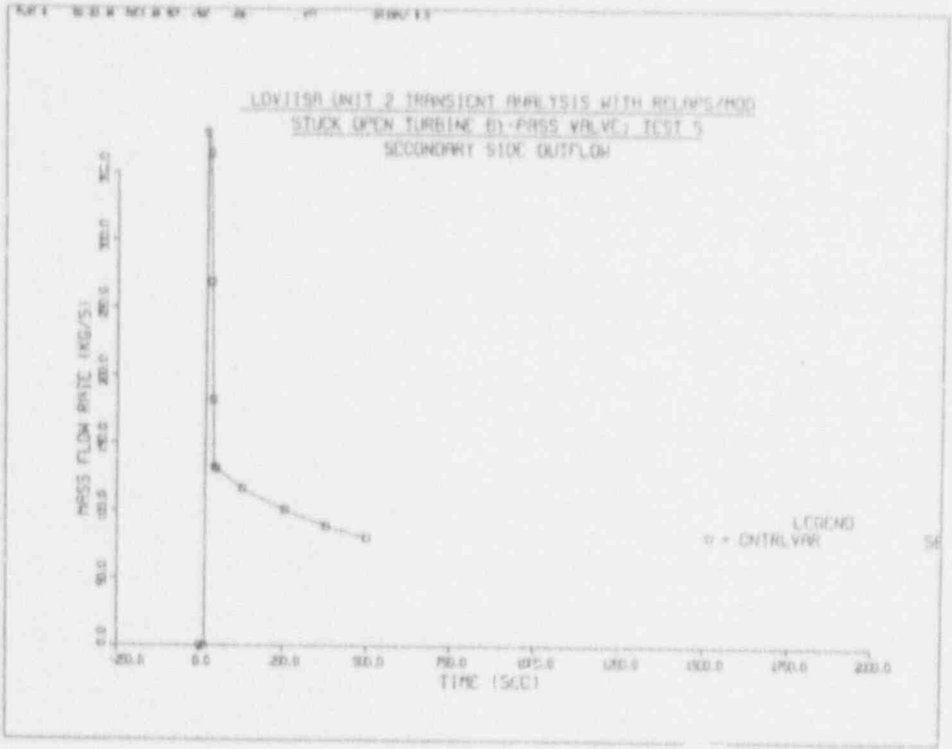


Figure 7.3.1 Mass flow rate through turbine by-pass valves.

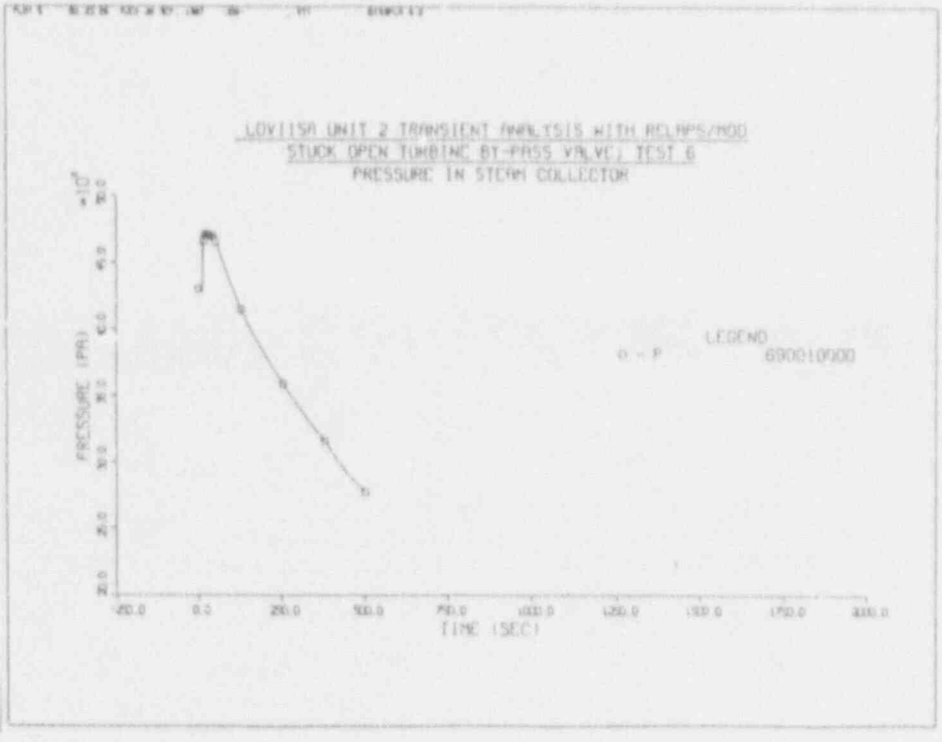


Figure 7.3.2 Secondary pressure.

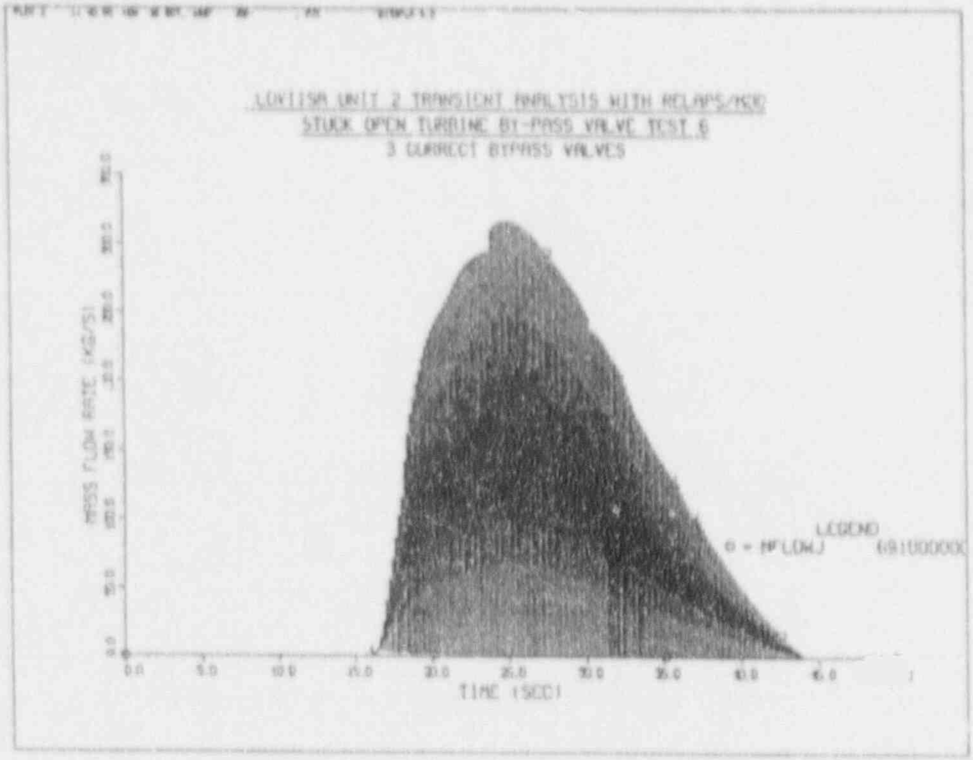


Figure 7.3.3 Mass flow rate through the servo v[illegible] model (Time step 0.1 s).

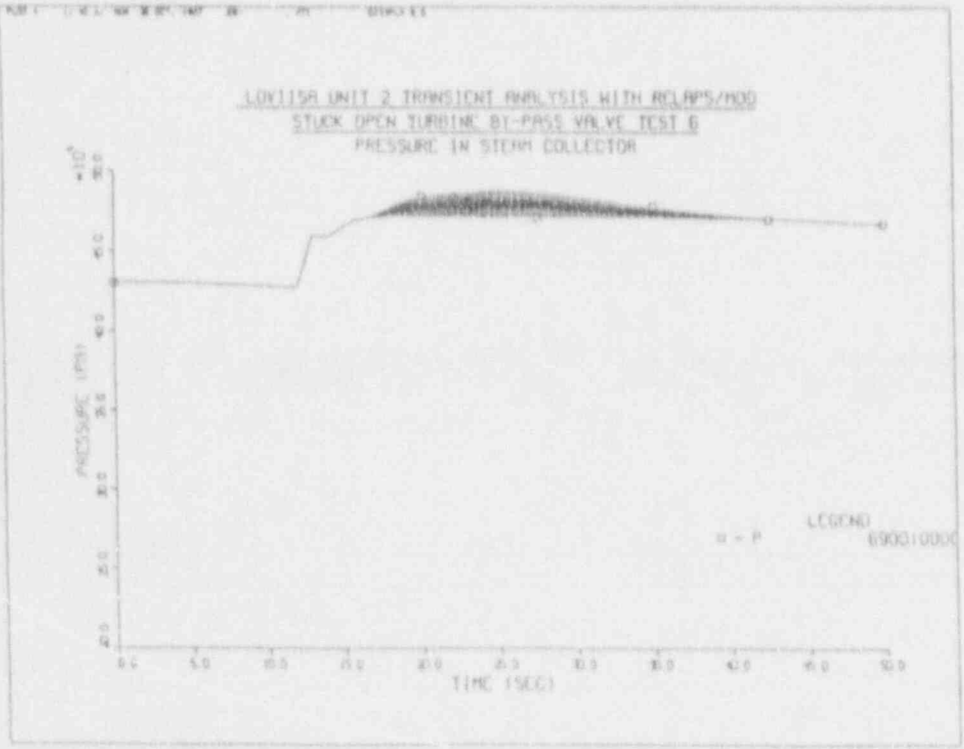


Figure 7.3.4 Secondary pressure (Time step 0.1 s).

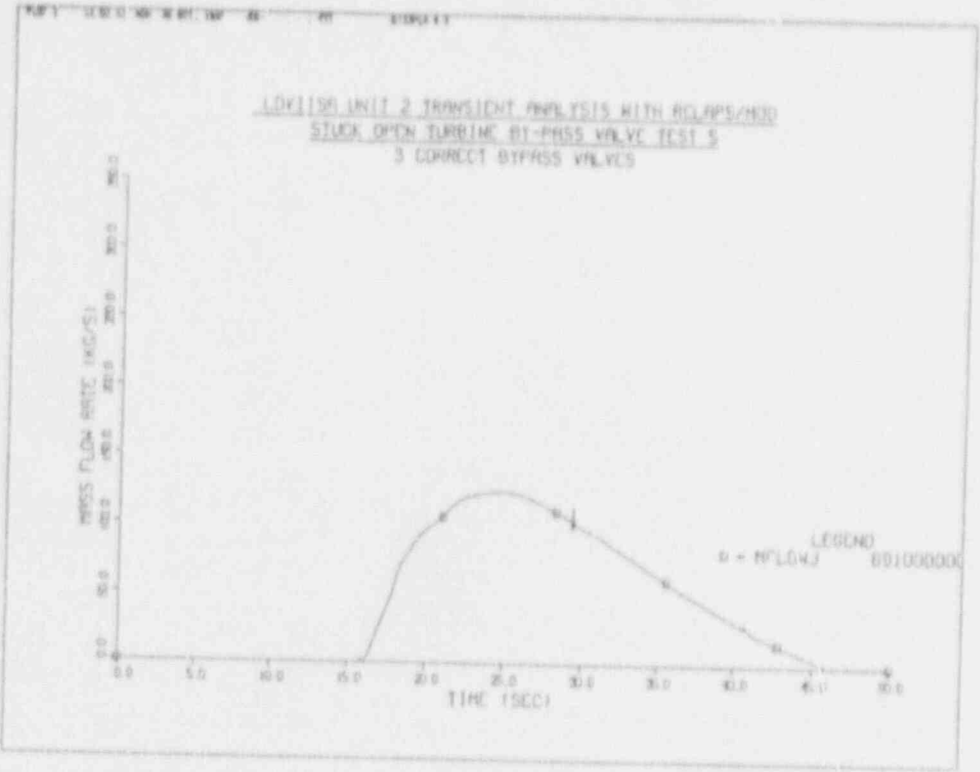


Figure 7.3.5 Mass flow rate through the servo valve model (Time step 0.05 s).

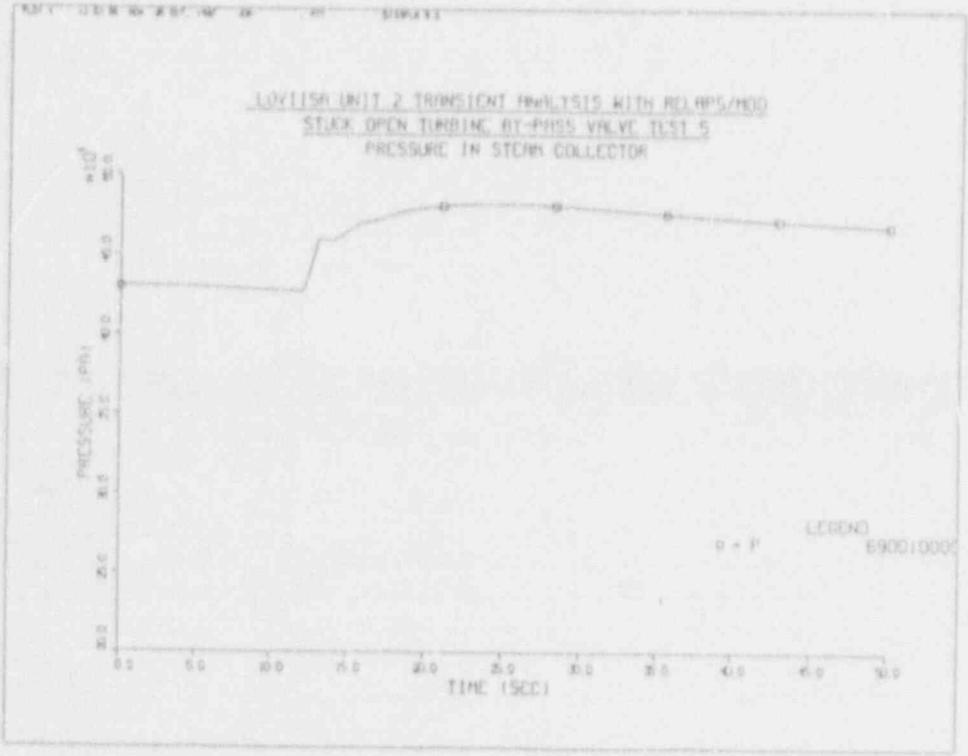


Figure 7.3.6 Secondary pressure (Time step 0.05 s).

8. RUN STATISTICS

The transient calculation model used in the base case for the analysis of the Loviisa 2 plant was modelled by 186 volumes, 196 junctions and 131 heat structures (with 702 mesh points). The volumes included three pump components with common dimensionless pump tables and 21 time dependent volumes. There were 12 valve components and 17 time dependent junctions. 147 trips and 67 control variables were used in order to describe plant control and safety signals.

The computer running time statistics is shown in Table 8.1. The requested maximum time step size was set just below the minimum Courant value, because from the experience this was known to be the most effective time usage. Between 15 and 50 seconds of the transient the requested time step was halved as explained in the previous chapter. The minimum material Courant limit occurred whole time in volume 205-02 (single loop hot leg). Only in the beginning before double and triple loop pumps were slowed the limitation varied between downcomer top (60-01) and triple loop hot leg (405-02) volume.

The computer CPU-time versus transient time was approximately 10 with the exclusion of the period between 15 and 50 second as shown in Figure 8.1. The curve was subjected to a discontinuity at 500 seconds when the code reseted the CPU- time counter due the changes in the restart input. The run was very stable and the checks for time step control did not cause any time step reduction.

The code efficiency number as stated in /1/ is obtained from:

$$(\mathrm{CPU} \times 10^{3}) / (\mathrm{C} \times \mathrm{DT}), \text{ where}$$

C = number of volumes in the model
DT = number of time steps
CPU = computer CPU-time

$$\frac{((5461.5-11.8+10740.8-6.7) \times 10^{3})}{(186 \times 16360)} = 5.3$$

The computer used for the calculation was CDC Cyber 180-840. The speed of the machine according to the supplier is 6 MIPS.

Table 8.1 Computer run statistics table

Transient time (s)	Computer CPU-time (s)	Requested time step (s)	Average time step (s)	Number of time steps	Courant limit (s)	Mass error ratio
0	11.8					
1.0	33.8	0.1	0.1	20	0.1001 [A]	$-5.2*10^{6}$
15.0	170.8	0.1	0.1	160	0.108 [B]	$3.0*10^{5}$
50.0	869.5	0.05	0.05	860	0.103 [C]	$1.2*10^{6}$
100.0	1381.1	0.1	0.1	1360	0.101 [C]	$5.9*10^{6}$
300.0	3486.8	0.1	0.1	3360	0.10	$-3.1*10^{6}$
500.0	5461.5	0.1	0.1	5360	0.101 [C]	$-2.2*10^{6}$
500.0	6.67					
700.0	2034.9	0.1	0.1	7360	0.101 [C]	$-1.8*10^{5}$
900.0	3952.9	0.1	0.1	9360	0.102 [C]	$4.4*10^{5}$
1100.0	5918.6	0.1	0.1	11360	0.101 [C]	$3.1*10^{5}$
1300.0	7901.7	0.1	0.1	13360	0.101 [C]	$2.3*10^{5}$
1600.0	10740.6	0.1	0.1	16360	0.105 [C]	$-9.1*10^{5}$

[A] Minimum Courant limit in volume 60-01
[B] Minimum Courant limit in volumes 60-01, 205-02 and 405-02
[C] Minimum Courant limit in volume 205-02

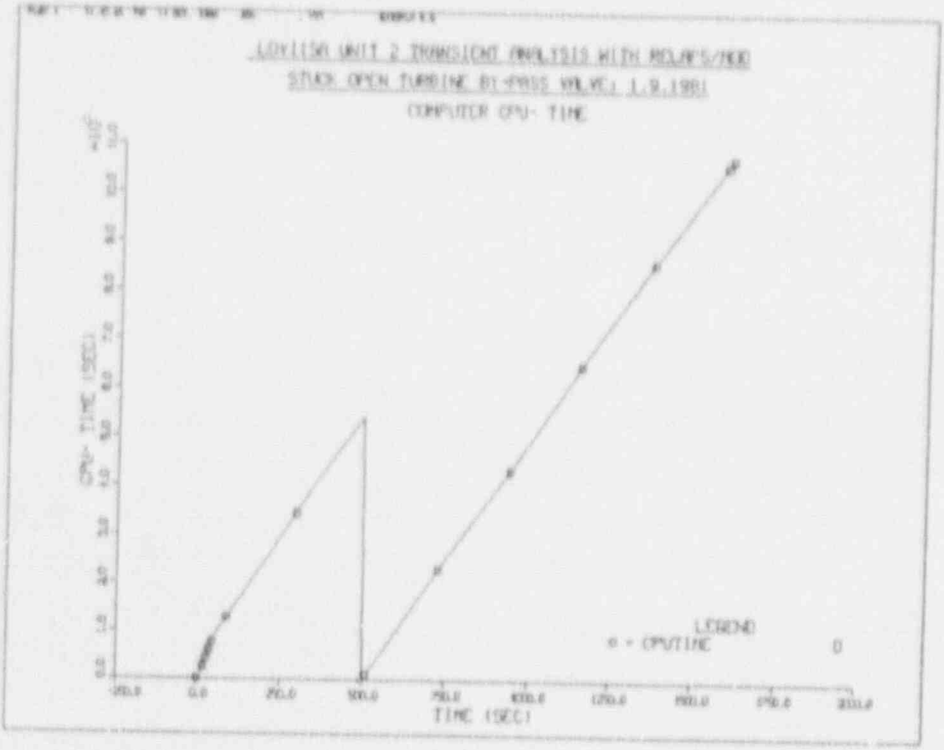


Figure 8.1 Computer CPU- time compared to calculated transient time.

9. CONCLUSIONS

The calculation of the LOVIISA Unit 2 transient was carried out with a nodalization model, which had been used in several safety analysis. Thus a laborious job to develop and check the input deck was not required. The model had been verified against some start-up commissioning tests.

The main difficulty with the actual plant transient calculation lies in modelling all control and safety signals. Some of these may play a significant role in the calculation by changing the timing of the phenomena or causing a threshold (= triggering) effect. The high pressure safety injection (HPSI) signal, which was actuated by the pressurizer water level is an example of such phenomena. If the calculated pressurizer water level had not decreased low enough, the HPSI- pumps would not have started at all and both the primary pressure and the pressurizer level behavior would have been much different. The safety injection was modelled as time dependent flow according to the plant data in order to diminish the effect of threshold phenomena. This helps the quantitative comparison of the code calculation, but one can question whether this is the appropriate method in code assessment.

The base case calculation gave quite good results especially qualitatively. The main quantitative disagreement between measured data and calculation was in the primary pressure and the pressurizer water level. However, this was traced to be an error in the nodalization model, not a code deficiency.

The cooling of the primary circuit right after the reactor scram was faster in the calculation than in the plant. Several possible reasons might be suspected, but the limited number of measurements does not give enough support for definite conclusions. This illustrates the problems when comparing the calculated results with data of a real plant equipped with "limited" instrumentation for operation and protection of the plant.

In the pressurizer wall heat transfer an anomalous behavior was discovered. The inability to easily print out or plot all calculated variables (terms of equations involved) prohibited quick examination of the anomaly. A larger selection of the expanded edit or plot variables would be helpful for error analyses.

An oscillatory behavior of the servo valve was also detected. The real cause of the malfunction was not found, but reduction of the time step size removed the oscillations. This phenomenon showed that the minor edit and plot frequency selected as an input may efficiently hide the real detailed behavior of the calculated parameter. Some words of warning in the manual would be useful.

The calculation with slightly different initial conditions pointed out, that only the primary mean temperature had some effect on the calculated results. The variation of other main parameters inside the range of measurement uncertainties did not change the results noteworthily.

The sensitivity study of the pump trip times demonstrated the importance of the correct loop flow rates in a multi-loop reactor model.

10. REFERENCES

/1/ D. E. Bessette, "Guidelines and Procedures for the International Thermal-Hydraulic Code Assessment and Applications Program". U.S. Nuclear Regulatory Commission, April 1986.

/2/ "Nuclear power plant LOVIISA, Description of main systems", Imatran Voima Oy. (In Finnish)

/3/ H. Tuomisto et. al.,"Computing Methods Assessment Analyses of the Loviisa Unit 2 Overcooling Incident on September 1, 1981", Proceedings of the ANS Topical Meeting on Anticipated and Abnormal Transients in Nuclear Power Plants, April 12-15, 1987, Atlanta, Georgia.

/4/ A. Valli, "Reactor scram due to disturbances in level measurements of the steam generators and stuck opening of one turbine by-pass valve", Special report 4/81, Imatran Voima Oy, January 1982. (In Finnish)

/5/ V. H. Ransom et. al., "RELAP5/MOD2 Code Manual", Vol. 1 & 2, NUREG/CR-4312, EG&G Idaho, Inc., 1985.

/6/ P. D. Wheatley et. al., "RELAP5/MOD2 Code Assessment at the Idaho National Engineering Laboratory", NUREG/CR-4454, EG&G Idaho, Inc., March 1986.

LIST OF APPENDICES

Appendix A illustrates parameters of group 00

- (1): electric power of generator SP10; abbreviation SP10E002
- (2): electric power of generator SP50; abbreviation SP50E002
- (12): mean temperature of hot legs; abbreviation YA10T802
- (13): mean temperature of cold legs; abbreviation YA10T803
- (14): differential pressure over reactor core; transducer YC10P001

APPENDIX A;1/2

```
 JSTP20            L02  JHLKIJLVIITYSRAPORTTI  KYMMA 00      6          81-09-01 KLO 09.19   SIVU
                   ==================================

                   TALLETUSSIGNAALI YZ10U401U01 SAATOSAUVAT           LUKITUS
                   TALLETUSHETKI     81-09-01 KLO 07 06.51

                                             154    152    P01    P05            KIINTILYVALI
        ( 1) SP10E002  GENERAATTORI SP10    EP                            MW       10 S
        ( 2) SP50E002  GENERAATTORI SP50    EP                            MW       10 S
        ( 3) RL301004  SYVE JHLK KP-ESIL     T                            CEL      10 S
        ( 4) RL701004  SYVE JHLK KP-ESILAMM  T                            CEL      10 S
        ( 5) RL10P001  SYOTTOVESISAILIO RL10 P                            BAR      30 S
        ( 6) RL50P001  SYOTTOVESISAILIO RL50 P                            BAR      30 S
        ( 7) RL10L002  SYOTTOVESISAILIO RL10 L        1.50   2.65         M        10 S
        ( 8) RL50L002  SYOTTOVESISAILIO RL50 L        1.50   2.69         M        10 S
        ( 9) RL40P001  HAARAKYTTOVESIJOKSI   P        40                  BAR      30 S
        (10) RL80P001  HAARAKYTTOVESIJOKSI   P        40                  BAR      30 S
        (11) RY95F001  HAAALISHULEI SYVESLO  F                            KG/S     10 S
        (12) YA101002  K-PIIRIEN KUUMAN KESKI-L                           CEL      ** S
        (13) YA101003  K-PIIRIEN KYLMAN KESKI-T                           CEL      ** S
        (14) YC10P001  REAKTORI              PD              3.00         BAR      10 S

           1      2     3     4     5     6     7     8     9    10    11    12    13    14
06.57.34 + 229 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291
06.58.34 + 230 + 226   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291
06.59.34 + 229 + 226   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291
07.00.34 + 230 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291               67
07.01.34 + 230 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   26.  2.68
07.01.54 + 230 + 224   222   223   6.7   6.8  2.49  2.53   45    44   2.4   291   262  2.67
07.02.14 + 229 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   262  2.68
07.02.34 + 231 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   262  2.68
07.02.54 + 230 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   262  2.67
07.03.14 + 229 + 226   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   262  2.68
07.03.34 + 230 + 226   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   262  2.69
07.03.54 + 231 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   262  2.68
07.04.14 + 230 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   262  2.68
07.04.34 + 230 + 226   222   223   6.7   6.8  2.49  2.54   45    44   2.4   291   262  2.68
07.04.54 + 229 + 226   222   223   6.7   6.8  2.48  2.55   45    44   2.4   291   262  2.68


 JSTP20            L02  JHLKIJLVIITYSRAPORTTI  KYMMA 00                 81-09-01 KLO 08 15   SIVU
                   ==================================
             1     2     3     4     5     6     7     8     9    10    11    12    13    14
07.05.04 + 229 + 226   222   223   6.7   6.8  2.48  2.55   45    44   2.4   291   262  2.67
07.05.14 + 230 + 226   222   223   6.    6.8  2.48  2.54   45    44   2.4   291   262  2.67
07.05.24 + 230 + 226   222   223   6.    6.8  2.48  2.54   45    44   2.4   291   262  2.69
07.05.34 + 230 + 227   222   223   6.    6.8  2.49  2.54   45    44   2.4   291   262  2.68
07.05.44 + 229 + 225   222   223   6.7   6.8  2.49  2.54   45    44   2.4   291   262  2.69
07.05.54 + 229 + 226   222   223   6.7   6.8  2.49  2.53   45    44   2.4   291   262  2.67
07.05.59 + 229 + 225   222   223   6.7   6.8  2.49  2.55   45    44   2.4   291   262  2.67
07.06.04 + 229 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   262  2.68
07.06.09 + 229 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   262  2.68
07.06.14 + 230 + 225   222   223   6.7   6.8  2.49  2.54   45    44   2.4   291   262  2.68
07.06.19 + 230 + 225   222   223   6.7   6.8  2.49  2.54   45    44   2.4   291   262  2.68
07.06.24 + 229 + 225   222   223   6.7   6.8  2.49  2.54   45    44   2.4   291   262  2.68
07.06.29 + 229 + 225   222   223   6.7   6.8  2.49  2.54   45    44   2.4   291   262  2.68
07.06.34 + 230 + 225   222   223   6.7   6.8  2.48  2.54   45    44   2.4   291   262  2.68
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07.06.44 + 230 + 225   222   223   6.8   6.8  2.48  2.53   45    44   2.4   291   262  2.69
07.06.49 + 230 + 226   222   223   6.8   6.8  2.48  2.53   45    44   2.4   291   262  2.67

07.06.54 + 227 + 226   222   223   6.8   6.8  2.48  2.54   45    44   2.4   291   262  2.58
07.06.59 + 227 + 192   222   223   6.8   6.8  2.48  2.54   45    44   2.4   291   262  2.58
07.07.06 + 178 + 192   222   223   6.8   6.8  2.50  2.55   45    44   2.4   291   262  2.29
07.07.11 + 178 +   0   222   223   6.8   6.8  2.50  2.55   45    44   2.4   291   262  2.23
07.07.16 +   0 +   0   222   223   6.7   6.8  2.50  2.55   50    47   2.4   291   262  1.40
07.07.21 +   0 +   0   222   223   6.7   6.8  2.50  2.55   50    47   2.4   282   265  1.40
07.07.26 +   0 +   0   222   223   6.7   6.   2.51  2.56   50    47   2.4   282   265    92
07.07.31 +   0 +   0   222   223   6.7   6.8  2.51  2.58   50    47   2.4   282   265    92
07.07.36 +   0 +   0   222   223   6.7   6.8  2.51  2.58   50    47   2.4   274   265    64
07.07.41 +   0 +   0   222   223   6.7   6.8  2.51  2.58   50    47   2.4   274   265    64
07.07.46 +   0 +   0   221   221   6.9   6.8  2.52  2.58   46    45   2.4   271   263    48
07.07.51 +   0 +   0   221   221   6.9   6.8  2.52  2.58   46    45   2.4   271   263    48
07.07.56 +   0 +   0   219   207   6.9   6.9  2.53  2.57   46    45   2.4   269   263    37
07.08.06 +   0 +   0   193   175   6.9   6.9  2.51  2.57   46    45   2.4   269   263    30
07.08.16 +   0 +   0   180   175   6.8   6.9  2.49  2.57   44    43   2.4   267   261    24
07.08.26 +   0 +   0   176   174   6.8   6.7  2.47  2.58   44    43   2.4   267   260    20
07.08.37 +   0 +   0   175   173   6.8   6.7  2.47  2.61   44    43   2.4   266   260    17
07.08.47 +   0 +   0   174   172   6.5   6.7  2.45  2.67*  43    41   2.6   265   259    14
```

APPENDIX A;2/2

```
JSTE20                    L02  JAK6LVIITYSHAVAINNOT  RYHMA 00   6         81-09-01 KLO 08 13  SIVU 6

              1        2        3        4        5        6        7        8        9       10      11       12       13       14
07.08.57   +  0    +   0      173      172      6.5      6.5     2.45     2.72*     42      41      2.6      264      258      .12
07.09.17   -  0    +   0      172      171      6.3      6.5     2.53     2.83*     40      39*     2.4      264      256      .10
07.09.38   +  0    +   0      170      170      6.3      6.3     2.64     2.87*     40      39*     2.3      263      255      .09
07.09.58   +  0    +   0      169      169      6.2      6.2     2.74*    2.87*     39*     38*     2.2      262      254      .09
07.10.18   -  0    +   0      168      168      6.0      6.3     2.79*    2.92*     37*     37*     2.2      260      252      .07
07.10.38   +  0    +   0      168      168      6.0      6.0     2.64     2.97*     37*     37*     2.2      258      250      .06
07.10.58   +  0    +   0      168      167      6.0      6.0     2.88     2.99*     36*     35*     2.2      257      249      .06
07.11.18   +  0    +   0      167      167      6.2      6.0     2.91     3.08*     35*     34*     4.1      255      248      .05
07.11.38   +  0    +   0      167      167      6.2      6.5     2.20     3.08*     35*     34*    24.5      253      246      .06
07.12.38   -  0    +   0      167      166      5.8      5.7     2.34     3.03*     32*     32*     2.2      249      242      .05
07.13.39   -  0    +   0      166      166      5.6      5.6     2.46     3.04*     30*     30*     2.6      244      238      .05
07.14.39   +  0    +   0      165      166      5.3      5.3     2.45     3.02*     28*     28*     2.4      240      234      .05
07.15.39   +  0    +   0      164      166      5.1      5.0     2.42     3.09*     27*     26*     2.4      237      231      .05
07.16.39   -  0    +   0      163      165      4.8      4.7     2.33     3.03*     25*     25*    14.9      233      228      .05

                    BINAARISUUREITTEN MUUTOKSET

                    BINAARISUUREITTEN ARVOT TALLETUSHETKELLA
```

Appendix B includes parameters of group 01

- (1): percentage reactor neutron power; abbreviation YX13X801
- (2): primary pressure; transducer YA10P801
- (3): maximum outlet temperature of group 1 fuel bundles; abbreviation YQ30T801
- (4): maximum outlet temperature of group 2 fuel bundles; abbreviation YQ30T802
- (5): pressurizer level, transducer YP10L002
- (6): pressurizer pressure, transducer YP10P001
- (7): steam generator YB11 pressure; transducer RA11P961
- (8): steam generator YB13 pressure; transducer RA13P961
- (9): steam generator YB15 pressure; transducer RA15P961
- (10): steam generator YB52 pressure; transducer RA52P961
- (11): steam generator YB54 pressure; transducer RA54P961
- (12): steam generator YB56 pressure; transducer RA56P961
- (13): mean loop temperature; abbreviation YA10T902

APPENDIX B;1/2

```
JSRP21                    L02  KEKISKLVIITYSHAVAINTI  RYHMA 01                81-09-01 KLO 08 18  SIVU 0

                          TALLETUSSIGNAALI YZ10U401U01 SAATOSAUVAT           LUKITUS
                          TALLETUSHETKI    81-09-01 KLO 07 06 51

                                                      PS1    PS2    PO1    PO3              KERAILYVALI
        ( 1) YX15X001  REAKT NEUTRONIVUO-KESKI-XP                              %            ** S
        ( 2) YA10P801  REAKTORI M-A VAL.      P                                BAR          ** S
        ( 3) YU301U01  PA-ELEM LAHTO 1.SUURIN T                  312           CEL          ** S
        ( 4) YU301U02  PA-ELEM LAHTO 2.SUURIN T                  312           CEL          ** !
        ( 5) YP10L002  PAINEENTASAAJA         L     6.9    2.4    2.8    7.2    M            1 S
        ( 6) YP10P001  PAINEENTASAAJA         P                                BAR          10 S
        ( 7) RA11P961  HOYRYNKEHITIN YB11     P                  52.0          BAR          1 S
        ( 8) RA13P961  HOYRYNKEHITIN YB13     P                  52.0          BAR          1 S
        ( 9) RA15P961  HOYRYNKEHITIN YB15     P                  53.0          BAR          1 S
        (10) RA52P961  HOYRYNKEHITIN YB52     P                  52.0          BAR          1 S
        (11) RA54P961  HOYRYNKEHITIN YB54     P                  52.0          BAR          1 S
        (12) RA56P961  HOYRYNKEHITIN YB56     P                  52.0          BAR          1 S
        (13) YA10T902  KIERTOPIIRIN    KESKI-T                                 CEL          5 S
        (14) YE12T001  VAKUVENTTIILILINJA     T                  150           CEL          60 S

             1      2      3      4      5      6      7      8      9      10     11     12     13     14
06.57.34    100    123    299    299    4.7*   122    43.4   43.8   44.1   43.6   43.9   43.9   276    44
06.58.34    100    123    299    299    4.7*   122    43.4   43.8   44.1   43.6   43.9   44.0   276    44
06.59.34    100    123    299    299    4.7*   122    43.4   43.8   44.1   43.6   43.9   44.0   276    44
07.00.34    100    123    299    299    4.7*   122    43.3   43.8   44.1   43.5   43.8   43.9   276    44
07.01.34    100    123    299    299    4.7*   122    43.3   43.7   44.1   43.4   43.8   43.9   276    44
07.01.54    100    123    299    299    4.7*   122    43.3   43.7   44.0   43.4   43.8   43.9   276    44
07.02.14    100    123    299    298    4.7*   123    43.4   43.7   44.1   43.5   43.8   43.9   276    44
07.02.34    100    123    299    299    4.7*   123    43.3   43.7   44.0   43.5   43.8   43.9   276    44
07.02.54    100    123    299    299    4.7*   122    43.3   43.7   44.0   43.4   43.8   43.9   276    44
07.03.14    100    123    299    299    4.7*   122    43.4   43.7   44.1   43.5   43.8   43.9   276    44
07.03.34    100    123    299    299    4.7*   122    43.3   43.7   44.1   43.4   43.8   43.9   276    44
07.03.54    100    123    299    299    4.7*   122    43.3   43.7   44.0   43.4   43.8   43.9   276    44
07.04.14    100    123    299    299    4.7*   122    43.4   43.7   44.0   43.4   43.8   43.9   276    44
07.04.34    100    123    299    298    4.7*   123    43.3   43.7   44.0   43.4   43.8   43.8   276    44
07.04.54    100    123    299    299    4.7*   122    43.3   43.7   44.0   43.5   43.8   43.9   276    44
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JSRP21                    L02  KEKISKLVIITYSHAVAINTI  RYHMA 01                81-09-01 KLO 08 18  SIVU

             1      2      3      4      5      6      7      8      9      10     11     12     13     14
07.05.04    100    123    299    298    4.7*   123    43.3   43.7   44.0   43.4   43.8   43.9   276    44
07.05.14    100    123    299    299    4.7*   123    43.4   43.7   44.0   43.4   43.8   43.9   276    44
07.05.24    100    123    299    299    4.7*   123    43.3   43.7   44.0   43.4   43.8   43.9   276    44
07.05.34    100    123    299    299    4.7*   122    43.3   43.7   44.0   43.4   43.8   43.8   276    44
07.05.44    100    123    299    299    4.7*   122    43.4   43.7   44.0   43.4   43.8   43.8   276    44
07.05.54    100    123    299    299    4.7*   122    43.3   43.7   44.0   43.4   43.8   43.8   276    44
07.05.59    100    123    299    299    4.7*   123    43.3   43.7   44.0   43.4   43.9   43.8   276    44
07.06.04    100    123    299    299    4.7*   123    43.3   43.7   44.0   43.4   43.8   43.8   276    44
07.06.09    100    123    299    299    4.7*   122    43.3   43.7   44.0   43.4   43.8   43.8   276    44
07.06.14    100    123    299    299    4.7*   122    43.4   43.7   44.0   43.4   43.8   43.8   276    44
07.06.19    100    123    299    299    4.7*   122    43.3   43.7   44.0   43.4   43.8   43.8   276    4
07.06.24    100    123    299    299    4.7*   122    43.3   43.7   44.0   43.4   43.8   43.8   276
07.06.29    100    123    299    299    4.7*   123    43.3   43.7   44.0   43.4   43.8   43.8   276    44
07.06.34    100    123    299    299    4.7*   123    43.3   43.7   44.0   43.4   43.8   43.8   276    44
07.06.39    100    123    299    299    4.7*   123    43.3   43.7   44.0   43.4   43.8   43.8   276    44
07.06.44    100    123    299    299    4.7*   123    43.4   43.7   44.0   43.4   43.8   43.9   276    44
07.06.49    100    123    299    299    4.7*   122    43.3   43.7   44.1   43.4   43.8   43.9   276    44

07.06.54    100    123    299    299    4.7*   123    44.0   44.4   44.8   44.2   44.3   44.6   276    44
07.06.59    100    123    299    299    4.8*   123    44.8   45.3   45.6   45.0   45.1   45.4   276    44
07.07.06     96    124    299    299    4.7*   123    48.8   49.2   49.7   48.9   48.6   49.5   276    44
07.07.11     96    124    299    299    4.4*   119    48.4   49.8   49.3   48.4   48.1   48.9   275    44
07.07.16     96    124    299    299    4.1*   119    47.9   48.3   48.8   47.9   47.8   48.4   275    44
07.07.21      3    119    294    295    3.9*   119    47.3   47.8   48.3   47.4   47.4   47.9   273    44
07.07.26      3    119    294    295    3.8*   119    47.0   47.5   47.9   47.0   47.1   47.5   272    44
07.07.31      3    119    294    295    3.7*   117    46.7   47.2   47.6   46.7   46.9   47.2   271    44
07.07.36      1    118    294    295    3.6*   117    46.4   47.0   47.4   46.5   46.7   47.0   270    44
07.07.41      1    118    294    295    3.5*   117    46.2   46.7   47.1   46.3   46.4   46.7   269    44
07.07.46      1    117    280    280    3.5*   117    45.9   46.4   46.8   46.0   46.2   46.6   268    44
07.07.51      1    117    280    280    3.4*   116    45.5   46.0   46.4   45.6   45.8   46.0   266    44
07.07.56      1    117    276    276    3.4*   116    45.2   45.7   46.1   45.3   45.5   45.7   265    44
07.08.06      1    117    276    276    3.3*   116    44.5   45.2   45.5   44.6   44.9   45.1   263    44
07.08.16      0    116    271    271    3.2*   116    43.9   44.3   44.8   44.0   44.2   44.4   262    44
07.08.26      0    116    269    269    3.1*   116    43.2   43.7   44.1   43.3   43.5   43.7   261    44
07.08.37      0    116    268    268    3.1*   115    42.5   42.9   43.4   42.6   42.8   42.9   260    44
07.08.47      0    116    267    266    3.0*   115    41.9   42.3   42.7   41.9   42.1   42.3   259    44
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APPENDIX B;2/2

8

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JSRP21                 L02 JÄLKI[illegible]LVIITYSHAKEMISTO RYHMÄ 01             81-09-01 KLO 08.18 SIVU 0

                1       2       3       4       5       6       7       8       9      10      11      12      13      14
07.08.57        0     116     267     267    3.0*     115    41.2    41.7    42.2    41.9    41.5    41.7     258      44
07.09.17        0     116     265     265    2.9*     115    40.2    40.6    41.1    40.2    40.4    40.6     256      44
07.09.38        0     116     264     264    2.7*     115    39.1    39.5    40.0    39.1    39.4    39.5     257      44
07.09.58        0     115     264     263    2.6*     115    38.1    38.6    39.1    38.2    38.5    38.6     255      44
07.10.18        0     115     262     262    2.4*     114    37.3    37.8    38.2    37.4    37.6    37.7     253      44
07.10.38        0     114     261     261    2.3*     114    36.4    36.9    37.3    36.5    36.7    36.9     251      44
07.10.58        0     114     260     260    2.1*     114    35.5    36.0    36.4    35.6    35.9    36.0     249      44
07.11.18        0     114     259     259    2.0*     114    34.7    35.1    35.5    34.7    34.9    35.1     247      44
07.11.38        0     114     257     256    1.9*       3    33.7    34.2    34.6    33.9    34.1    34.2     246      44
07.12.38        0     114     253     253    1.6* [illegible] 31.6  32.0    32.5    31.7    31.9    32.0     242      44
07.13.39        0     120     249     249    1.8*     120    29.6    30.0    30.3    29.7    29.9    29.9     238      44
07.14.39        0     120     245     245    1.7*     119    27.8    28.2    28.6    27.9    28.1    28.2     234      44
07.15.39        0     121     242     242    1.6*     120    26.2    26.7    27.0    26.3    26.6    26.6     231      44
07.16.39        0     122     239     239    1.6*     121    24.7    25.1    25.5    24.8    25.1    25.1     227      44

                    BINÄÄRISUUREITTEN MUUTOKSET

                    BINÄÄRISUUREITTEN ARVOT TALLETUSHETKELLÄ
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Appendix C includes parameters of group 02

- (1): steam generator YB11 water level; transducer YB11L005
- (2): steam generator YB13 water level; transducer YB13L005
- (3): steam generator YB15 water level; transducer YB15L005
- (4): steam generator YB52 water level; transducer YB52L005
- (5): steam generator YB54 water level; transducer YB54L005
- (6): steam generator YB56 water level; transducer YB56L005
-(13): secondary pressure in steam collector; transducer RA10P002
-(14): secondary pressure in steam collector; transducer RA50P002

APPENDIX C;1/2

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JSTP22                     LO2  HAIRIOSELVITYSRAPORTTI  RYHMA 02                  91-09-01 KLO 08.21   SIVU 0

                           TALLETUSSIGNAALI YZ10U001U01 SAATOSAUVAT               LUKITUS
                           TALLETUSHETKI      91-09-01 KLO 07.06.51

                                                         PS4     PS2     P01     P03            KERAILYVALI
           ( 1) YB11L005  HOYRYNKEHITIN YB11     L                                      M          10 S
           ( 2) YB13L005  HOYRYNKEHITIN YB13     L                                      M          10 S
           ( 3) YB15L005  HOYRYNKEHITIN YB15     L                                      M          10 S
           ( 4) YB52L005  HOYRYNKEHITIN YB52     L                                      M          10 S
           ( 5) YB54L005  HOYRYNKEHITIN YB54     L                                      M          10 S
           ( 6) YB56L005  HOYRYNKEHITIN YB56     L                                      M          10 S
           ( 7) RL72F001  SYVL JALK PAAJ RL72    F                                      KG/S       30 S
           ( 8) RL73F001  SYVL JALK PAAJ RL73    F                                      KG/S       30 S
           ( 9) RL90F001  SYVL JALK KE-ESILAMM   F                                      KG/S       30 S
           (10) RL70F001  SYVL JALK KP-ESILAMM   F                                      KG/S       30 S
           (11) RL90P002  SYVL JALK KE-ESIL      P                                      BAR        30 S
           (12) RL70P002  SYVL JALK KP-ESIL      P                                      BAR        30 S
           (13) RA10P002  HOYRYTUKKI             P                                      BAR         5 S
           (14) RA50P002  HOYRYTUKKI             P                                      BAR         5 S

              1       2       3       4       5       6       7       8       9      10      11      12      13      14
06.57.34   2.06    2.02    2.05    2.02    2.09    2.08      0     1.2     369     377      67      67    43.0    43.2
06.58.34   2.05    2.02    2.05    2.02    2.09    2.09      0     1.2     369     373      67      67    43.1    43.2
06.59.34   2.06    2.01    2.05    2.02    2.09    2.02      0     1.2     369     376      67      67    43.1    43.2
07.00.34   2.06    2.02    2.05    2.03    2.09    2.03      0     1.2     368     378      66      67    43.0    43.1
07.01.34   2.05    2.02    2.05    2.03    2.10    2.04      0     1.2     370     378      66      67    43.0    43.1
07.01.54   2.05    2.02    2.05    2.03    2.10    2.04      0     1.2     367     378      66      67    43.0    43.1
07.02.14   2.05    2.02    2.05    2.02    2.09    2.03      0     1.2     367     378      67      67    43.0    43.1
07.02.34   2.05    2.02    2.05    2.02    2.09    2.04      0     1.2     369     379      66      67    43.0    43.1
07.02.54   2.05    2.02    2.05    2.03    2.09    2.04      0     1.2     369     377      66      67    43.0    43.1
07.03.14   2.05    2.02    2.05    2.02    2.09    2.03      0     1.2     369     377      67      67    43.0    43.1
07.03.34   2.04    2.02    2.05    2.03    2.09    2.03      0     1.2     367     377      67      67    43.0    43.1
07.03.54   2.05    2.02    2.05    2.03    2.09    2.03      0     1.2     366     379      67      67    43.0    43.1
07.04.14   2.05    2.02    2.05    2.02    2.09    2.03      0     1.2     366     379      67      67    43.0    43.1
07.04.34   2.05    2.02    2.05    2.03    2.08    2.03      0     1.2     368     376      67      67    43.0    43.1
07.04.54   2.05    2.02    2.05    2.02    2.09    2.03      0     1.2     370     377      67      67    43.0    43.1
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JSTP22                     LO2  HAIRIOSELVITYSRAPORTTI  RYHMA 02                  91-09-01 KLO 08.21   SIVU 1

              1       2       3       4       5       6       7       8       9      10      11      12      13      14
07.05.04   2.05    2.02    2.05    2.02    2.09    2.03      0     1.2     370     377      67      67    43.0    43.1
07.05.14   2.05    2.02    2.05    2.02    2.09    2.02      0     1.2     370     377      67      67    43.0    43.1
07.05.24   2.05    2.02    2.05    2.03    2.09    2.03      0     1.2     373     380      67      67    43.0    43.1
07.05.34   2.05    2.02    2.05    2.02    2.09    2.03      0     1.2     373     380      66      67    43.0    43.0
07.05.44   2.05    2.02    2.05    2.02    2.09    2.04      0     1.2     373     380      66      67    43.0    43.1
07.05.54   2.05    2.02    2.05    2.02    2.09    2.04      0     1.2     372     380      66      67    43.0    43.1
07.05.59   2.05    2.02    2.05    2.02    2.09    2.04      0     1.2     372     380      66      67    43.0    43.1
07.06.04   2.05    2.02    2.05    2.03    2.09    2.04      0     1.2     372     380      66      67    43.0    43.1
07.06.09   2.05    2.02    2.05    2.03    2.09    2.04      0     1.2     372     380      66      67    43.0    43.1
07.06.14   2.05    2.02    2.05    2.02    2.09    2.04      0     1.2     372     380      66      67    43.0    43.1
07.06.19   2.05    2.02    2.05    2.02    2.09    2.04      0     1.2     372     377      66      67    43.0    43.1
07.06.24   2.05    2.02    2.05    2.03    2.09    2.03      0     1.2     371     377      66      67    43.0    43.1
07.06.29   2.05    2.02    2.05    2.02    2.09    2.03      0     1.2     371     377      66      67    43.0    43.1
07.06.34   2.05    2.02    2.05    2.02    2.10    2.03      0     1.2     371     377      66      67    43.0    43.1
07.06.39   2.05    2.02    2.05    2.02    2.10    2.03      0     1.2     371     377      66      67    43.0    43.1
07.06.44   2.05    2.02    2.05    2.02    2.10    2.03      0     1.2     371     377      66      67    43.0    43.1
07.06.49   2.05    2.02    2.05    2.02    2.10    2.03      0     1.2     371     377      66      67    43.0    43.1

07.06.54   2.03    2.01    2.05    2.01    2.09    2.02      0     1.2     365     377      66      67    43.1    43.2
07.06.59   2.03    2.01    2.05    2.01    2.09    2.02      0     1.2     365     377      71      67    44.0    44.6
07.07.06   1.49    1.61    1.83    1.49    2.06    1.57      0     1.2     365     377      71      67    46.8    48.4
07.07.11   1.49    1.61    1.83    1.49    2.06     .57      0     1.2     365     377      71      67    48.1    47.7
07.07.16   1.91    1.66    2.02    1.38    2.09    1.40   17.4     1.5     365     377      71      67    48.0    47.4
07.07.21   1.91    1.66    2.02    1.38    2.09    1.40   17.4     1.5     365     272      71      67    47.7    47.1
07.07.26   2.15    1.97    2.07    1.69    2.10    1.69   17.4     1.5     212     272      71      61    47.4    46.9
07.07.31   2.15    1.97    2.07    1.69    2.10    1.69   17.4     1.5     212     272      61      61    47.1    46.6
07.07.36   2.16    2.09    2.06    1.89    2.12    1.88   17.4     1.5     212     272      61      61    46.9    46.4
07.07.41   2.16    2.09    2.06    1.89    2.12    1.88   17.4     1.5     212     272      61      61    46.6    46.2
07.07.46   2.19    2.13    2.07    2.01    2.13    2.01      0     1.5     212     272      61      61    46.4    45.9
07.07.51   2.19    2.13    2.07    2.01    2.13    2.01      0     1.5     212     193      61      61    46.0    45.6
07.07.56   2.25    2.18    2.08    2.19    2.15    2.12      0     1.5     188     193      61      63    45.7    45.3
07.08.06   2.30    2.21    2.08    2.29    2.16    2.22      0     1.5     188     193      62      63    45.0    44.6
07.08.16   2.35    2.23    2.09    2.31    2.17    2.29      0     1.2     188     193      62      63    44.4    44.0
07.08.26   2.40    2.25    2.10    2.37    2.17    2.35      0     1.2     159     167      62      64    43.7    43.3
07.08.37   2.44    2.27    2.10    2.43    2.18    2.41      0     1.2     159     167      64      64    43.0    42.6
07.08.47   2.45    2.28    2.11    2.47    2.18    2.45      0     1.2     159     167      64      64    42.3    41.9
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APPENDIX C;2/2

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JSTE22                        LO2 JÄLKI[illegible] RYHMÄ 02     8          81-09-01 KLO 08.21   SIVU 0

               1      2      3      4      5      6      7      8      9     10     11     12     13     14
07.08.57     2.44   2.29   2.11   2.50   2.18   2.48    .0    1.2    87     88     84     84    41.7   41.3
07.09.17     2.43   2.31   2.11   2.53   2.18   2.51    .0    1.2    87     88     84     84    40.6   40.2
07.09.38     2.43   2.33   2.11   2.53   2.18   2.51    .0    1.2    79     86     84     84    39.6   39.2
07.09.58     2.42   2.34   2.12   2.53   2.18   2.51    .0    1.2    52     76     84     85    38.6   38.2
07.10.18     2.41   2.34   2.13   2.51   2.18   2.49    .0    1.2    52     76     83     85    37.7   37.4
07.10.38     2.41   2.34   2.13   2.51   2.18   2.49    .0    1.2    47     53     84     84    36.9   36.5
07.10.58     2.40   2.33   2.14   2.51   2.17   2.50    .0    1.2    42     49     84     84    35.9   35.6
07.11.18     2.40   2.33   2.15   2.51   2.17   2.51    .0    1.2    42     49     84     84    35.1   34.7
07.11.38     2.39   2.31   2.16   2.51   2.16   2.51    .0    1.2    38     46     85     85    34.1   33.9
07.12.38     2.37   2.32   2.18   2.46   2.15   2.47    .0    1.2    50    105     83     84    32.1   31.7
07.13.39     2.35   2.33   2.19   2.42   2.15   2.44    .0    1.2    34     40     84     85    29.9   29.7
07.14.39     2.33   2.30   2.21   2.39   2.15   2.42    .0    1.2    36     44     84     84    28.1   27.9
07.15.39     2.32   2.30   2.22   2.37   2.17   2.40    .0    1.2   130    114     82     80    26.6   26.4
07.16.39     2.32   2.35   2.23   2.38   2.20   2.41    .0    1.2    38     46     83     84    25.0   24.9

                  BINAARISUUREITTEN MUUTOKSET

                  BINAARISUUREITTEN ARVOT TALLETUSHETKELLA
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Appendix D includes parameters of group 03

- (6): mass flow rate of high capacity make-up pump TK11, transducer TK11F001

- (9): mass flow rate of letdown line TE50; transducer TE50F001

-(11): back pressure in letdown line TE50; transducer TE50P001

-(14): subcooling in the reactor inlet; abbreviation YA10T817

APPENDIX D;1/2

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JSSP29                      LO2 JALKIVIIYSRAPORTTI RYHMA 03                81-09-01 KLO 08.29   SIVU 01

                            TALLETUSSIGNAALI YZ10U401U01 SAATOSAUVAT              LUKITUS
                            TALLETUSHETKI     81-09-01 KLO 07.06.51

                                                         PS4      PS2      P01      P03              KERAILYVALI
          ( 1) 1J20F001  HATALISAVESI 1J20        F                                       KG/S         10 S
          ( 2) 1J60F001  HATALISAVESI 1J60        F                                       KG/S         10 S
          ( 3) 1H20F001  TRAV. JALK JAAHD 1H20    F                                       KG/S         10 S
          ( 4) 1H60F001  TRAV. JALK JAAHD 1H60    F                                       KG/S         10 S
          ( 5) 1B21F001  BOORI JALKIPU 11/21      F                                       KG/S         10 S
          ( 6) 1K11F001  PSU 1K11 PAINEPUOLI      F                    20.0               KG/S          5 S
          ( 7) 1K12F001  PSU 1K12 PAINEPUOLI      F                    20.0               KG/S          5 S
          ( 8) 1L10F001  ULOSLASKU 1L10           F                                       KG/S          5 S
          ( 9) 1E50F001  ULOSLASKU 1E50                                                   KG/S          5 S
          (10) 1L10P001  ULOSLASKU 1L10           P                                       BAR          30 S
          (11) 1E50P001  ULOSLASKU 1E50           P                                       BAR          30 S
          (12) 1V96P001  LISAVESITUKKI            P           8.0                         BAR          10 S
          (13) 1S97P001  LISAVESITUKKI            P           0.0                         BAR          10 S
          (14) YA10181Z  REAKTORIN KIEHUMISVARA   1            40                         CEL          ** S

              1     2     3     4     5     6     7     8     9    10     11     12     13     14
06.57.34      0     0     0     4    .0     0     0    .0     6   2.81   2.32   14.1   14.2    50
06.58.34      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.2    50
06.59.34      0     0     0     4     0    .0     0     0     6   2.81   2.32   14.1   14.1    50
07.00.34      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    50
07.01.34      0     0     0     4    .0    .0     0     0     6   2.81   2.32   14.1   14.1    50
07.01.54      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    50
07.02.14      0     0     0     4    .0     0    .0     0     6   2.81   2.32   14.1   14.2    51
07.02.34      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    51
07.02.54      0     0     0     4     0     0    .0    .0     6   2.81   2.32   14.2   14.1    50
07.03.14      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    51
07.03.34      0     0     0     6    .0     0    .0     0     6   2.81   2.32   14.1   14.2    51
07.03.54      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.2    50
07.04.14      0     0     0     4    .0     0     0     0     6   2.81   2.32   14.2   14.1    51
07.04.34      0     0     0     4     0     0     0     0     6   2.81   2.32   14.2   14.1    51
07.04.54      0     0     0     4    .0     0     0    .0     6   2.81   2.32   14.1   14.1    51
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JSSP29                      LO2 JALKIVIIYSRAPORTTI RYHMA 03                81-09-01 KLO 08.29   SIVU 02

              1     2     3     4     5     6     7     8     9    10     11     12     13     14
07.05.04      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    51
07.05.14      0     0     0     4    .0     0     0     0     6   2.81   2.32   14.2   14.2    50
07.05.24      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.2    50
07.05.34      0     0     0     4     0     0    .0    .0     6   2.81   2.32   14.1   14.2    51
07.05.44      0     0     0     4     0     0     0     0     6   2.81   2.32   14.2   14.1    51
07.05.54      0     0     0     4    .0    .0     0     0     6   2.81   2.32   14.1   14.1    51
07.05.59      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.2    51
07.06.04      0     0     0     4     0     0    .0     0     6   2.81   2.32   14.1   14.2    51
07.06.09      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    51
07.06.14      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    51
07.06.19      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.2    51
07.06.24      0     0     0     4     0     0     0     0     6   2.81   2.32   14.2   14.2    51
07.06.29      0     0     0     4     0     0     0     0     6   2.81   2.32   14.2   14.1    51
07.06.34      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    51
07.06.39      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.2    51
07.06.44      0     0     0     4     0     0     0    .0     6   2.81   2.32   14.1   14.2    51
07.06.49      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.2    51

07.06.54      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.2    51
07.06.59      0     0     0     4    .0     0    .0     0     6   2.81   2.32   14.1   14.1    51
07.07.04      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    51
07.07.11      0     0     0     4    .0    .0     0     0     6   2.81   2.32   14.1   14.0    51
07.07.16      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.0    51
07.07.21      0     0     0     4    .0    .0    .0     0     6   2.81   2.32   14.1   14.1    51
07.07.26      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    51
07.07.31      0     0     0     4     0    .0     0     0     6   2.81   2.32   14.1   14.1    51
07.07.36      0     0     0     4     0     0     0     0     6   2.81   2.32   14.0   14.1    49
07.07.41      0     0     0     4    .0     0     0    .0     6   2.81   2.32   14.0   14.1    49
07.07.46      0     0     0     4     0     0     0     0     6   2.81   2.32   14.0   14.1    52
07.07.51      0     0    .0     4    .0    .0     0     0     6   2.81   2.32   14.0   14.1    53
07.07.56      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.1    54
07.08.06      0     0     0     4    .0    .0    .0     0     6   2.81   2.32   14.1   14.1    54
07.08.16      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.2    56
07.08.26      0     0     0     4     0    .0     0     0     6   2.81   2.32   14.1   14.1    58
07.08.37      0     0     0     4     0     0     0     0     6   2.81   2.32   14.1   14.2    57
07.08.47      0     0     0     4    .0    .0     0     0     6   2.81   2.31   14.1   14.1    60
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APPENDIX D;2/2

JSSB23 LO2. JALKISELVITYSRAPORTTI. RYHMA 03 6 81-09-01 KLO 08 23 SIVU 6

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
07.08.57	0	0	0	4	0	0	0	0	6	2.81	2.31	14.1	14.2	60
07.09.17	0	0	0	4	0	0	.0	0	6	2.81	2.32	14.0	14.1	61
07.09.38	0	0	0	4	0	0	0	0	6	2.81	2.32	14.1	14.1	62
07.09.58	0	0	0	4	.0	.0	.0	0	6	2.81	2.32	14.1	14.1	64
07.10.18	0	0	0	4	0	0	0	0	6	2.81	2.31	14.2	14.1	66
07.10.38	0	0	0	4	.0	0	.0	0	6	2.81	2.31	14.1	14.1	69
07.10.58	0	0	0	4	0	0	0	0	6	2.81	2.31	14.2	14.1	70
07.11.18	0	0	0	4	.0	0	.0	0	6	2.81	2.32	12.1	14.4	72
07.11.38	0	0	0	4	0	0	0	0	6	2.81	2.32	12.1	11.5	73
07.12.38	0	0	0	4	0	8.6	.0	.0	2.4	2.85	2.40	15.5	15.2	78
07.13.39	0	5	0	4	10.0	4.7	.0	.0	2.6	2.84	2.41	15.7	15.2	86
07.14.39	0	0	0	4	11.2	5.9	.0	0	1.7	2.86	2.38	15.5	15.6	90
07.15.39	0	0	0	4	12.3	7.0	.0	.0	1.9	2.85	2.36	15.8	15.4	93
07.16.39	0	0	0	4	13.2	7.9	.0	.0	2.1	2.83	2.39	[illegible]	14.9	97

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Appendix E includes parameters of group 17

- (1): mean pressure in secondary steam collector; abbreviation RA00P901
- (2): mean primary loop temperature; abbreviation YA10T902
- (3): primary pressure; transducer YA10P801

APPENDIX E;1/2

6 8

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JSRP1V                 L02  JALKISELVITYSRAPORTTI  RYHMA 17                81-09-01 KLO 08 10    SIVU 0

                       TALLETUSSIGNAALI YD14D001B42 PÄÄKIERTOPUMPPU YD14          LAUKAISUSUOJAUS
                       TALLETUSHETKI      81-09-01 KLO 07.06.47

                                                       PS4      PS2      P01      P03              KERAILYVALI
            ( 1) HA00P901  HÖYRYTUKKI              P                                      BAR           1 %
            ( 2) YA101902  KIERTOPIIRIEN     KESKI-T                                      CEL           5 %
            ( 3) YA10P901  REAKTORI N-A VAL        P                                      BAR          ** %
            ( 4) YD11E001  PÄÄKIERTOPUMPPU YD11    E1                                     A            10 %
            ( 5) YD12E001  PÄÄKIERTOPUMPPU YD12    E1                                     A            10 %
            ( 6) YD13E001  PÄÄKIERTOPUMPPU YD13    E1                                     A            10 %
            ( 7) YD14E001  PÄÄKIERTOPUMPPU YD14    E1                                     A            10 %
            ( 8) YD15E001  PÄÄKIERTOPUMPPU YD15    E1                                     A            10 %
            ( 9) YD16E001  PÄÄKIERTOPUMPPU YD16    E1                                     A            10 %
            (10) YD11S009  INJEKTIVESI VUOTO F-SAV %                                      %            30 %
            (11) YD12S009  INJEKTIVESI VUOTO F-SAV %                                      %            30 %
            (12) YD13S009  INJEKTIVESI VUOTO F-SAV %                                      %            30 %
            (13) YD14S009  INJEKTIVESI VUOTO F-SAV %                                      %            30 %
            (14) YD15S009  INJEKTIVESI VUOTO F-SAV %                                      %            30 %
            (15) YD16S009  INJEKTIVESI VUOTO F-SAV %                                      %            30 %

              1      2      3      4      5      6      7      8      9     10     11     12     13     14     15
06.57.34   43.5    276    123    127    111    114    122    121    124     18     32     21     31     55     3
06.58.34   43.5    276    123    126    112    117    121    124    122     18     32     21     31     55     3
06.59.34   43.5    276    123    125    111    115    119    121    123     18     32     21     31     55     3
07.00.34   43.4    276    123    122    107    113    121    121    123     18     32     21     31     55     3
07.01.34   43.4    276    123    125    109    115    120    125    121     18     32     21     31     55     3
07.01.54   43.4    276    123    121    107    114    116    122    120     18     32     21     31     55     3
07.02.14   43.4    276    123    126    110    118    123    124    126     18     32     21     31     55     3
07.02.34   43.4    276    123    126    112    114    122    119    121     18     32     21     31     55     3
07.02.54   43.4    276    123    122    109    115    120    120    121     18     32     21     31     55     3
07.03.14   43.4    276    123    125    113    114    122    122    123     18     32     21     31     55     3
07.03.34   43.4    276    123    124    113    116    123    121    125     18     32     21     31     55     3
07.03.54   43.4    276    123    125    109    114    126    120    124     18     32     21     31     55     3
07.04.14   43.4    276    123    121    111    114    122    117    125     18     32     21     31     55     3
07.04.34   43.4    276    123    123    106    116    121    121    121     18     32     21     31     55     3
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JSRP1V                 L02  JALKISELVITYSRAPORTTI  RYHMA 17                81-09-01 KLO 08 10    SIVU 0

              1      2      3      4      5      6      7      8      9     10     11     12     13     14     15
07.04.54   43.4    276    123    125    114    116    123    116    122     18     32     21     31     55     3
07.05.04   43.4    276    123    125    111    115    123    117    120     18     32     21     31     55     3
07.05.14   43.4    276    123    121    116    117    123    120    122     18     32     21     31     55     3
07.05.24   43.4    276    123    123    109    116    122    121    122     18     32     21     31     55     3
07.05.34   43.4    276    123    123    113    114    123    122    122     18     32     21     31     55     3
07.05.44   43.4    276    123    124    107    116    122    123    120     18     32     21     31     55     3
07.05.49   43.4    276    123    125    109    115    120    121    116     18     32     21     31     55     3
07.05.54   43.4    276    123    125    109    115    120    121    116     18     32     21     31     55     3
07.05.59   43.4    276    123    123    113    115    123    119    120     18     32     21     31     55     3
07.06.04   43.4    276    123    123    113    115    123    119    120     18     32     21     31     55     3
07.06.09   43.4    276    123    123    111    118    121    119    122     18     32     21     31     55     3
07.06.14   43.4    276    123    123    111    118    125    119    122     18     32     21     31     55     3
07.06.19   43.4    276    123    126    113    116    120    123    120     18     32     21     31     55     3
07.06.24   43.4    276    123    126    113    116    120    123    120     18     32     21     31     55     3
07.06.29   43.4    276    123    121    112    117    123    122    122     18     32     21     31     55     3
07.06.34   43.4    276    123    121    112    117    123    122    122     18     32     21     31     55     3
07.06.39   43.4    276    123    122    112    116    120    117    122     18     32     21     31     55     3
07.06.44   43.4    276    123    122    112    116    120    117    122     18     32     21     31     55     3

07.06.49   43.4    276    123    121    113    115    123    122    124     18     32     21     31     55     3
07.06.54   44.3    276    123    121    113    115    123    122    124     18     32     21     31     55     3
07.06.59   45.2    276    123    119    112    112      0    116    117     18     32     21     31     55     3
07.07.06   46.4    276    124    119    112    113      0    116    117     18     32     21     31     55     3
07.07.11   48.0    275    124      0      0      0      0    119      0     18     32     21     31     55     3
07.07.16   47.8    275    124      0      0      0      0    119      0     18     32     21     31     55     3
07.07.21   47.5    273    119      0      0      0      0    113      0     18     32     21     31     55     3
07.07.26   47.3    272    119      0      0      0      0    113      0     18     32     21     31     55     3
07.07.31   47.0    271    119      0      0      0      0    110      0     18     32     21     31     55     3
07.07.36   46.7    270    118      0      0      0      0    110      0     18     32     21     31     55     3
07.07.41   46.4    269    118      0      0      0      0    108      0     18     32     21     31     55     3
07.07.46   46.2    268    117      0      0      0      0    108      0     18     32     21     30     55     3
07.07.56   45.5    265    117      0      0      0      0    110      0     17     32     21     30     55     3
07.08.06   44.8    263    117      0      0      0      0    108      0     17     32     21     30     55     3
07.08.16   44.1    262    116      0      0      0      0    112      0     17     32     21     30     54     3
07.08.26   43.5    261    116      0      0      0      0    110      0     17     32     21     30     54     3
07.08.37   42.7    260    116      0      0      0      0    109      0     17     32     21     30     54     3
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APPENDIX E;2/2

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JSRP19                 LO2  JALKI[illegible]  RYHMA 17                 01-09-01 KLO 08.10   SIVU 0

               1      2      3     4     5     6     7     8     9    10    11    12    13    14    15
07.08.47    42.1    259    116     0     0     0     0   106     0    17    32    21    30    54    34
07.08.57    41.5    258    116     0     0     0     0   117     0    16    32    21    30    54    34
07.09.17    40.4    258    116     0     0     0     0   108     0    16    32    21    28    54    34
07.09.38    39.3    257    116     0     0     0     0   102     0    16    32    21    28    54    34
07.09.58    38.5    255    115     0     0     0     0   112     0    16    32    21    26    54    34
07.10.18    37.6    253    115     0     0     0     0   111     0    16    32    21    26    54    34
07.10.38    36.7    251    114     0     0     0     0   107     0    16    32    19    26    54    34
07.10.58    35.8    249    114     0     0     0     0   108     0    16    30    19    27    54    32
07.11.18    34.9    247    114     0     0     0     0   112     0    16    29    17    27    54    32
07.11.38    34.0    246    114     0     0     0     0   111     0    16    29    17    27    54    30
07.12.39    31.9    242    114     0     0     0     0   112     0    15    29    18    28    54    29
07.13.39    29.6    238    120     0     0     0     0   112     0    16    30    20    28    54    31
07.14.39    28.1    234    120     0     0     0     0   109     0    15    32    21    29    54    33
07.15.39    26.5    231    121     0     0     0     0   109     0    17    32    21    29    55    35
07.16.39    25.0    227    122     0     0     0     0   107     0    17    32    21    29    55    34

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Appendix F includes parameters of group 30

- (1): total vapor generation rate of steam generators YB11, 15 and 13; transducer RA10F801
- (2): total vapor generation rate of steam generators YB54, 52 and 56; transducer RA50F801
- (3): opening rate of turbine by-pass valve RC11; transducer RC11S003
- (4): opening rate of turbine by-pass valve RC12; transducer RC12S003
- (5): opening rate of turbine by-pass valve RC51; transducer RC51S003
- (6): opening rate of turbine by-pass valve RC52; transducer RC52S003

APPENDIX F;1/2

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USRE24                     L02 JALKI[illegible] RYHMA 50                      81-09-01 KLO 08.25  SIVU 01

                           TALLETUSSIGNAALI [illegible] TURPIINI 1           GA PIKAS
                           TALLETUSHETKI    81-09-01 KLO 07.06.58

                                                 PS4    PS2    PO1    PO3          KERAILYVALI
          ( 1) HA10F801  HOYKEH 11/15/13 SUMMA  F                            KG/S        ** S
          ( 2) HA50F801  HOYKEH 54/52/56 SUMMA  F                            KG/S        ** S
          ( 3) HC11S003  TURB SA10 UHITUSSAV    S                            %            5 S
          ( 4) HC12S003  TURB SA10 UHITUSSAV    S                            %            5 S
          ( 5) HC51S003  TURB SA50 UHITUSSAV    S                            %            5 S
          ( 6) HC52S003  TURB SA50 UHITUSSAV    S                            %            5 S
          ( 7) RD10P001  7 BAR TUKKI            P                            BAR         60 S
          ( 8) RD40P001  5BAR TUKKI             P        4.20   5.20         BAR         60 S
          ( 9) RD70P001  7/9 BAR TUKKI          P                            BAR         60 S
          (10) LC00S002  OMAKAYTTOKOY  44/5 SAV S                            %           40 S
          (11) RU52S002  OMAKAYTTOKOY  44/7 SAV S                            %           10 S
          (12) RU33S002  OMAKAYTTOKOY  44/7 SAV S                            %           10 S
          (13) RU72S002  OMAKAYTTOKOY  44/7 SAV S                            %           10 S
          (14) RU73S002  OMAKAYTTOKOY  44/7 SAV S                            %           10 S

              1      2      3      4      5      6      7      8      9     10     11     12     13     14
06.57.34    400    390      0      0      0      0    6.9   4.74    7.6     1      1      2      3      0
06.58.34    399    388      0      0      0      0    6.9   4.74    7.6     1      1      2      3      0
06.59.34    398    391      0      0      0      0    6.9   4.74    7.6     1      1      2      3      0
07.00.34    399    390      0      0      0      0    6.9   4.74    7.6     1      1      2      3      0
07.01.34    399    393      0      0      0      0    6.9   4.72    7.7     1      1      2      3      0
07.02.14    400    392      0      0      0      0    6.9   4.73    7.7     1      1      2      3      0
07.02.34    397    391      0      0      0      0    6.9   4.73    7.6     1      1      2      3      0
07.02.54    400    391      0      0      0      0    6.9   4.73    7.6     1      1      2      3      0
07.03.14    399    392      0      0      0      0    6.9   4.74    7.6     1      1      2      3      0
07.03.34    399    391      0      0      0      0    6.9   4.74    7.7     1      1      2      3      0
07.03.54    401    389      0      0      0      0    6.9   4.74    7.7     1      1      2      3      0
07.04.14    399    392      0      0      0      0    6.9   4.74    7.7     1      1      2      3      0
07.04.34    399    393      0      0      0      0    6.9   4.74    7.7     1      1      2      3      0
07.04.54    400    392      0      0      0      0    6.9   4.74    7.7     1      1      2      3      0
07.05.04    401    391      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
```

```
USRE24                     L02 JALKI[illegible] RYHMA 50                      81-09-01 KLO 08.25  SIVU 0

              1      2      3      4      5      6      7      8      9     10     11     12     13     14
07.05.14    397    393      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.05.24    400    392      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.05.34    404    390      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.05.44    402    392      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.05.54    399    394      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.04    399    394      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.09    400    393      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.14    400    393      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.19    401    392      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.24    401    392      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.29    399    392      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.34    399    392      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.39    400    389      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.44    400    389      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.49    399    392      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.54    399    393      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0
07.06.59    398    392      0      0      0      0    6.9   4.75    7.7     1      1      2      3      0

07.07.06    353    318      7     16      0      0    6.9   4.74    7.7     1      1      2      3      0
07.07.11    353    318     41     44    100     40    6.9   4.74    7.7     1      1      2      3      0
07.07.16    353    318     30     33    100     31    6.9   4.74    7.7     1      1      2      3      0
07.07.21    197    120     23     26    100     23    6.9   4.74    7.7     1      1      2      3      0
07.07.26    197    130     16     16    100     16    6.9   4.74    7.6     1      1      2      3      0
07.07.31    197    120      7     11    100      9    6.9   4.74    7.6     1      1      2      3      0
07.07.36    137     70      1      3    100           6.9   4.74    7.6     1      1      2      3      0
07.07.41    137     70      0      0    100      1    6.9   4.74    7.6     1      1      2      3      0
07.07.46     99     41      0      0    100      1    6.9   4.74    7.6     1      1      2      3      0
07.07.51     99     41      0      0    100      1    6.9   4.74    7.6     1      1      2      3      0
07.07.56     88     41      0      0    100      1    6.9   4.74    7.6     1      1      2      3      0
07.08.01     88     41      0      0    100      1    6.9   4.74    7.6     1      1      2      3      0
07.08.06     88     41      0      0    100      1    7.0   4.70    7.6     1      1      2      3      0
07.08.16     85     38      0      0    100      1    7.0   4.70    7.6     1      1      2      3      0
07.08.26     83     38      0      0    100      1    7.0   4.70    7.5     1      1      2      3      0
07.08.37     81     40      0      0    100      1    7.0   4.70    7.5     1      1      2      3      0
07.08.47     80     40      0      0    100      1    7.0   4.70    7.5     1      1      2      3      0
07.08.57     81     37      0      0    100      1    7.0   4.70    7.5     1      1      2      3      0
```

APPENDIX F;2/2

```
JSRP24                  LO2  JALKITULOSTUSRAPORTTI  RYHMA 30              81-09-01 KLO 08.25  SIVU 0

              1     2     3     4     5      6     7     8      9     10    11    12    13    14
07.09.17     81    27     0     0   100      1   6.5   4.66   7.5    1     1     2     3     0
07.09.38     82    27     0     0   100      1   6.5   4.66   7.2    1     1     2     3     0
07.09.58     81    24     0     0   100      1   6.5   4.66   7.2    1     1     3     3     0
07.10.18     80    25     0     0   100      1   6.1   4.60   7.2    1     1    10     3     0
07.10.38     82    27     0     0   100      1   6.1   4.60   7.0    1     1    20     3     0
07.10.58     83    27     0     0   100      1   6.1   4.60   7.0    1     1    36     3     0
07.11.18     85    34     0     0   100      1   6.3   4.54   7.0    1     1    53     3     0
07.11.38     85    37     0     0   100      1   6.3   4.54   7.4    1     1    62     3     0
07.11.58     81    26     0     0   100      1   6.3   4.54   7.4    1     1     2     5     0
07.12.38     80    27     0     0   100      1   6.3   4.48   7.1    1     1     2    26     0
07.13.39     73    25     0     0   100      1   5.8   4.39   6.4    1     1     2     2     0
07.14.39     71    21     0     0   100      1   5.5   4.11*  6.1    1     1     2     2     0
07.15.39     71    19     0     0   100      1   5.2   3.80*  5.8    1     1     2     2     0
07.16.39     70    20     0     0   100      1   4.9   3.76*  5.5    1     1     2     2     0

                    BINAARISUUREITTEN MUUTOKSET

07.09.18  RA54S006B02  TUORHYPUTKEN PARSUV        KIINNI
07.09.19  RA13S006B02  TUORHYPUTKEN PARSUV        KIINNI
07.09.23  RA15S006B02  TUORHYPUTKEN PARSUV        KIINNI
07.09.25  RA56S006B02  TUORHYPUTKEN PARSUV        KIINNI
07.09.26  RA11S006B02  TUORHYPUTKEN PARSUV        KIINNI
07.09.26  RA52S006B02  TUORHYPUTKEN PARSUV        KIINNI

                    BINAARISUUREITTEN ARVOT TALLETUSHETKELLA

      ( 1) RA10S001H01  P##HOYRYTUKIN  VAHVENT    KIINNI                              1
      ( 2) RA30S001H01  P##HOYRYTUKIN  VAHVENT    KIINNI                              1
      ( 3) RA11S001B02  TUOREHOYRY RA11 VAHUVE    KIINNI                              1
      ( 4) RA13S001B02  TUOREHOYRY RA13 VAHUVE    KIINNI                              1
      ( 5) RA15S001B02  TUOREHOYRY RA15 VAHUVE    KIINNI                              1
      ( 6) RA52S001B02  TUOREHOYRY RA52 VAHUVE    KIINNI                              1
      ( 7) RA54S001B02  TUOREHOYRY RA54 VAHUVE    KIINNI                              1
      ( 8) RA56S001B02  TUOREHOYRY RA56 VAHUVE    KIINNI                              1
      ( 9) RA11S002B02  TUOREHOYRY RA11 VAHUVE    KIINNI                              1
      (10) RA13S002B02  TUOREHOYRY RA13 VAHUVE    KIINNI                              1
      (11) RA15S002B02  TUOREHOYRY RA15 VAHUVE    KIINNI                              1

JSRP24                  LO2  JALKITULOSTUSRAPORTTI  RYHMA 30              81-09-01 KLO 08.25  SIVU 0

      (12) RA52S002B02  TUOREHOYRY RA52 VAHUVE    KIINNI                              1
      (13) RA54S002B02  TUOREHOYRY RA54 VAHUVE    KIINNI                              1
      (14) RA56S002B02  TUOREHOYRY RA56 VAHUVE    KIINNI                              1
      (15) RA10S002B02  P##HOYRYTUKIN SUV        (KIINNI   )                          0
      (16) RA30S002B02  P##HOYRYTUKIN SUV        (KIINNI   )                          0
      (17) RA11S005B02  TUOREHOYRYPUTKEN SUV     (KIINNI   )                          0
      (18) RA11S006B02  TUORHYPUTKEN PARSUV       AUKI                                0
      (19) RA11S007B02  TUOREHOYRYPUTKEN SUV      KIINNI                              1
      (20) RA13S005B02  TUOREHOYRYPUTKEN SUV     (KIINNI   )                          0
      (21) RA13S006B02  TUORHYPUTKEN PARSUV       AUKI                                0
      (22) RA13S007B02  TUOREHOYRYPUTKEN SUV      KIINNI                              1
      (23) RA15S005B02  TUOREHOYRYPUTKEN SUV     (KIINNI   )                          0
      (24) RA15S006B02  TUORHYPUTKEN PARSUV       AUKI                                0
      (25) RA15S007B02  TUOREHOYRYPUTKEN SUV      KIINNI                              1
      (26) RA52S005B02  TUOREHOYRYPUTKEN SUV     (KIINNI   )                          0
      (27) RA52S006B02  TUORHYPUTKEN PARSUV       AUKI                                0
      (28) RA52S007B02  TUOREHOYRYPUTKEN SUV      KIINNI                              1
      (29) RA54S005B02  TUOREHOYRYPUTKEN SUV     (KIINNI   )                          0
      (30) RA54S006B02  TUORHYPUTKEN PARSUV       AUKI                                0
      (31) RA54S007B02  TUOREHOYRYPUTKEN SUV      KIINNI                              1
      (32) RA56S005B02  TUOREHOYRYPUTKEN SUV     (KIINNI   )                          0
      (33) RA56S006B02  TUORHYPUTKEN PARSUV       AUKI                                0
      (34) RA56S007B02  TUOREHOYRYPUTKEN SUV      KIINNI                              1
```

Appendix G includes parameters of group 32

- (5): secondary pressure in steam line from steam generator YB11; transducer RA11P005

- (6): secondary pressure in steam line from steam generator YB13; transducer RA13P005

- (7): secondary pressure in steam line form steam generator YB15; transducer RA15P005

- (8): secondary pressure in steam line from steam generator YB52; transducer RA52P005

- (9): secondary pressure in steam line from steam generator YB54; transducer RA54P005

-(10): secondary pressure in steam line from steam generator YB56; transducer RA56P005.

APPENDIX G;1/2

```
JSRP26            L02 JALKISELVITYSRAPORTTI RYHMA 92                81-09-01 KLO 08.47  SIVU 0
                  ==================================

                  TALLETUSSIGNAALI 5A00G01U07 TURBIINI 1            SA PIKAS
                  TALLETUSHETKI    81-09-01 KLO 07.06.58

                                                E54    E52    P01    P03           KERAILYVALI
         ( 1) SP10E002  GENERAATTORI SP10    EP                        MW          10 S
         ( 2) SP50E002  GENERAATTORI SP50    EP                        MW          10 S
         ( 3) SU10Y010  TURBIINI 1           Y                         1/MIN       10 S
         ( 4) SU50Y010  TURBIINI 2           Y                         1/MIN       10 S
         ( 5) RA11P005  ENNEN SA10S01        P            40.0         BAR         10 S
         ( 6) RA13P005  ENNEN SA10S02        P            40.0         BAR         10 S
         ( 7) RA15P005  ENNEN SA10S03/S05    P            40.0         BAR         10 S
         ( 8) RA52P005  ENNEN SA50S03/S05    P            40.0         BAR         10 S
         ( 9) RA54P005  ENNEN SA50S01        P            40.0         BAR         10 S
         (10) RA55P005  ENNEN SA50S02        P            40.0         BAR         10 S

              1      2      3      4      5     6     7     8     9     10
06.57.34  + 229  + 225   3006   3008   43.1  43.2  42.8  42.8  43.2  43.1
06.58.34  + 230  + 226   3006   3004   43.1  43.2  42.9  42.9  43.2  43.1
06.59.34  + 229  + 226   3006   3004   43.1  43.2  42.8  42.8  43.2  43.1
07.00.34  + 230  + 225   3004   3004   43.0  43.2  42.8  42.8  43.1  43.1
07.01.34  + 230  + 225   3004   3001   43.0  43.1  42.7  42.7  43.0  43.0
07.02.14  + 229  + 225   3004   3004   43.0  43.2  42.8  42.7  43.1  43.0
07.02.34  + 231  + 225   3006   3004   42.9  43.1  42.7  42.7  43.0  43.0
07.02.54  + 230  + 225   3004   3004   42.9  43.1  42.7  42.7  43.1  43.0
07.03.14  + 229  + 226   3004   3004   43.0  43.2  42.7  42.7  43.1  43.0
07.03.34  + 230  + 226   3004   3004   43.0  43.1  42.7  42.7  43.1  43.0
07.03.54  + 231  + 225   3004   3004   43.0  43.1  42.7  42.7  43.1  43.0
07.04.14  + 230  + 225   3004   3004   43.0  43.2  42.7  42.7  43.1  43.0
07.04.34  + 230  + 226   3004   3004   43.0  43.1  42.7  42.7  43.0  43.0
07.04.54  + 229  + 226   3004   3004   43.0  43.1  42.7  42.7  43.1  43.0
07.05.04  + 229  + 226   3004   3004   42.9  43.2  42.7  42.7  43.1  43.0
07.05.14  + 230  + 226   3004   3004   43.0  43.1  42.7  42.7  43.1  43.0
07.05.24  + 230  + 226   3004   3004   42.9  43.1  42.7  42.7  43.1  43.0
07.05.34  + 230  + 222   3004   3001   43.0  43.1  42.7  42.7  43.1  43.0
07.05.44  + 229  + 225   3004   3004   43.0  43.2  42.7  42.7  43.0  42.9
```

```
JPRB26            L02 JALKISELVITYSRAPORTTI RYHMA 92                81-09-01 KLO 08.47  SIVU 0
                  ==================================

              1      2      3      4      5     6     7     8     9     10
07.05.54  + 229  + 226   3004   3004   42.9  43.1  42.7  42.7  43.0  43.0
07.05.59  + 229  + 225   3004   3004   42.9  43.1  42.7  42.7  43.0  43.0
07.06.04  + 229  + 225   3004   3004   42.9  43.1  42.7  42.7  43.1  43.0
07.06.09  + 229  + 225   3004   3001   42.9  43.1  42.7  42.7  43.1  42.9
07.06.14  + 230  + 225   3004   3001   42.9  43.1  42.7  42.7  43.1  42.9
07.06.19  + 230  + 225   3004   3004   42.9  43.1  42.7  42.7  43.1  43.0
07.06.24  + 229  + 225   3004   3004   42.9  43.1  42.7  42.7  43.1  43.0
07.06.29  + 229  + 225   3001   3001   42.9  43.1  42.7  42.7  43.1  42.9
07.06.34  + 230  + 225   3001   3001   42.9  43.1  42.7  42.7  43.0  42.9
07.06.39  + 230  + 225   3001   2999   42.9  43.1  42.7  42.7  43.0  43.0
07.06.44  + 230  + 225   3001   2999   42.9  43.1  42.7  42.7  43.0  43.0
07.06.49  + 230  + 226   3001   3001   42.9  43.1  42.7  42.7  43.0  43.0
07.06.54  + 227  + 226   3001   3001   42.9  43.2  42.7  42.7  43.1  43.0

07.06.59  + 227  + 192   2999   2999   44.5  43.2  44.4  44.2  43.1  44.4
07.07.06  + 178  + 192   2999   2999   44.5  45.2  44.4  44.2  44.9  44.4
07.07.11  + 178  +   0   2976   2959   49.0  45.2  49.0  48.8  44.9  48.9
07.07.16  +   0  +   0   2976   2959   49.0  48.7  49.0  48.8  48.0  48.9
07.07.21  +   0  +   0   2903   2884   48.1  48.7  49.2  47.8  48.0  47.9
07.07.26  +   0  +   0   2903   2884   48.1  47.9  48.2  47.8  47.3  47.9
07.07.31  +   0  +   0   2843   2811   47.3  47.9  47.4  47.0  47.3  47.1
07.07.36  +   0  +   0   2843   2811   47.3  47.3  47.4  47.0  46.8  47.1
07.07.41  +   0  +   0   2790   2747   46.8  47.3  46.9  46.6  46.8  46.7
07.07.46  +   0  +   0   2790   2747   46.8  46.7  46.9  46.6  46.3  46.7
07.07.51  +   0  +   0   2741   2665   46.2  46.7  46.3  46.0  46.3  46.1
07.07.56  -   0  +   0   2741   2665   46.2  46.1  46.3  46.0  45.8  46.1
07.08.06  +   0  +   0   2696   2630   45.5  45.5  45.6  45.[illegible]  45.1  45.5
07.08.16  +   0  +   0   2649   2576   44.8  44.8  45.0  44.7  44.4  44.8
07.08.26  +   0  +   0   2606   2525   44.1  44.1  44.3  44.0  43.7  44.1
07.08.37  +   0  +   0   2566   2476   43.5  43.4  43.6  43.4  43.1  43.4
07.08.47  +   0  +   0   2521   2425   42.7  42.7  42.9  42.6  42.3  42.7
07.08.57  +   0  +   0   2480   2378   42.1  42.1  42.3  42.0  41.7  42.1
07.09.17  -   0  +   0   2399   2290   41.0  41.0  41.1  40.7  40.6  40.9
07.09.38  +   0  +   0   2322   2202   39.2* 34.7* 39.1* 38.0* 35.4* 38.9*
07.09.58  +   0  +   0   2258   2132   21.9* 20.2* 21.4* 20.9* 19.2* 21.6*
07.10.18  -   0  +   0   2194   2066   12.3* 11.5* 11.7* 11.7* 11.1* 12.1*
```

APPENDIX G;2/2

```
JSRP26                    LO2  JAKSOLLVITYSHAVAKIII  NYRAN 3X                81-09-01 KLO 08.47  SIVU1

               1       2      3      4       5      6      7      8      9     10
07.10.38  +    0   +   0   2134   2004    7.1*   6.8*   6.6*   8.2*   8.2*   8.7*
07.10.58  +    0   +   0   2079   1946    4.3*   4.2*   3.7*   7.6*   7.7*   7.7*
07.11.18  +    0   +   0   2023   1891    2.6*   2.6*   2.3*   7.3*   7.4*   7.4*
07.11.38  +    0   +   0   1972   1839    1.7*   1.6*   1.3*   7.1*   7.2*   7.2*
07.11.58  +    0   +   0   1920   1790    1.1*   1.3*   1.0*   7.0*   7.1*   7.0*
07.12.38  -    0   +   0   1826   1698    1.0*   1.0*   1.0*   6.6*   6.8*   6.7*
07.13.39  -    0   +   0   1694   1572    1.0*   1.0*   1.0*   6.3*   6.4*   6.3*
07.14.39  +    0   +   0   1574   1461    1.0*   1.0*   1.0*   5.9*   6.1*   5.9*
07.15.39  +    0   +   0   1468   1363    1.0*   1.0*   1.0*   5.7*   5.6*   5.6*
07.16.39  -    0   +   0   1367   1273    1.0*   1.0*   1.0*   5.4*   5.5*   5.4*

             BINAARISUUREITTEN MUUTOKSET


             BINAARISUUREITTEN ARVOT TALLETUSHETKELLA
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11. ABSTRACT *(200 words or less)*

RELAP5/MOD2 simulations have been conducted for an overcooling type transient that occurred at the Loviisa Unit 2. The code assessment work in the report was based on the available plant data that were saved through the normal plant instrumentation into memory of the plant computer. The RELAP5 results matched well the main measured parameters, in particular if the general trends were examined. The biggest quantitative differences were found between calculated and measured values of the primary pressure and pressurizer water level. The importance of the modelling of the pressurized vessel wall was demonstrated when condensation on the wall alone was able to stop and turn down the pressure increase.

12. KEY WORDS/DESCRIPTORS *(L[illegible] phrases that will assist researchers in locating the report.)*

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Loviisa Unit 2
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