NUREG/IA-0008

International Agreement Report

Assessment Study of RELAP-5 MOD-2 Cycle 36.01: Based on the Doel-2 Steam Generator Tube Rupture Incident of June 1979

Prepared by
E. J. Stubbe

Tractionel
Rue de la Science 31
B-1040 Brussels, Belgium

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

October 1986

Prepared as part of
The Agreement on Research Participation and Technical Exchange
under the International Thermal-Hydraulic Code Assessment
and Application Program (ICAP)

Published by
U.S. Nuclear Regulatory Commission

Available from

Superintendent of Documents
U.S. Government Printing Office
P.O. Box 37082
Washington, D.C. 20013-7082

and

National Technical Information Service
Springfield, VA 22161

NUREG/IA-0008

International Agreement Report

Assessment Study of RELAP-5 MOD-2 Cycle 36.01: Based on the Doel-2 Steam Generator Tube Rupture Incident of June 1979

Prepared by
E. J. Stubbe

Tractionel
Rue de la Science 31
B-1040 Brussels, Belgium

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

October 1986

Prepared as part of
The Agreement on Research Participation and Technical Exchange
under the International Thermal-Hydraulic Code Assessment
and Application Program (ICAP)

Published by
U.S. Nuclear Regulatory Commission

NOTICE

EXECUTIVE SUMMARY

Severe plant transients following a Steam Generator Tube Rupture (SGTR) have a relative high probability of occurrence. Such transients provide a direct release path of contaminated coolant to the environment thereby breaching several barriers built in the concept, and induce a rather complex asymmetric plant behaviour.

Analyses of most of the reported SGTR events clearly show that there is substantial operator involvement required to mitigate the consequences of such events for which the operator could rarely follow prescribed procedures. Therefore, the operators had to rely on their skill and insight to bring the plant to a cold shutdown.

All the reported events of this type clearly demonstrate :

. a need to have better emergency response guidelines;
. a need to have a better manual control over safety systems such as the high pressure safety injection;
. a need to better understand the different phenomena which may determine the sequence of events.

The SGTR accident that occurred at the DOEL-2 plant on June 25th 1979 clearly demonstrated above features and triggered a need to acquire the tools and develop the needed skill to cope with these problems.

The resulting data and recordings made during this transient provide a valuable data base for assessing both code and code users, as real plant data are scarcely available and eliminate the scaling problems inherent in small scale test facility data for code assessment.

The code assessment work presented in this document was based on all the available data (from plant computer and plant recordings) from this incident. Although the initial plant conditions were well known, it must be emphasized that the quantity and the quality of the available data from real plants are by nature inferior to well instrumented test facility data. Furthermore, the timing and the intensity of the operator involvement during such transient were not readily available and had to be inferred from the available data.

The objective of this study was to assess the code RELAP-5 MOD-2 CYCLE 36.01 performance, preferentially based on the comparison of trends rather than comparison of absolute values.

The study revealed some important features of the code which can be summarised as follows :

1. The code is capable to simulate the observed phenomena reasonably well and can be used to predict similar transients. However, lack of precise boundary conditions does not allow one to quantify the error margin from this analysis.

2. The code performance is acceptable. The time step is constant and Courant limited for 99 % of the transient, and the execution time on a CYBER-176 is about 1.8 times the transient time. The mass error ratio remains negligible.

3. Impressive improvements over RELAP-5 MOD-1 CYCLE 19 have been observed in the steady break flow rate, and the water vapour flow slip (CCFL) in the pressuriser when pressuriser spray is actuated.

4. Excessive water level swell observed in the intact S.G. during cooldown may be attributed to excessive interphase momentum transfer in the S.G. riser region when bulk boiling is initiated.

5. Excessive interphase mass and heat transfer for condensation and evaporation in quasi stagnant flow conditions was observed in the vapour space of the isolated affected steam generator.

6. Erratic natural circulation in the affected steam generator leads to an anomalous cooldown capacity of the steam generator. This behaviour can be suppressed by inserting high form loss factors in the natural circulation flow path.

7. While some anomalies may be reduced by a judicious choice of the nodalisation and/or code options, this study suggests that further improvements in the constitutive equation package, in function of the various flow regimes is needed to take full benefit of the potential of a 6 equation code.

ABSTRACT

This report presents a code assessment study based on a real plant transient that occurred at the DOEL 2 power plant in Belgium on June 25th 1979.

DOEL 2 is a two-loop WESTINGHOUSE PWR plant of 392 Mwe. A steam generator tube rupture occurred at the end of a heat-up phase which initiated a plant transient which required substantial operator involvement and presented many plant phenomena which are of interest for code assessment.

While real plant transients are of special importance for code validation because of the elimination of code scaling uncertainties, they introduce however some uncertainties related to the specifications of the exact initial and boundary conditions which must be reconstructed from available on-line plant recordings and on-line computer diagnostics.

Best estimate data have been reconstructed for an assessment study by means of the code RELAP5/MOD2/CYCLE 36.01. Because of inherent uncertainties in the plant data, the assessment work is focussed on phenomena whereby the comparison between plant data and computer data is based more on trends than on absolute values. Such approach is able to uncover basic code weaknesses and strengths which can contribute to a better understanding of the code potential.

This work was performed by TRACTIONEL, being the Architect-Engineer for all DOEL plants, in cooperation with the utility EBES which owns and runs these plants.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

1. INTRODUCTION

Severe plant transients following a Steam Generator Tube Rupture (SGTR) have a relative high probability of occurrence (ref. 1). Such transient provide a direct release path of contaminated coolant to the environment thereby breaching several barriers built in the concept, and induce a rather complex asymmetric plant behaviour.

Analyses of most of the reported SGTR events clearly show that there is substantial operator involvement required to mitigate the consequences of such events for which the operator could rarely follow prescribed procedures. Therefore the operators had to rely on their skill and insight to bring the plant to a cold shutdown.

All the reported events of this type clearly demonstrate :

. a need to have better emergency response guidelines;
. a need to have a better manual control over safety systems such as the high pressure safety injection;
. a need to better understand the different phenomena which may determine the sequence of events.

The SGTR accident that occurred at the DOEL-2 plant on June 25th 1979 clearly demonstrated above features and triggered a need to acquire the tools and develop the needed skill to cope with these problems.

The resulting data and recordings made during this transient provide a valuable data base for assessing both code and code users, as real plant data are scarcely available and eliminate the scaling problems inherent in small scale test facility data for code assessment.

The code assessment work presented in this document is based on all the available data (from plant computer and plant recordings) from this incident. Although the initial plant conditions are well known, it must be emphasized that the quantity and the quality of the available data from real plants are by nature inferior to well instrumented test facility data. Furthermore, the timing and the intensity of the operator involvement during such transient are not readily available and have to be inferred from the available data.

Hence the objective of this study is to assess a code performance preferentially based on the comparison of trends rather than comparison of absolute values.

After a brief description of the plant characteristics (chapter 2) and the anatomy of the SGTR transient (chapter 3), the plant nodalisation for the code RELAP-5 MOD-2 is discussed in chapter 4.

The base case results are described in chapter 5 followed by a discussion of these base case results in chapter 6, and of the sensitivity results in chapter 7. Chapter 8 briefly presents some run statistics.

2. DOEL-2 PLANT AND SYSTEM DESCRIPTION

This section provides a description of the plant and principal systems relevant to understanding the DOEL-2 steam generator tube rupture event during the first hour following the tube rupture. Principal plant components and systems associated with the event include the reactor coolant system, the high pressure safety injection system, portions of the charging and letdown system, the secondary side steam and auxiliary feedwater systems including the power operated atmospheric steam dump valves.

DOEL-2 is a WESTINGHOUSE 2 loop pressurized water reactor (PWR) rated at 392 MWe (NET) and commissioned in 1975, for which TRACTIONEL was the architect/engineer. This plant is part of the twin concept with DOEL-1, as they share some common engineered safety system such as the high pressure safety injection system (HPSI).

2.1. Reactor coolant system

A flow schematic of the reactor coolant system (RCS) is presented in fig. 2.1. The reactor vessel (2R1) is equipped with 2 reactor coolant loops (A and B) comprising each 1 steam generator (2E1A, 2E1B) and 1 main coolant pump (2P1A, 2P1B).

DOEL-2 is equipped with a 8ft core consisting of 121 fuel assemblies with 179 fuel rods per assembly (outside cladding diameter is 10.79 mm). The nominal core power is 1187 MWth. The primary coolant pumps, with a rated power of 2.44 MW each maintain a loop flowrate of 3628 kg/s with a net pump head of 4.275 bar.

A 24 m^3 pressuriser (2R2) is connected by a 10" surgeline to the "B" loop hot leg.

Two pressuriser spray lines connect the pressuriser spray nozzle with both cold legs, yielding a maximum total spray flow of 1500 l/min under nominal conditions when spray valves are fully open (2PR001, 2PR002 and 2PR006).

The pressuriser is equipped with pressuriser heaters (proportional + back-up) with a total maximum power of 850 kW. The heaters are switched off automatically when the pressuriser level drops below 20 % .

2.2. High pressure safety injection (SI)

The Doel 1-2 plants are equipped with a common HPSI system consisting of 4 motordriven pumps, which through a system of valves and interconnected piping can feed cold water from the refueling water storage tanks into both cold legs of the RCS and also directly into the downcomer of the reactor vessel.

Fig. 2.2 shows a flow schematic of the HPSI system.

Fig. 2.3 and 2.4 illustrate the flow delivery curves of the HPSI system in function of the reactor backpressure for the cases with and without DOWNCOMER injection respectively.

Fig. 2.5. gives the pump characteristic of the HPSI pumps.

The HPSI pumps are actuated on generation of a SI signal. For this event, the SI signal was generated at low - low pressuriser pressure (117 bar) and pumps start feeding cold water when reactor pressure drops below the high head cut-off pressure of the HPSI pumps (108 bar).

2.3. Doel 2 charging and letdown system

The water inventory and primary water chemistry in the reactor coolant system is maintained by the charging and letdown system.

For the charging system, 3 positive displacement pumps take suction from the volumetric control tank and feed cold borated water via a regenerative heat exchanger into the cold leg of loop B.

The flowrate is normally controlled by the programmed water level in the pressuriser which controls the speed of the pumps. Normally only 1 pump is in operation. The flowrate per pump varies between 8.7 m^3/hr for lowest speed of 140 RPM to 14.7 m^3/hr at 234 RPM.

The charging system also provides the seal injection water for both main coolant pumps. Part of the seal water goes into the RCS and part returns to the charging system.

The letdown flow is controlled mainly by three orifices in a letdown line connected to the intermediate leg between S.G. and primary pump of loop B. The orifices are sized to discharge respectively 10, 10 and 20 t/hr. The backpressure is controlled by an automatic control valve.

The letdown is closed when the pressuriser water level decreases below 20 % .

Upon generation of a SI signal, phase A containment isolation is initiated which cuts off the compressed - air supply in the reactor building. The containment isolation valve in the letdown line, being a fail close valve, remains closed as long as the SI signal is not RESET.

2.4. Steam generators - Main steam lines - Auxiliary feedwater system

A schematic drawing of the Doel-2 main steam and auxiliary feedwater system is given in fig. 2.6.

The Doel-2 steam generators are U-type Westinghouse series 44 models, with a nominal heat transfer area of 4130 m^2 consisting of 3260 tubes (ϕ_{out} = 22.2 mm) with average length of 18.16 m.

The power-operated atmospheric steam dump valves are hydraulic operated valves each with a steam capacity of 5 % of the total plant steam flow (or 33.3 kg/s at 72 bar).

These valves (one per S.G.) are used to relieve minor pressure increases in the S.G., to avoid lifting the safety valves (6 per SG) and provide also a means of plant cooldown when the condenser is unavailable.

The main steam isolation valves (MSIV) are HOPKINSON valves. During the DOEL 2 event, both MSIV were closed during the heat-up phase and accident.

Also the main feedwater pumps were not operational at the moment the break occurred. The auxiliary feedwater system supplies cold feedwater to the S.G. when the main feedwater system in unavailable.

The system consists of 2 motor-driven auxiliary feedwater pumps (MPA and MPB) and one steam turbine-driven auxiliary pump (TP) (Fig. 2.6.). These pumps take suction from the auxiliary feedwater storage tank and suppletion water storage tank.

The auxiliary feedwater actuation logic is shown in fig. 2.7. The pump characteristics are shown in fig. 2.8. for one motor driven pump, and fig. 2.9 for the steam turbine driven auxiliary feedwater pump.

2.5. Plant diagnostics and uncertainty bands.

2.5.1. Measured plant parameters

Fig. 1 and 2 of annexe 1 illustrate the recorded temperatures

- hot leg loop A : sensor TR/2RC5 (see fig. 2.1.)
- hot leg loop B : sensor TR/2RC25
- cold leg loop A : sensor TR/2RC09
- cold leg loop B : sensor TR/2RC29

The precision of the temperature sensors is estimated at about 1.5 %

. Fig. 3 and 4 of annexe 1 illustrate the recorder pressures
  - RCS pressure : sensor PRA/2RC11 in hot leg A.
  - pressuriser pressure : sensor PICA/2PR61 in pressuriser.

The precision of the pressure sensors is estimated at ± 2 bar at the nominal system pressure resulting in an uncertainty of 1.3 %

. Pressuriser level (fig. 5 of annexe 1) : sensor LRCA/2PR11. The uncertainty band for the level gauge is estimated at 5 %

. Steam generator pressure
  - intact SG (fig. 6 in annexe 1) : sensor MS4A
  - affected SG (fig. 7 in annexe 1) : sensor MS4B. These sensors are located just upstream of the main steam isolation valves.

The tolerance on the S.G. pressure gauges is estimated at 3%

. Steam generator water level (narrow gauge)
  . intact SG (fig. 6 in annexe 1) : sensor FW9A
  . affected SG (fig. 7 in annexe 1) : sensor FW9B.

The tolerance on the S.G. level gauges is estimated at 16 %.

2.5.2. Recorder uncertainties

For the parameter values, a global recorder uncertainty of 3 % should be added to the instrument uncertainty.

For the timing, an estimated off-set of 2 min should be acounted for, from comparing time values in the computer listing to recorded times on figures 1 to 6 of annexe 1.

Furthermore, by comparing fig. 1 and fig. 2 of annexe 1, a large horizontal time shift (about 20 min) is evident due to improper adjustement of timing. Hence, some engineering judgment is required to synchronise the recorder data which can be done on the basis of some important events (time of break) and on the basis of the timing listed in the plant computer listing.

FIG. 2-1 - FLOW SCHEMATIC OF PRIMARY COOLANT SYSTEM

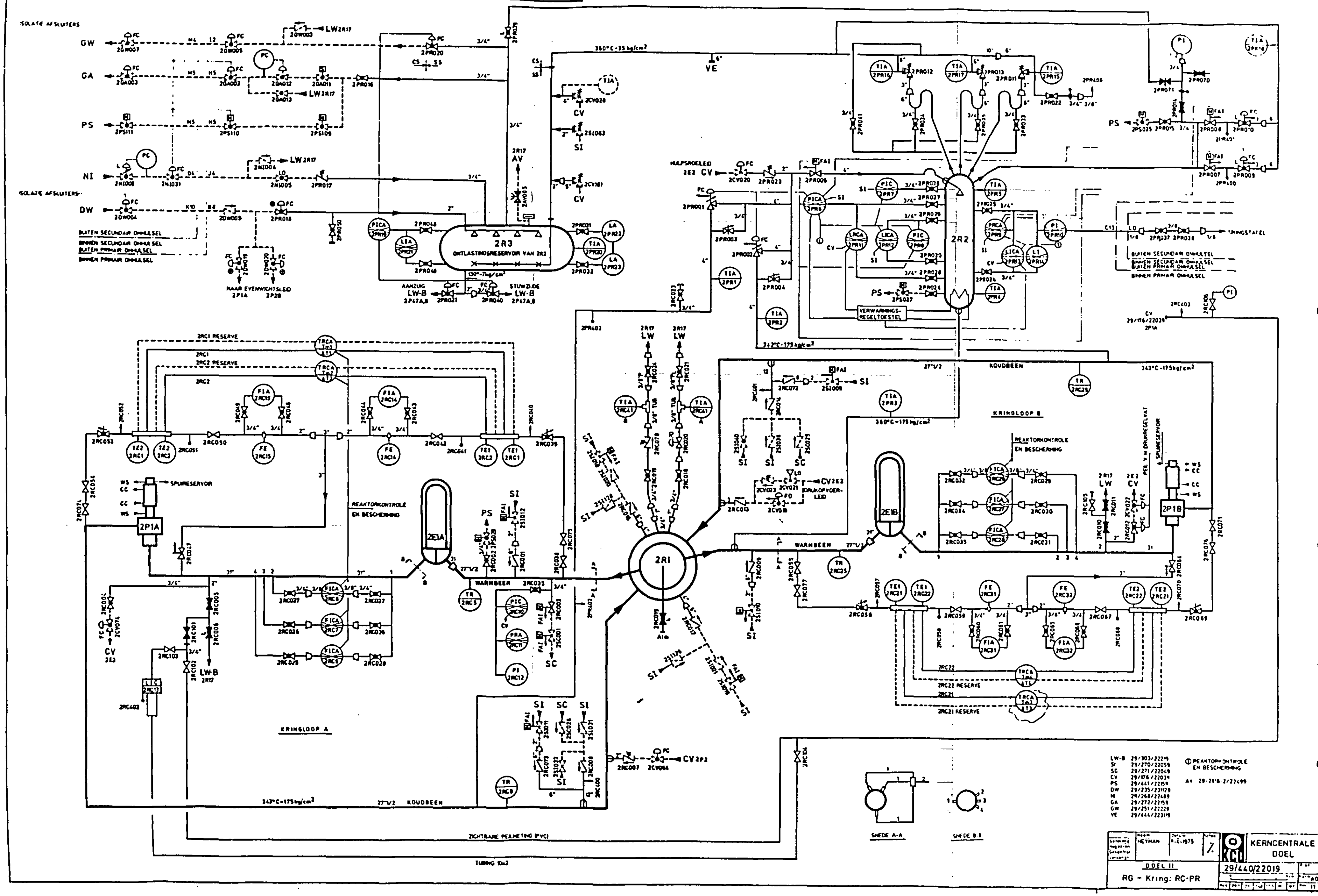


FIG 2.2 - FLOW DIAGRAM OF HIGH PRESSURE SAFETY INJECTION SYSTEM

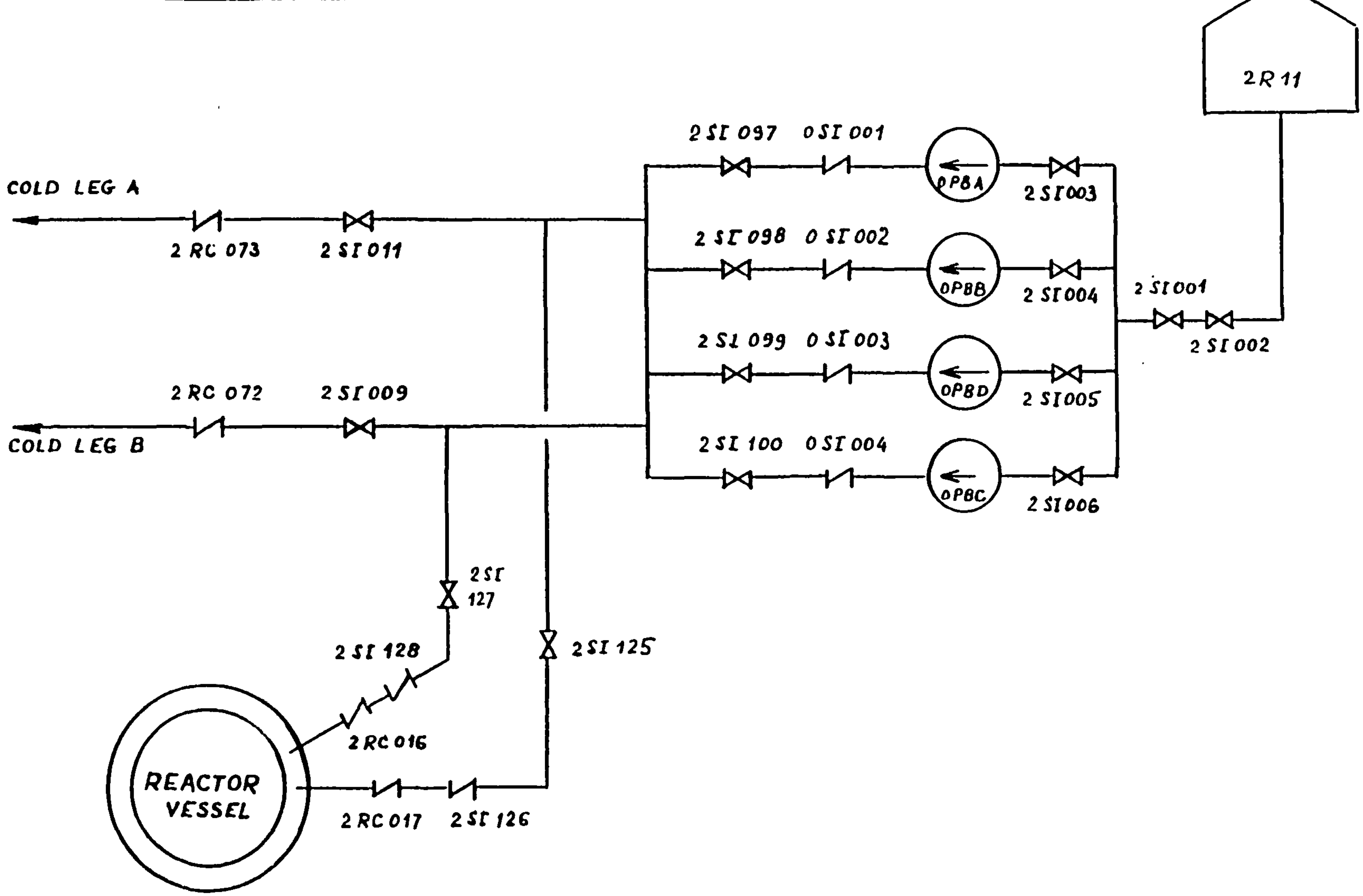


FIG.: 2·3 - DOEL 2 HPSI ECCS FLOW DELIVERY CURVES FOR FOUR LINES CONNECTING TO BOTH CL AND HL OR TO BOTH COLD LEGS AND VESSEL DOWNCOMER.

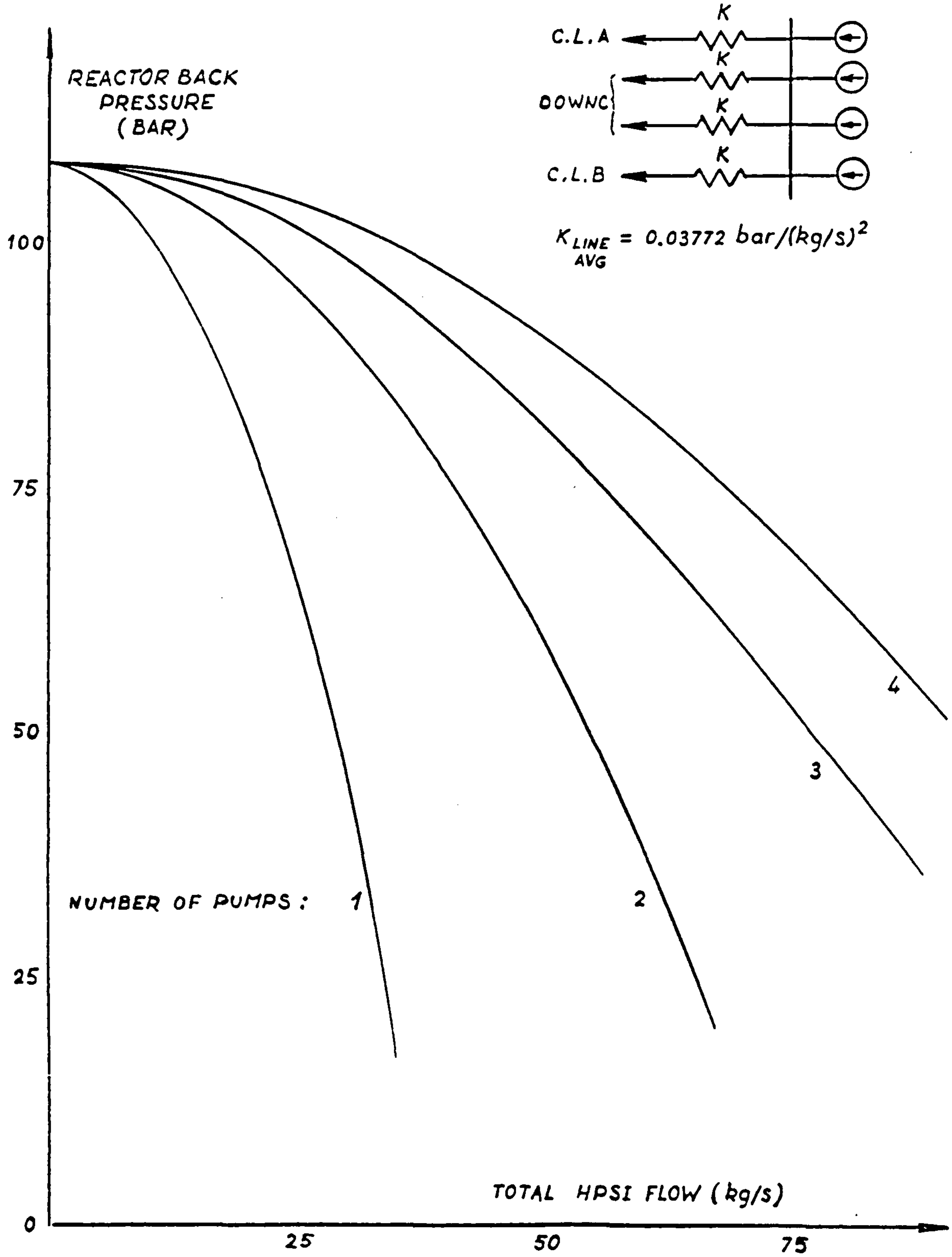


FIG 2.4 - DOEL 2 HPSI ECCS FLOW DELIVERY CURVES FOR TWO LINES TO BOTH COLD LEGS OPEN.

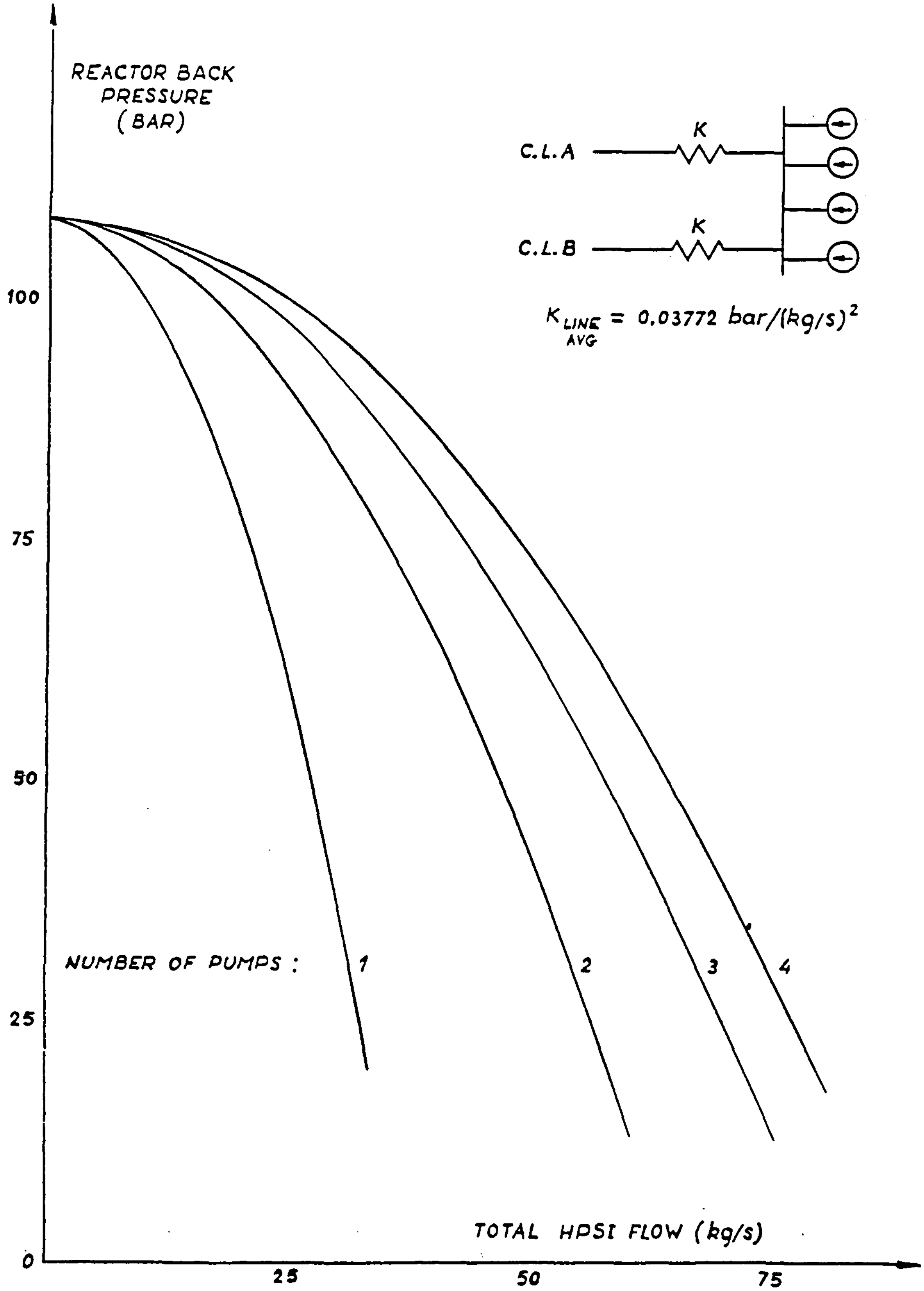


FIG 2.5 - HPSI PUMP CHARACTERISTIC (BEST ESTIMATE)

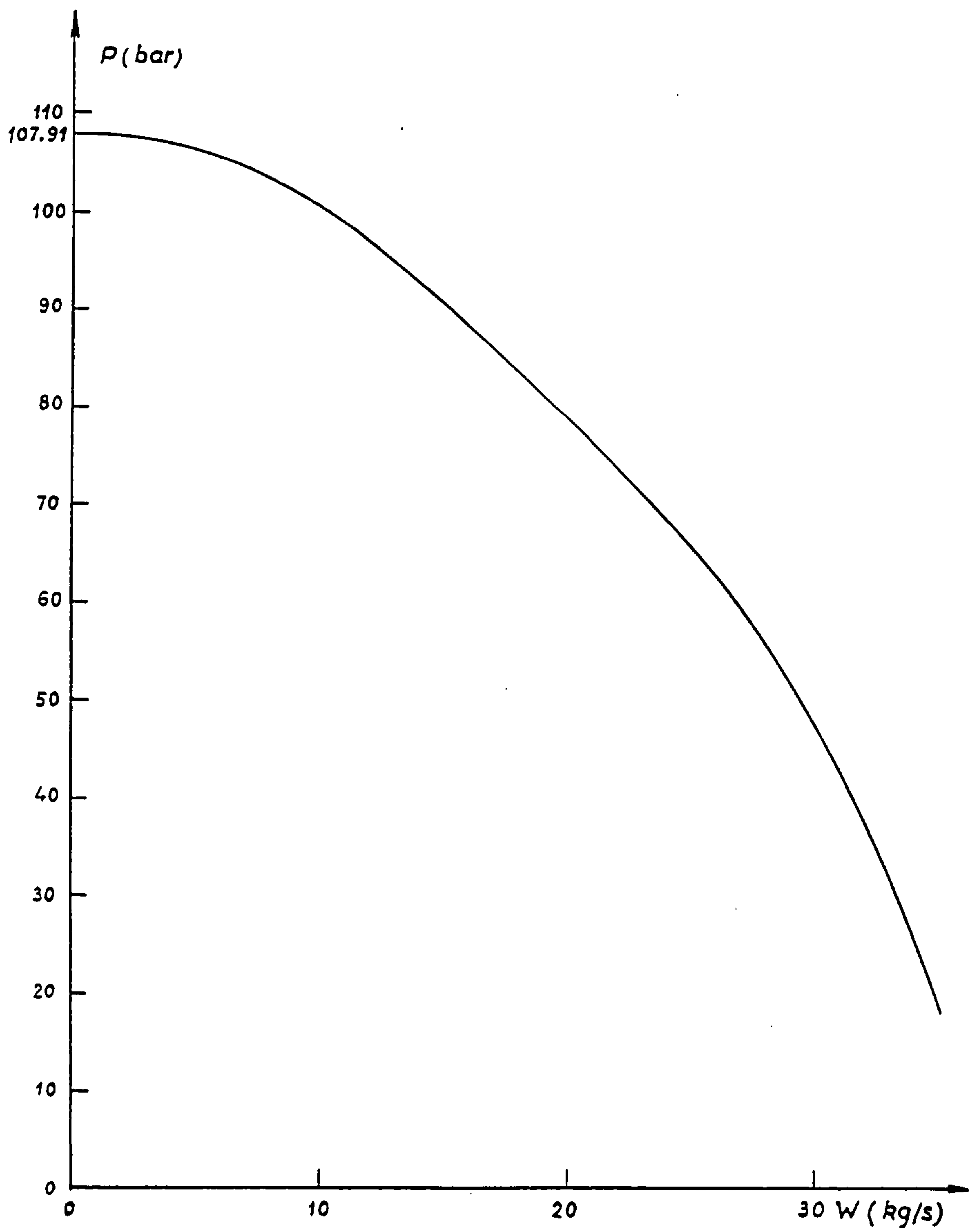


FIG 2.6: FLOW DIAGRAM OF THE AUXILIARY FEEDWATER SYTEM

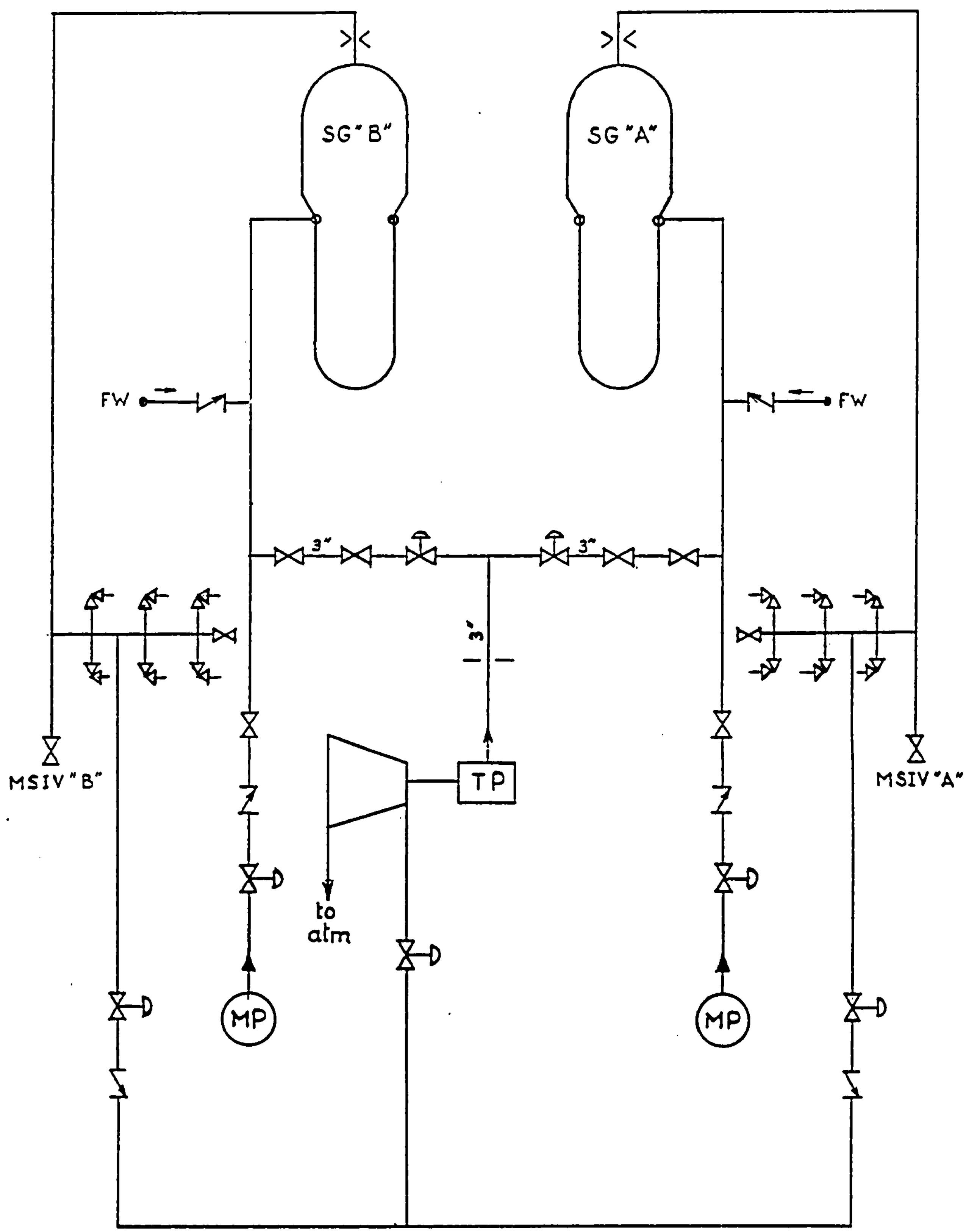
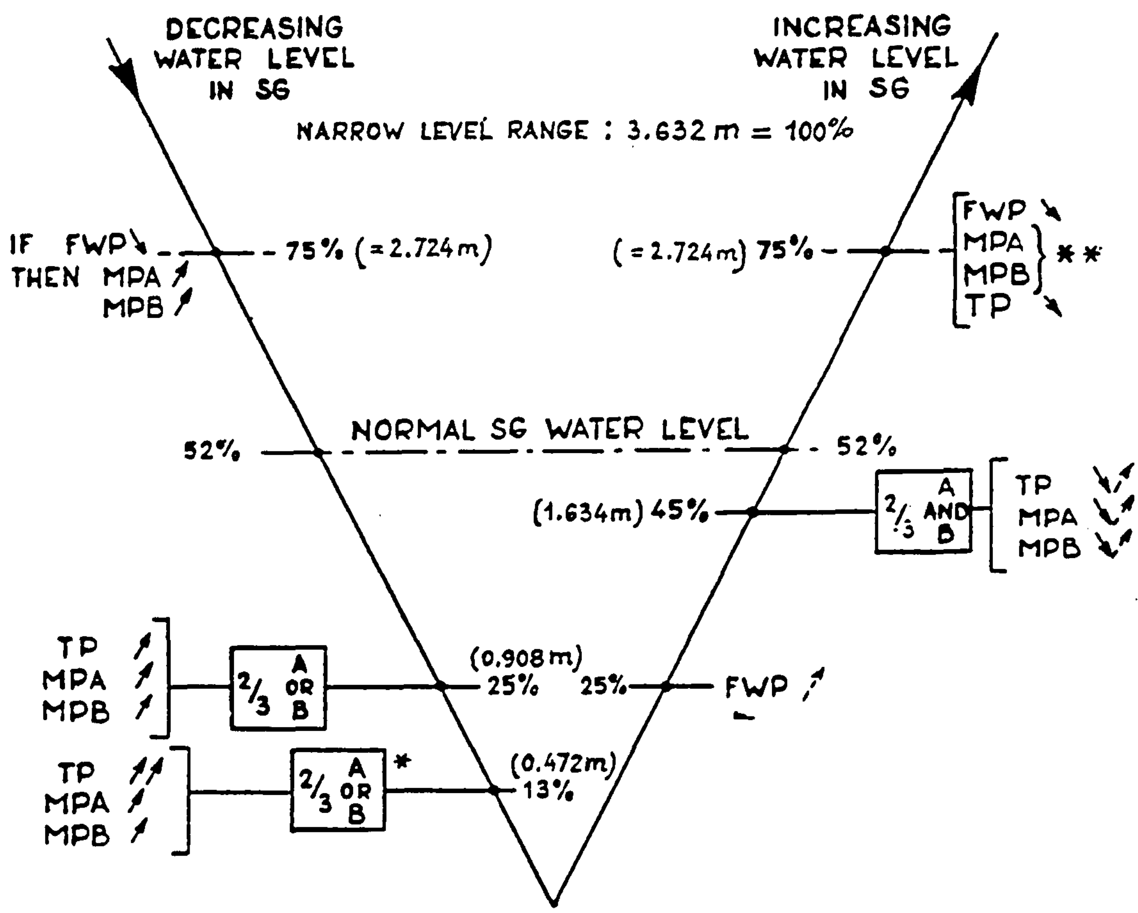


FIG 2.7 : AUXILIARY FEEDWATER ACTUATION TRIP

(for power levels > 20 %)

REF : DOEL 1708/95 REV. B (20.01.77). VOL. 1 - CHAP. 10



* : IF ALSO FW TEMPERATURE < 150°c THEN FWP ↘, FW VALVES ↘ FOR BOTH SG.

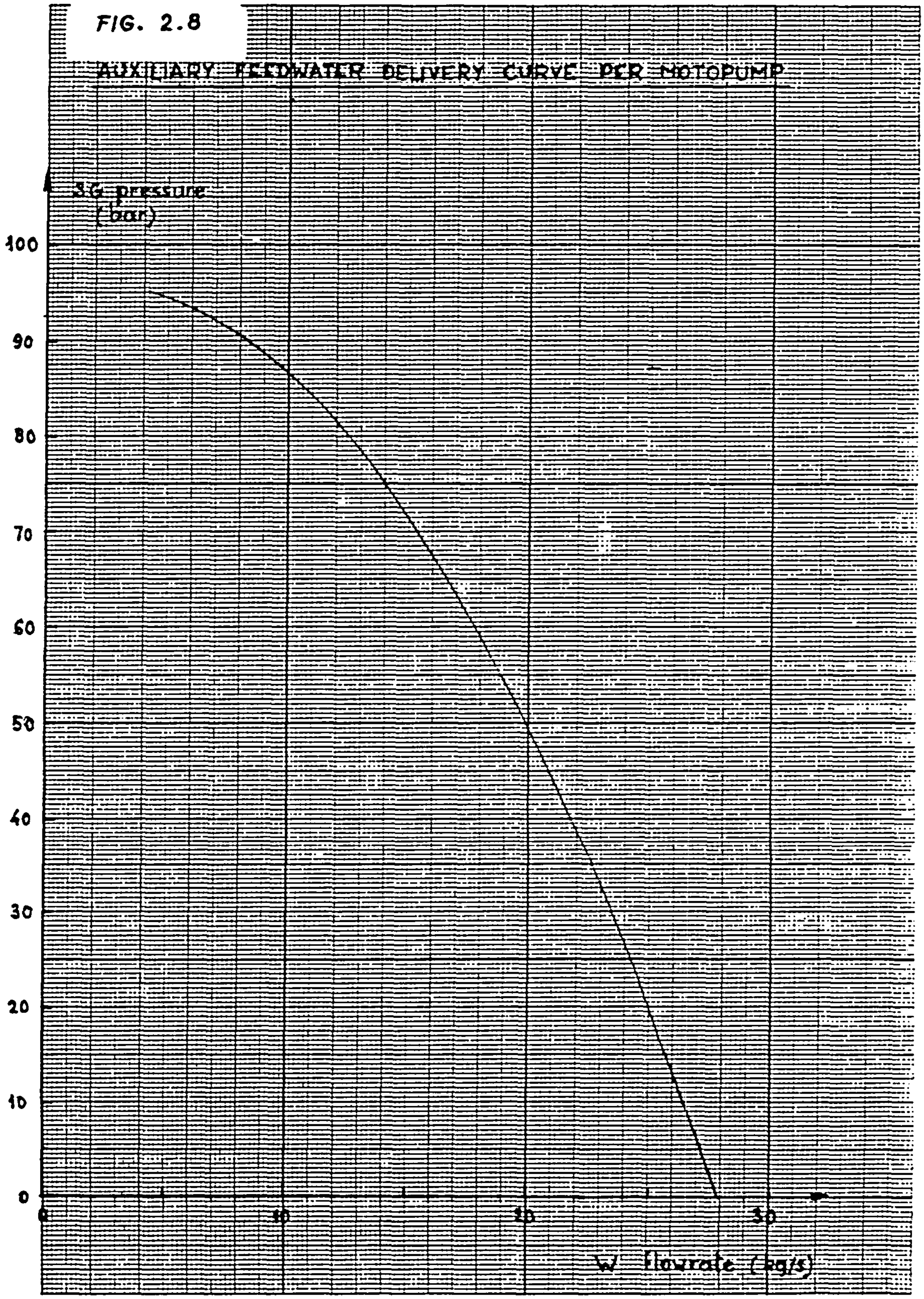
** : IF "SI" OR "DIESELS" TRIP IS SEQUENCED BY VITAL BUS LOADING LOGIC

SYMBOLS :

FWP	:	Feedwaterpumps
MPA	:	Motopump A
MPB	:	Motopump B
TP	:	Turbopump

↗	:	Automatic start	↘	:	Automatic TRIP
↗↗	:	Can't stop manually	↘↘	:	Can't start manually
↗ (dashed)	:	Can start manually	↘ (dashed)	:	Can TRIP manually

FIG. 2.8


AUXILIARY FEEDWATER DELIVERY CURVE PER MOTOPUMP
SG pressure
(bar)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
W flowrate (kg/s)

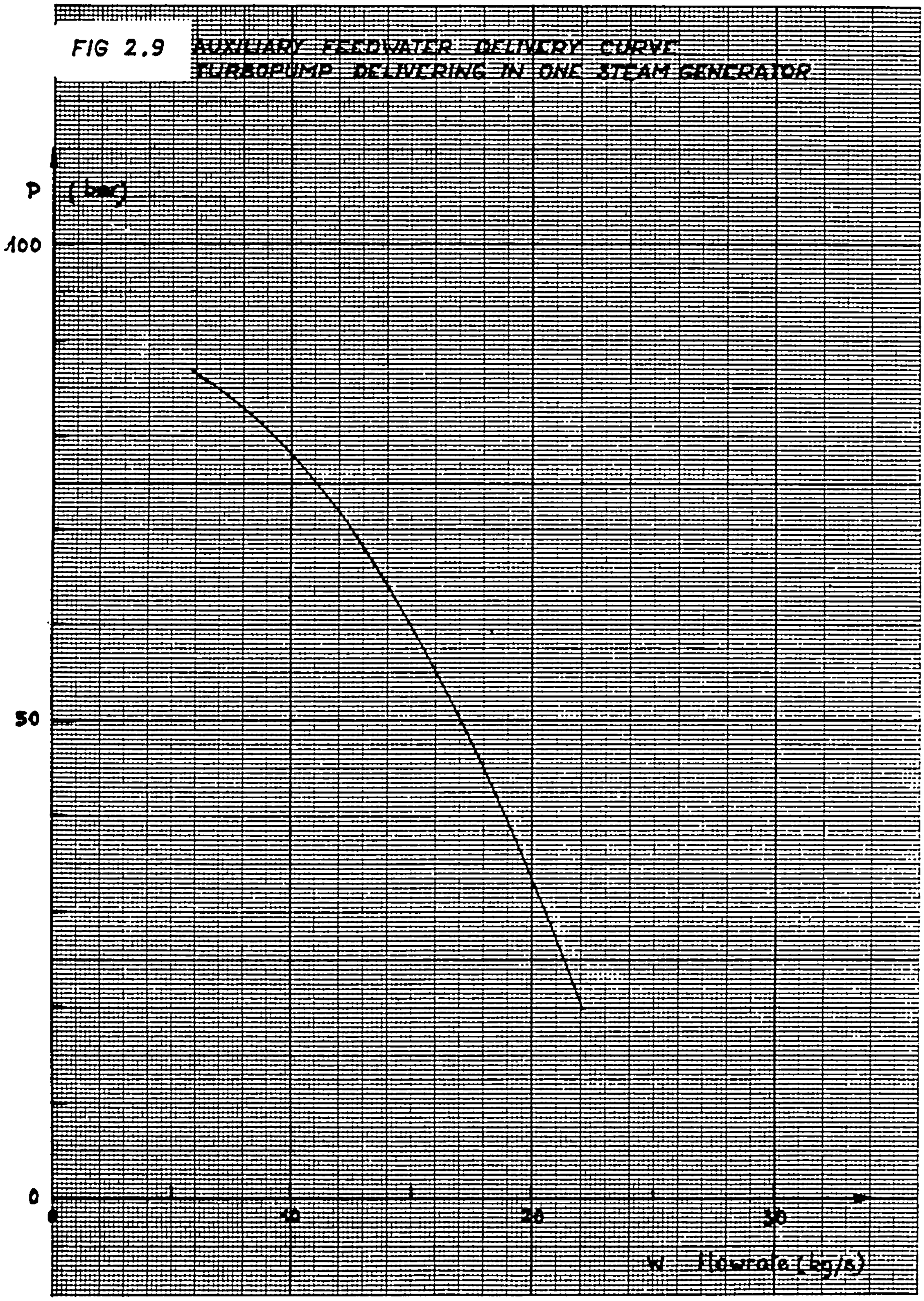


FIG 2.9 AUXILIARY FEEDWATER DELIVERY CURVE
TURBOPUMP DELIVERING IN ONE STEAM GENERATOR

3. ANATOMY OF THE PLANT TRANSIENT

Part of the material presented in this chapter, and chapters 5, 6 and 7 has been presented before at two meetings in the U.S.A. (References 2 and 3). Information presented in these references and essential for code assessment is repeated in this document for completeness sake.

A report on the incident was issued on October 25th, 1979 (see annexe 1). From the raw plant recordings (figures 1 to 7 of the annexe), figure 3.1 was reconstructed for the most important plant variables.

From the original plant computer records, relevant computer diagnostics were retrieved and shown in table 3.1.

From this information, the best estimate sequence of events and operator interventions, as shown in fig. 3.2, was reconstructed, and is used as the basis for the event simulation.

3.1. Plant status prior to the SGTR (fig. 3.1 prior to point A)

At the moment the event occurred on June 25th 1979, the primary system was being heated up after a 24 hour stop for repair work on the main steam isolation valves.

The pressure had reached the rated value of 155 bar, with a RCS temperature of about 255°C.

The water level in the pressuriser was kept constant at 25 % by the automatic control of the charging flow. For the letdown, two orifices of about 10t/hr each were available.

The reactor was subcritical with all control rods down. Both primary pumps were running and the pressuriser heaters were ON. On the secondary side, the steamlines were both isolated by the main steam isolation valves and no condenser vacuum was present. The main feedwater pumps were not operational and water level in both S.G.'s was manually controlled around 29 % level narrow band by means of the blowdown. The auxiliary feedwater pumps were not running.

The total heating power was about 11 MWth (2.5 MWth per primary coolant pump and 6 MWth decay heat).

3.2. Initiating event : (fig. 3.1, between points A and D)

At 19.20 hr (= t_0) a quick level decrease in the pressuriser and a pressure decrease (≈ 2.5 bar/min) in the RCS was observed followed by a demand for increased charging capacity, and closure of the letdown line when the pressuriser level dropped below 20 %

While the pressuriser level recording went off scale (point B) a quick level increase in the B loop steam generator was observed (point C).

When the radiation monitoring channels of the SG blowdown recorded a maximum activity level, the operator diagnosed within a couple of minutes the cause of the event to be a leak in the B steam generator.

Post examination of the failed tube revealed a longitudinal crack of about 7 cm long located in the U bend and most probably caused by stress corrosion cracking. The initial break flowrate was about 15 kg/s (300 gpm).

3.3. Mitigation phase (fig. 3.1., between points D and L)..

- The faulted S.G. was completely isolated on the steam side, but the isolation of the steam discharge to the turbo-pump was omitted.

- The atmospheric steam dump valve setpoint of the affected S.G. was set at maximum pressure to avoid steam release from this S.G.

. A third charging pump was started in an attempt to compensate the leak rate.

. By steam discharge to the atmosphere from the intact S.G. (point D), the operator started to cool down the plant, causing a decrease in temperature and a faster depressurization rate at t_0 + 15 min, in the RCS.

. At t_0 + 18 min, the operator tripped the primary pump of the affected loop to reduce the RCS heat input.

. At t_0 + 20 min, the safety injection signal was generated on low RCS pressure (117 bar) (point E) which caused the emergency diesels to start, initiated the containment isolation phase A, and caused ventilation isolation of the reactor building.

. When reaching a pressure of 107 bar in the RCS (point F) all four HPSI pump injection started and stabilized the RCS pressure.

. Steam discharge from the intact S.G. caused a water level drop below the low setpoint of 0.9 m on the narrow band level gauge (point G) and opened both steam discharge lines to the turbine driven auxiliary feedwater pump. This resulted in a quick pressure decrease of both S.G.'s (point H) followed by a rapid increase in the S.G.-A water level. The steam discharge from the affected S.G. through the turbine driven auxiliary feedwater pump was stopped about 8 min. later (POINT I) during which time about 1 ton of steam was released.

. In an attempt to reduce the leak rate by equilibrating the RCS pressure to the affected S.G., the operator started the primary pump B and used the full pressuriser spray capacity (point J) which caused a rapid drop of the RCS pressure. Vapour condensation in the pressuriser, combined with the full HPSI capacity caused a rapid increase in the water inventory such that the pressuriser water level went off scale high (point K) at which time the operator stopped the pressuriser spray. This caused the pressure to increase from 75 bar to the cutt-off head of the HPSI pumps and stabilized at 107 bar (Point L).

3.4. Safety injection cancelling phase (fig. 3.1 between L and R)

A further primary pressure decrease was mandatory to

. reduce the break mass flow rate and avoid flooding of the SG-B main steam lines;

. avoid the opening of the safety valves of the faulted S.G;

. start as soon as possible the shutdown cooling system (28 bar).

Therefore the operator first tried to cancel the S.I. signal in order to be able to trip the HPSI pumps. A circuit fault however did regenerate the S.I. signal on low RCS pressure after reset, each time requiring about 5 min before resetting. After about 20 min, the concerned bistables were flicked over manually which cancelled definitively the SI signal.

Three HPSI pumps were tripped (point M) and soon after (point N) the remaining pump was stopped after checking the subcooling margin. The RCS pressure dropped to about 65 bar (point O), for which pressure the charging system compensated the leak rate.
An attempt to open the letdown line failed as the isolation phase A also eliminated the compressed air supply in the reactor building.
It took the operator about 20 min to restore the air supply and to open the pneumatic isolation valves of the letdown line (POINT P).

After stopping a charging pump (point Q) the pressure decreased to the point where the residual heat removal system could be coupled to the reactor coolant system (point R).

TABLE 3.1.

SGTR : CHRONOLOGY OF EVENTS (PLANT COMPUTER)

Actual time	Elapsed time (s)	Computer diagnostic	Comment or set point
19.20.00.00	0.0	(rupture assumed)	L_{PR} = 25 %
19.22.50.47	170.47	demand for higher charging flow	$L_{PR} < 25$ %
19.23.15.67	195.67	pressure in pressuriser below reference	P_{REF} = 155 bar
19.23.30.67	210.7	PR heaters OFF	$L_{PR} \leq 20$ %
19.23.32.17	212.2	1st letdown orifice (closed/2CV024)	$L_{PR} \leq 20$ %
19.23.32.77	212.8	2nd letdown orifice (closed/2CV025)	$L_{PR} < 20$ %
19.23.36.37	216.4	Pressuriser low level alarm	$L_{PR} < 20$ %
19.23.37.57	217.6	Letdown valve 2CV022 closed	$L_{PR} < 20$ %
19.23.41.77	221.7	Pressuriser block valve 2PR008 closed	$P \leq 145$ bar
19.25.42.37	342.4	Spray valve PR008 closing	$P \leq 145$ bar
19.26.14.05	374.0	Low RCS pressure alarm	$p < 155 - 1.8$ bar
19.30.29.77	629.8	Low-low pressuriser pressure alarm	$p \leq 147$ bar
19.30.30.07	630.1	High level SGB (1/3)	$L_{SGB} \geq 65$ % (= 2,36m)
19.30.31.28	631.3	High level SGB (2/3) (L > 65 %)	$L_{SGB} \geq 65$ %
19.35.37.87	937.9	Computer saturation starts	
		start 3rd charging pump start cooldown with SG	} assumed
19.37.19.57	1039.6	Computer saturation stops	
19.38.31.65	1111.7	Reactor coolant pump B tripped	normal
19.38.59	1139.0	Low pressure in SGA	
19.40.17.88	1217.9	Pressuriser pressure < 118.5 kg/cm^2	P_{PR} 117 bar
19.40.19.18	1219.2	SCRAM (from SI generation)	
19.40.19.18	1219.2	Diesels start	
19.40.19.27	1219.3	High flow in MSB (at venturi)	

TABLE 3.1.
(continued)

SGTR : CHRONOLOGY OF EVENTS (PLANT COMPUTER)

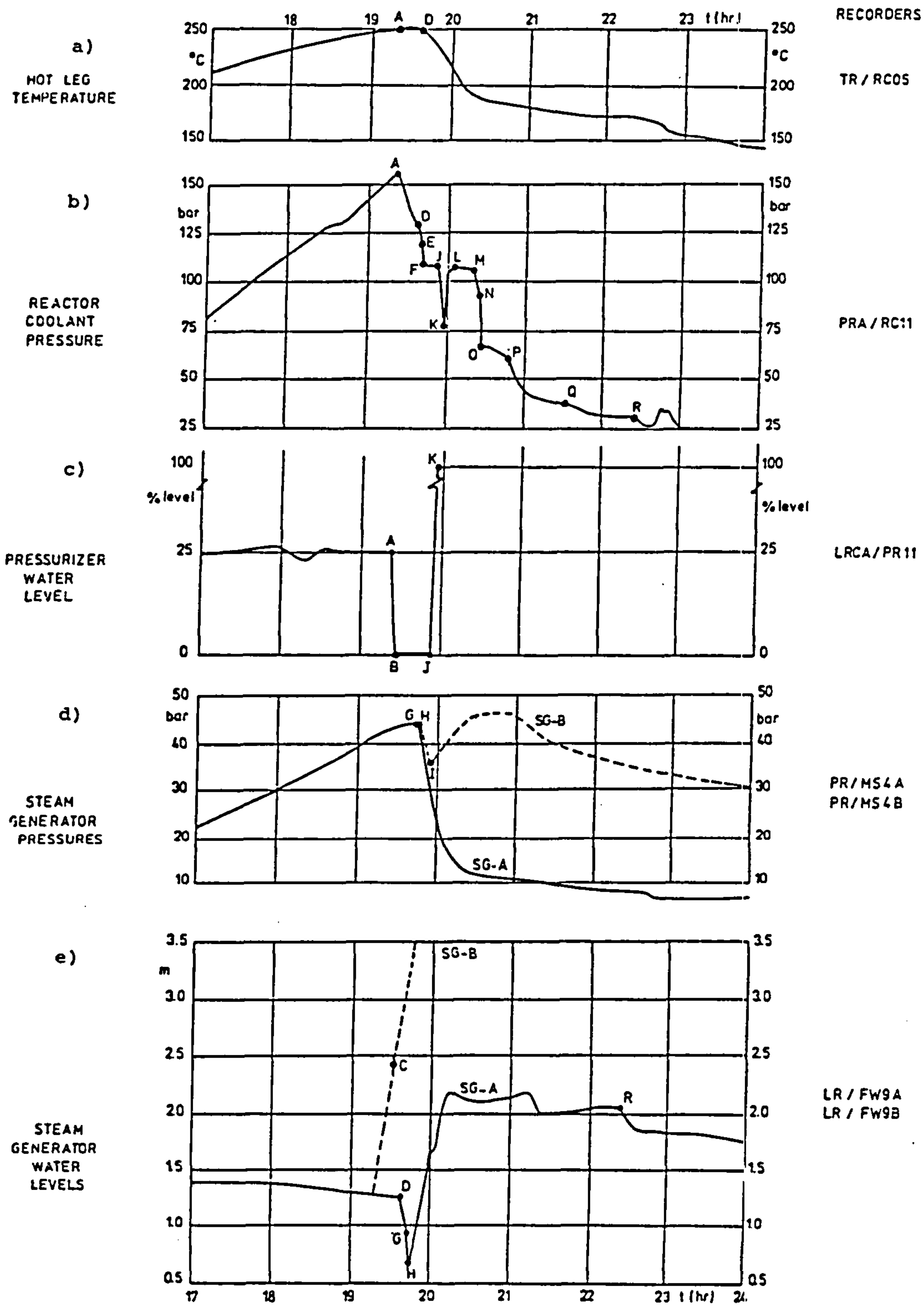
Actual time	Elapsed time (s)	Computer diagnostic	Comment or set point
19.40.19.27	1219.8	Ventilation isolation in containment	SI
19.40.19.57	1219.6	Containment isolation (phase A)	SI
19.40.23.49	1223.5	Start command SI pump D	SI
19.40.23.61	1223.6	SI pump D started	
19.40.23.66	1223.7	Start command SI pump A	SI
19.40.23.75	1223.8	SI pump A started	
19.40.23.77	1223.8	Isolation of compressed air	SI
19.40.24.19	1224.2	Safety injection alarm	SI
19.40.24.20	1224.2	Start command SI pump C	SI
19.40.24.31	1224.3	SI pump C started	
19.40.24.45	1224.5	High MS flow B stopped	
19.40.24.49	1224.5	Start command SI pump B	SI
19.40.24.60	1224.6	SI pump B started	
19.40.33.07	1233.1	Valve 2SI011 open	Cold leg A
19.40.33.37	1233.4	Valve 2SI009 open	Cold leg B
19.40.33.67	1233.7	Valve 2SI127 open	Downcomer
19.40.34.87	1234.9	Valve 2SI125 closed	Downcomer
19.42.04.27	1324.4	Computer saturation starts	
19.42.55.87	1375.9	Computer saturation stops	
19.43.48.32	1428.3	Very high AFW flow (2FW-51) to SGA	
19.44.02.47	1442.5	Low level in SGA	L $\leq$ 25 % (0,9 m)
19.44.39.14	1479	Very high AFW flow to SGB	
19.44.42.37	1482	Steam admission valve (SGB) to turbopump open	TP starts
19.44.50.77	1490.8	Steam admission valve (SGA) to turbopump open	TP starts
19.46.49.24	1609.2	Very high AFW to SGB	

TABLE 3.1.
(continued)
SGTR : CHRONOLOGY OF EVENTS (PLANT COMPUTER)

Actual time	Elapsed time (s)	Computer diagnostic	Comment or set point
19.46.22.70	1582.7	Low pressure in SGB	
19.46.28.87	1588.9	Low level in SGA	LSGA $<$25 %
19.46.40.05	1600.0	Low pressure in SGB	
19.48.01.15	1681.1	High AFW to SGB stopped	Trip turbopump
19.48.02.00	1682.0	Computer saturation starts	
19.53.12.00	1992	Computer saturation stops	
19.53.12.44	1992.4	Motopump B disarmed	Trip motopump B
19.55.05.72	2105.7	Start of primary coolant pump B	manual
19.56.33.67	2193.7	Reduce charging pump speed	P_R level normal
19.57.10.87	2231	Pressuriser level normal	$L_{PR} > 25$ %
19.57.28.57	2249	PR heaters on	
19.58.09.67 19.58.12.97	2287 2293	Spray valve 2PR001 closed Spray valve 2PR002 closed	spray stopped
19.58.33.07 19.58.33.67	2313 2314	Spray valve 2PR001 not closed Spray valve 2PR002 not closed	spray on
19.58.47.77	2328	High pressuriser level	$L_{PR} \geq 30$ %
19.59.37.17	2377	Very high pressuriser level	$L_{PR} \geq 70$ %
20.00.15.15	2415	Reset command all SI pumps	
20.00.15.16	2415	SI cancelled	
20.00.21.05	2421	SI generated	
20.03.20.77	2601	Spray valve 2PR001 closed	
20.03.24.07	2604	Spray valve 2PR002 closed	
20.03.52.57	2633	High level SGA	$L_{SGA} \geq 65$ %
20.05.05.00	2705	High level SGA (2/3)	$L_{SGA} > 65$ %

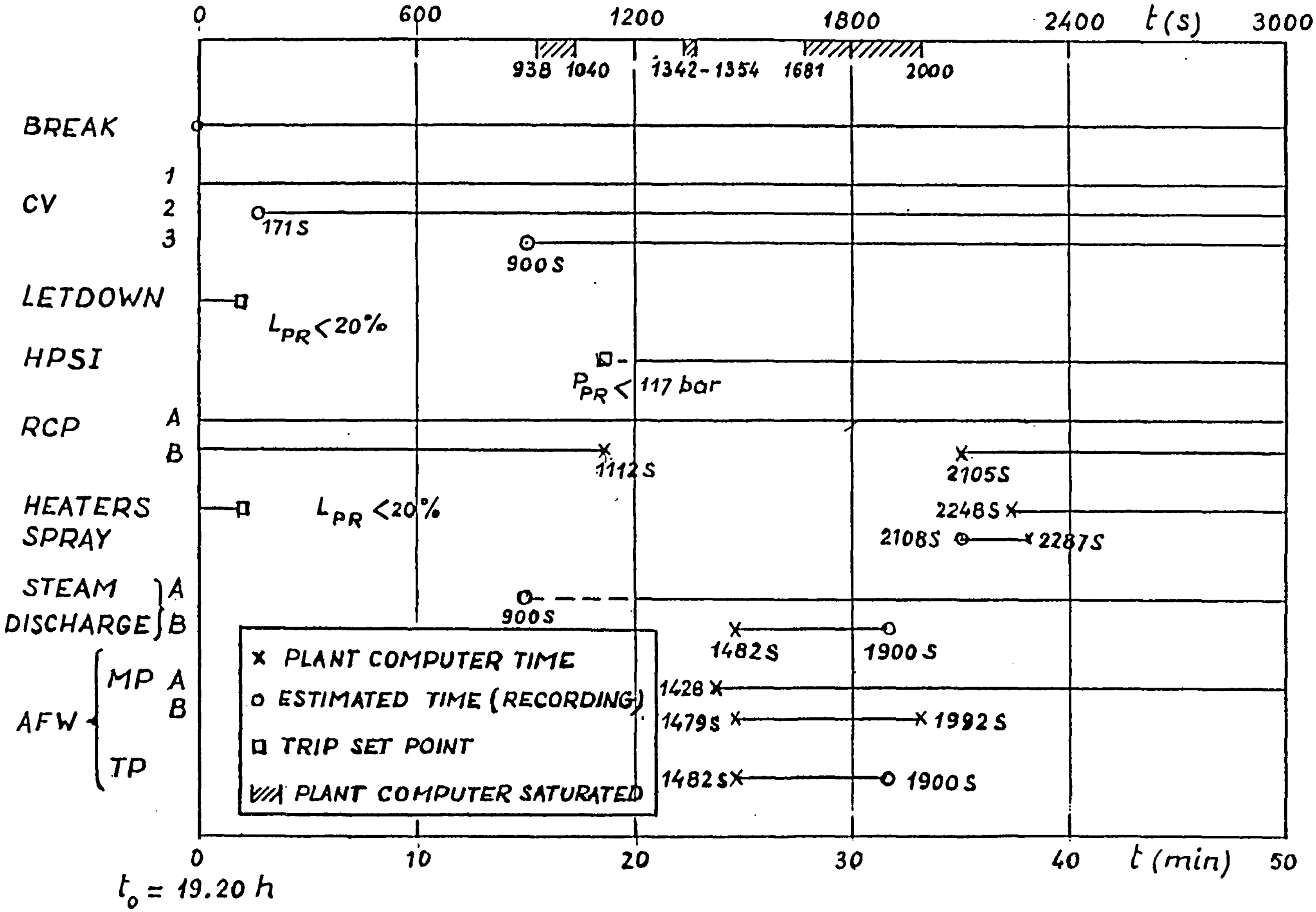
FIG 3.1

EVOLUTION OF SOME IMPORTANT SYSTEM PARAMETERS DURING TRANSIENT



DOEL 2 - SGTR INCIDENT 25 JUNE 1979

FIG 3.2 SEQUENCE OF EVENTS (DOEL 2 - SGTR 4)



4. CODE AND MODEL DESCRIPTION FOR PLANT SIMULATION

The code used was RELAP-5 MOD-2 cycle 36.01 and was processed on a CDC machine CYBER 176.

The simulation was performed over a period of 2700 s, starting at the estimated time of rupture at t_o = 19hr 20 min. (Point A on fig. 3.1) This period covers the most interesting plant transient phenomena.

The input data deck for the base case is joined in annexe 2.

In order to understand and interpret the main parameters of the input data deck, the general and special nodalisation features are described in this chapter.

The general nodalisation philosophy is a compromise between precision and economy. For the primary system, a minimum transport time of 0.15 s was selected, at nominal conditions, leading to a four volume representation of the core. The minimum length of the loops was taken to correspond to the length of the horizontal section of the cross over legs. In the U tube bundle, the number of axial nodes is based on a rule of thumb of about 2° ΔT per volume, in order to obtain an acceptable heat transfer and temperature drop between primary and secondary. This resulted in 10 axial nodes in the upgoing leg, and 5 axial nodes in the descending leg of the U tube bundle. This also sets the volume length in the riser of the S.G.

The simulation of the S.G. separator and dryer region was principally based on the RELAP-5 requirements for the mechanistic separator model, as recommended in the manual (Ref. 4).

The pressuriser nodalisation was chosen fine enough to accommodate large insurges and outsurges. All important structures were modeled as heat slabs in order to properly account for the important structural heat exchange between structures and fluid during important temperature (or pressure) changes in the system.

For completeness, also the heat release to the containment was accounted for.

This resulted in the nodalisation scheme as shown in fig. 4.1., consisting of 154 volumes, 158 junctions and 164 heat slabs (563 mesh points).

The remainder of this chapter explains the detailed nodalisation features for the

. reactor vessel
. primary loops
. S.G.
. pressuriser.

Furthermore, special nodalisation features are described for

. the leak simulation
. the high pressure safety injection system
. the charging and letdown system
. the pressuriser spray and heaters
. the S.G. atmospheric steam dump valve
. the auxiliary feedwater system.

4.1. <u>Nodalisation of the primary coolant system and S.G.</u>

The numbering logic for the RCS system is as follows :

a. reactor vessel components 010 - 099
b. B loop components 100 - 199
c. A loop components 200 - 299
d. pressuriser components 300 - 399
e. Steam generator (secondary components) : 600 - 699 (SGB)
700 - 799 (SGA)

Table 4.1. compares the calculated steady state conditions at 100 % power with the nominal plant values for most relevant parameters.

Table 4.2. summarises the geometrical data, in terms of free volume, coolant mass inventory at 100 % power and the structural mass inventory which are compared to nominal plant data (where available).

4.1.1. Reactor vessel nodalisation (volumes 011 - 099)

Table 4.3. summarises the dimensions of the hydrodynamic components corresponding to the volume arrangement shown in fig. 4.2.

Table 4.4. summarises the individual pressure losses in the reactor vessel from which the junction form loss factors are derived.

4.1.2. Nodalisation of the primary loops (volume numbers 111 - 153, 211 - 253)

Tables 4.5 and 4.6 summarize respectively the dimensions of the hydrodynamic components for the loops B and A.

The nominal pressure losses in primary loops (hot leg, intermediate legs and cold legs) amount to 0.31 bar.

Additional form loss factors have been added in the junctions of the intermediate legs, such that the frictional plus form losses in the primary piping add up to this nominal value.

4.1.3. Nodalisation of S.G. U tube bundle (volumes 121 - 125, 221 - 225).

The detailed nodalisation for 1 SG is shown in fig. 4.3. and table 4.7 summarizes the dimensions of the hydrodynamic components on primary and secondary side.

As seen in table 4.7, all U tubes have been globalised into one pipe with 10 volumes on the hot side (122/01 - 122/10) and 5 volumes on the cold side (124/01 - 124/05) with a total area of about 1 m^2. For the simulation of the leak, the volumes 122/09 and 122/10 have been replaced by 1 branch 123 in order to accommodate the leak junction.

The frictional pressure losses in the U tube bundle are based on a drawn tubing roughness of 0.1 micron and a hydraulic diameter 19.66 mm (inside diameter of 1 tube).

Additional form loss factors for contraction and expansion are added for the hemispherical bottom of the SG primary sides, in order to obtain a total pressure loss of 1.56 bar between inlet and outlet of a steam generator.

4.1.4. Simulation of the primary pumps (Vol. 140, 240).

The pump geometrical data are summarised in table 4.5.

Inlet-outlet form losses :

The pump inlet and outlet form losses are chosen to obtain the nominal loop pressure drop corresponding to the nominal pump head.

ΔP_f pressure vessel	:	2.16 bar
ΔP_f steam generator	:	1.56 bar
ΔP_f primary loops	:	0.31 bar
ΔP_f pump inlet-outlet	:	0.295 bar

		4.325 bar
Buoyancy head	-	0.050 bar

Nominal net pump head	:	4.275 bar

Pump hydraulic data :

- Since not enough data are available, the built-in WESTINGHOUSE PUMP model was selected as a best guess.

- The pump hydraulic torque, the motor torque and the frictional torque at nominal speed (990 RPM) are based on the nominal pump head (58 m), the volumetric flowrate (4.826 m^3/s) and the pump gross power (2.44 MW).

- The frictional torque at zero was taken from the measured value for cold water and adjusted to hot water conditions.

4.1.5. Pressuriser nodalisation

Table 4.8. summarises the geometrical data for the hydrodynamic components of the pressuriser and the surgeline.

The pressuriser spray is taken from volumes 152 and 252 in the cold legs and forced in volume 317 of the pressurizer, by means of 2 time dependent junctions (J345, J346) to correspond to a nominal maximum spray flow rate of 1500 l/min when spray valves are fully opened.

Fig. 4.4 provides pressuriser level data.

The pressuriser level taps are connected to a ΔP cell which effectively compares the weight of a reference water column to the weight of the water (and steam) in the pressuriser.

The electrical signal, corresponding to a pressure difference varies between 0 and 100 % for water level varying between lower tap and upper tap. Hence, one can write.

$$\text{Level (\%)} = 100 \times \frac{\Delta P_z - \Delta P_o}{\Delta P_{100} - \Delta P_o} = 100 \times \frac{\sum_i \rho_i g h_i - \rho_v g H}{\rho_l g H - \rho_v g H}$$

wherein : g = earth gravity

ρ = density

H = distance between level taps (= 8.243 m)

h = height of hydrodynamic volume

subscript i = index of hydrodynamic volumes in pressuriser

z = water level

v = vapour at saturated conditions

l = liquid at saturated conditions

o = 0 %

100 = 100 %

The pressuriser is equipped with various level measurement cells which are of two types :

a. cold calibrated at atmospheric pressure and 60°C.
In this case the values of the densities of water and vapour are constant at 1 bar and 60°C.

$$\text{Hence } L_c\ (\%) = 100 \times \frac{\sum_i \rho_i g h_i - \rho_v^c g H}{\rho_l^c g H - \rho_v^c g H} \qquad (a)$$

superscript c : cold calibrated conditions

b. Hot calibrated conditions at nominal power :
p = 155 bar (saturation)

$$\text{Hence } L_H\ (\%) = 100 \times \frac{\sum_i \rho_i g h_i - \rho_v^h g H}{\rho_l^h g H - \rho_v^h g H} \qquad (b)$$

superscript h = hot calibrated conditions

Since there is no adjustment for different fluid temperatures in the pressuriser, there can be a strong difference between the real (collapsed) water level and the measured level with the hot or the cold calibrated cells. This relationship is shown in fig. 4.5 for different fluid conditions in the pressuriser.

By means of the control variables, the various water levels are calculated in the program :

CNTRLVAR 900 : calculates the collapsed water level

CNTRLVAR 901 : calculates L_h (expression (b) above)

CNTRLVAR 902 : calculates L_c (expression (a) above)

using the summation control variable with

	HOT	COLD
$\text{gain} = \dfrac{1}{\rho_l gH - \rho_v gH}$	$2.515\ 10^{-5}$	$1.2459\ 10^{-5}$
$\text{constant} = -\rho_v\ gH$	- 8248 Pa	0

4.1.6. Nodalisation of the S.G secondary side.

Fig. 4.3. illustrates the correspondence between real S.G. volumes and RELAP-5 nodalisation.

Table 4.7. summarises the geometrical data for the various hydrodynamic components of the S.G. and the main steamlines up to the MSIV valves.

The single junction forward form loss factors are chosen in order to obtain a nominal recirculation of 6. This is mainly controlled by the junctions 617 (K_F = 3.3), 623Ø1 (K_F = 20.4), 623Ø2 (K_F = 1.0), and 623Ø3 (K_F = 1.81) around the separator.

Since strong reversed natural circulation was observed during some calculation, very large reverse form loss (K_F = 1000) factors were introduced in the downcomer, the junctions into the feedwater inlet plenum and the separator.

The S.G. outlet venturi was modelled in the outlet junction 630/01 with effective venturi area of 0.13 m^2 (K_F = 0.2269, K_R = 0.4969).

4.2. Special code models and options

This paragraph deals with some code models which were incorporated especially for simulating the SGTR event.

4.2.1. Steam generator B tube leak model.

The break junction is modelled as a single junction (J618) connecting the outlet of a pipe component (V 122) on the primary side to a branch component (V 621) on the secondary side. The cross flow junction option (S = 3) was used with an orifice type form loss (K_F = K_R = 2.6). With these options, the area of the junction was adjusted to a final value of 1.724 cm^2 for which the calculated water level rise in the affected S.G. matched the recorded data (fig. 3.1 - e). Since the plant was close to a hot shutdown condition without any normal feedwater addition, the resulting water level signal demonstrated almost a straight line from which the leak rate could be determined a posteriori with acceptable precision. The initial break flowrate determined in this way amounts to 14.9 kg/s (= 300 gpm), and the adjusted area of 1.724 cm^2 corresponds to about 57 % of the crosssectional area of 1 S.G. tube.

4.2.2. High pressure safety injection

From the plant computer information, it turned out that 1 SI valve for downcomer injection closed at t = 19.40.34.87. Shortly afterwards the plant computer was satured during 12 seconds and it is not known if the valve was opened manually. However, since the RCS pressure during the SI period stays close to the cut-off pressure of the HPSI pumps, one should infer that downcomer injection did take place with 4 SI lines to the primary.

Hence the programmed HPSI delivery curve used corresponds most likely to the configuration of figure 2.3. Owing to the uncertainty of direct downcomer injection, only two SI injection points were modelled in both cold legs. Hence, coldwater taken from TDV (170, 270) at 15°C, is injected for 50 % in cold leg A (TDJ 271) and 50 % in cold leg B (TDJ 171) with a RCS pressure flowrate dependance corresponding to the flow delivery curve of fig. 2.3 (4 pumps). The table trip number 571 simulates the generation of a SI signal when pressure in pressuriser drops below 117bar. The SI flowrate look-up table consists of a compensated RCS pressure (CNTRLVAR 070) and SI flowrate.

Instead of taking the local pressure at the injection points, for controlling the SI flow, the upper plenum pressure was taken (V043) combined with a numerical smoothing as follows :

$$P_{(SI)} = 0.9\ P_{OLD} + 0.1\ P_{043(NEW)}$$

This technique may introduce a lag time (7.5 seconds to 96 %) but avoids strong fluctuations in the SI flow due to strong pressure feedback between injection volume pressure and corresponding SI flow.

4.2.3. Steam generator A atmospheric steam dump valve

The steam relief capacity of this valve corresponds to 5 % of the total plant steam flowrate of 666 kg/s. The valve (V791) was modelled as a motorvalve for which the flow area was adjusted to yield the nominal relief capacity at nominal pressure (i.e. 33.3 kg/s at 72 bar) with $K_F = K_R = 1.0$.

The valve was programmed to open with a constant rate between 900 and 1200 s. The exact actuation of this valve is not recorded. In order to reduce excessive water level swell by sudden opening of this valve, a duration of 300 s was selected (see also chapter 7).

4.2.4. RCS charging and letdown system.

The charging and letdown flowrate were not monitored during the event, hence a best estimate reconstruction has been implemented, based on the plant conditions at the time of the break, and the plant computer data.

The plant is equipped with three volumetric charging pumps.
Per pump, the minimum charging flow is 8.7 m^3/hr (= 2.42 kg/s) at 140 RPM
the maximum charging flow is 14.7 m^3/hr (= 4.08 kg/s) at 234 RPM
One assumes that at the moment of the tube rupture, one charging pump was operational at 50 % flow capacity or 3,2 kg/s.
At on elapsed time of 170 s, the plant computer signals a need to start an additional charging pump, from which is inferred that the maximum charging capacity of 4.08 kg/s is reached in 170 s, and that a second charging pump is actuated at full speed (additional 4,08 kg/s). A third charging pump is added around 900 s (estimated time, since computer was saturated between 938 s and 1 040 s), for which again full speed was assumed in order to cope with the primary coolant inventory loss.

From the computer information, it is known that 2 letdown orifices of each 10 t/hr in nominal conditions, were open at time of the tube rupture. Furthermore, there exists also a leak path via the primary pump seals back to the CV tank.

The initial letdown flow was estimated from the required charging - letdown flow mismatch during the heat-up phase in order to maintain a constant water level in the pressuriser.

A total thermal heat input of 11.85 MWth (decay heat + 2 primary coolant pumps + pressuriser heaters) at a RCS pressure of 155 bar and 255°, would lead to an isobaric volumetric expansion of 4.38 10^{-3} m^3/s, which can be compensated by an excess letdown of 3.6 kg/s (density = 804 kg/m^3). Hence the initial letdown flow was taken at 3.6 + 3.2 = 6.8 kg/s and maintained constant until the letdown closes at 170 s.

It should be recognised that a maximum net charging flowrate of max. 12.24 kg/s is not much smaller than the initial estimated leak flow of 14.9 kg/s. The resulting pressuriser level evolution could hence be affected by a very large uncertainty.

4.2.5. Pressuriser spray and heaters

The pressuriser heaters are incorporated as a heat source of 850 kW in the heat slab bounding pressuriser volume 312. The actuation logic for the heaters is such that the heaters are switched off when the water level drops below 20 % (variable trip 580) and are switched on at an elapsed time of 2248 s (variable trip 542) conform to the plant computer data (fig. 3.2).

The pressuriser spray lines are simulated explicity, except for the spray flowrate which is controlled, not by the pressure head of the primary coolant pumps, but by 2 time dependent junctions (J 345, 346) in order to force a nominal spray flow of 1500 l/min when the spray valve is opened (see nodalisation on fig. 4.1.). The spray flow is injected in volume 317 which corresponds roughly to the elevation of the pressuriser spray nozzle.

From the computer data, there is no trace for the opening time of the spray. However, since the operator started the second primary coolant pump (at an elapsed time of 2106 s) in order to use full spray, it is assumed that the spray was initiated a few seconds after starting the primary pump (variable trip 529) and stopped at an elapsed time of 2287 s (variable trip 530) as registered by the plant computer.

4.2.6. Auxiliary feedwater system

The auxiliary feedwater motordriven pumps (one for each SG) are modelled by a TDV (605, 705) and a TDJ (607, 707) which inject cold water (35°C) in the SG's, at a rate controlled by the SG pressure (volumes 630, 730) conform to the delivery curves for each motordriven pump (fig. 2.7).

For the turbine driven pump, the auxiliary feedwater flow to both SG's and the steam flow to the turbine is evaluated by means of a complex turbine driven auxiliary feedwater pump control block (Fig. 4.6) conform to the flow schematic of fig. 2.6.

The turbine driven auxiliary feedwater pump flow to each SG depends on the SG back pressure (P_A, P_B) the pump head (P_p) and the flow resistances in the common branch, (Kp,c) and both individual branches (Kp,a and Kp,b) as follows :

$$W^2_{p,a} = \frac{P_p - P_A - K_{p,c} W^2_p}{K_{p,a}} \quad (a)$$

$$W^2_{p,b} = \frac{P_p - P_B - K_{p,c} W^2_p}{K_{p,b}} \quad (b)$$

Assuming a known turbine driven auxiliary feedwater pump head (Pp) and a total pump flow (Wp) from former cycle, the individual flows can be evaluated by means of control blocks 865,866 and 868 conform to eq. (a), and by means of control blocks 865,867 and 869 conform to eq (b). The total turbine driven auxiliary feedwater pump flow is then obtained in the adder 872.

Knowing the total pump flow, one then can evaluate the pump head (Pp) from the known pump characteristic :

$$P_p = \left(\frac{n}{n_o}\right)^2 P_{p,o} - K_p \left[W_p - \left(\frac{n}{n_o}\right) W_{p,o}\right]^2 \qquad (c)$$

wherein $P_{p,o}$ is the maximum pump head

$W_{p,o}$ is the net pump flowrate at max. pump head

K_p is the pump loss factor

n/no is the speed ratio of the turbine driven auxiliary feedwater pump

The expression (c) is evaluated in control blocks 880, 881 and 882. Knowing the total pump flow (Wp in block 872), one can also calculate the required pump power in blocks 874 and 875 conform to the expression (d) :

$$Vp = \left(\frac{n}{no}\right)^3 \left[Vp,f + d \left(\frac{no}{n}\right) Wp\right] \qquad (d)$$

Wherein Vp, f is the power required at zero flow (friction)
d is the power coefficient for given pump flow.

At this point one has to verify if the required pump power does not exceed the maximum turbine power which is controlled by the available steam flow to the turbine. Since such turbine is supposed to yield full power for a large range of steam pressures, the available steam from the SG is throttled down to 9 bar at the turbine inlet valve and one can reasonably assume that down to 9 bar in the SG's, the turbine can provide full power, which is rated at 368 kW.

Based on the general Rateau laws, one assumes that the power varies with the third power of the speed, and for required pump power above 368 kW (from d), the new speed ratio becomes:

$$\frac{368}{Vp} = \left(\frac{n}{no}\right)^3 \text{ with limit : } n \leq no$$

The actual speed radio is evaluated in control blocks 876, 877 and 878.

Finally, knowing the turbine power Vp, one can calculate the gross steamflowrate extracted from the SG at the highest pressure; according to the turbine power-flowrate characteristic (e) :

$$W_{v,T} = W_{v,e} + \frac{Vp}{\Delta H} \qquad (e)$$

Wherein : $W_{v,T}$ = Vapour flowrate to turbine

$W_{v,o}$ = Vapour flow not producing work (dissipation)
ΔH = enthalpy drop of steam expanding from 9 bar to atmosphere.

This is evaluated in control block 883 which gives the steamflow extracted from 1 SG (at highest pressure).

Direct feedback from outlet to inlet is applied for stabilisation purposes of some vital parameters such as Wp (872), Pp (882) and Vp (875), whereby the new value at the actual time step is based for 50 % on the output value of the preceeding step and for 50% on the new input parameters.

The actuation control logic for the auxiliary feedwater motor driven pumps and turbine driven auxiliary feedwater pump was not based on the water level program of fig. 2.6, for 2 reasons :

First, the operator has taken over the auxiliary feedwater system in the manual mode for some periods in the transients, and secondly, to avoid the feedback of discrepancies in the calculation of the water level into the operation of the auxiliary feedwater system (see also chapter 7).

Hence, the actuation logic for this system was based on the recorded timing for the start of the auxiliary feedwater system, and on a best estimate timing for the trip of the turbine driven auxiliary feedwater pump (logical trip 661 which goes into trip units 862 and 863 of the turbine driven auxiliary feedwater pump control logic).

1/2

Table 4.1 : Comparison between system nominal parameters and calculated steady state conditions (after stabilization)

Component	Variable	Units	Nominal		Calculated	Comments
G013/02 , 03	Primary coolant flow	kg/s	3628.		3626.7	
C 140 , C 240	Pump head	m	58.		58.	$\rho = 751.72$
C 140 , C 240	Pump speed	rad/s	103.67		103.67	fixed input
C 153 , C 111	ΔP reactor vessel	bar	2.16		2.156	
C 025 , C 041	ΔP core	bar	1.		0.992	
C 113/01, C 131/01	ΔP steam generator	bar	1.56		1.57	
(G011/02)/(G01302+03)	Vessel head bypass flow	%	0.24		0.25	
(G025/02)/(G023/01)	Core bypass flow	%	4.5		4.52	
T 013	Vessel inlet temperature	°C	287.3		287.3	
T 043	Vessel outlet temperature	°C	317.1		316.8	
T043 - T013	Δt core	°C	29.8		29.6	
P 112	System nominal pressure	bar	155.1		155.1	
CV610 + CV710	Total heat output	MW	1192.		1192.	

Table 4.1 : Comparison between system nominal parameters and calculated steady state conditions (after stabilization)

Component	Variable	Units	Nominal		Calculated	Comments
J609 , J709	Feedwater flowrate	kg/s	333.		333.	fixed input
J63401 , 73401	Steam flowrate	kg/s	333.		332.6	
T 610	Feedwater temperature	°C	230.		230.	fixed input
P 630	SG steam pressure	bar	58.8		59.	
CV 611 , 711	SG downcomer water level	m	11.662		11.69	
	recirculation ratio		(6)		5.7	
CV600, 700	SG water mass	kg	36220		36030	

TABLE 4.2

		FREE VOLUME (m^3)			WATER MASS (t) AT 100% POWER			STRUCTURAL MASS (t)			
		RELAP	NOMINAL	%	RELAP	NOMINAL	%	RELAP	NOMINAL	%	
1	Reactor vessel	56.302	56,77 58.	-0.8 +6.	40,453			300,64	214+90	1	
2	Hot legs	2.845	2.825	+0.7	1,956			8,70			
3	Cold legs	3.015	2.933	+2.8	2,268			9,21			
4	Pump suction legs	3.251	3.25	0	2,443			9,86			
5	Pump casing	7.757	7.758 11.072	0 -29.9	5,830			51,99	52	-0.02	
6	SG primary	26.762	26.74	+0.1	19,452			38.56			
7	Pressuriser	24.156	24.06	+0.4	8,480 1,007*			44,34	48	-7.6	
8	Surge line	0.650	0.6512	-0.2	439			2,87			
9	Total for primary coolant syst. (1 + 2 + 3 + 4 + 5 + 6 + 7 + 8)	168.368	170. 168.49	-1. +0.1	114,277			584,49			
10	SG secondary side	136.495	136,5	0	33.200 2,825*	{ 2820* 33400 39298	-0,54 -8,33	241.08			
11	Steam lines	97.132			2,900			99.91 103,37			
12	Collector	3.824			0,113			5.94			
13	Total for secondary side (10 + 11 + 12)	237.451			39,038			691.38			
14	Total for S.G component (6 + 10)	190.019	189,98	+0.02	55.477	58.	-4.35	279,64	280	-0.13	
15	Grand total	595.838			209.792			1835.15			

TABLE 4.3 : Summary of reactor vessel nodalisation (volumes)
(STEADY STATE 11/85)

Component	Area	Length	Volume	Watermass	Name	Type
n°	m^2	m	m^3	kg	——	——
011	2.169	1.584	(3.436)	2583	VDCOMER	BRANCH(2)
013	2.0874	0.872	(1.8202)	1368	INOZZLE	BRANCH(3)
015	1.41	4.083	(5.758)	4328	DOWNCOM	ANNULUS(3)
021	(4.199)	0.638	2.679	2014	VESBOT	SNGLVOL
023	(8.4)	0.638	5.359	4029	LMIXPL	BRANCH(3)
025	(3.528)	1.013	3.574	2687	CORINPL	BRANCH(2)
031	2.5	4[0.6095]	(6.095)	4333	CORE	PIPE (4)
035	(0.808)	2.438	1.9706	1481	CORBYPS	SNGLVOL
039	(3.821)	0.6085	2.3252	1600	COREX	BRANCH(3)
041	(5.692)	0.8965	5.103	3512	CORPLEN	SNGLVOL
043	(5.902)	1.584	9.349	6435	UPPLEN	BRANCH(3)
045	(5.904)	1.496	8.833	6083	DOME	BRANCH(1)
——	——	——	56.302	40453	——	——

( ) : data in brachets are not entered in input data, but are calculated by program from other intered data.

TABLE 4.4: SUMMARY OF REACTOR VESSEL PRESSURE DROP

Component numbers	Description		Nominal	Calculated
V153 - V111	ΔP vessel (bar)		2.165	2.156
W02502/W2302	Core bypass %		4.5	4.52
W01101/W1302+03	Upper head bypass %		0.24	0.248
V153 - V013	Inlet nozzle ΔP(bar)		0.372	0.3623
V013 - V01503	Downcomer ΔP(bar)		0.124	0.1265
V01503 - V025	Lower plenum ΔP(bar)		0.524	0.4538
V025 - V03101	Core support plate ΔP(bar)		0.2	0.197
V3101,02,03,04	Core rod friction ΔP(bar)		0.19	0.195
J3101,02,03	Core rod grids ΔP (bar)		0.4	0.398
V3104 - V041	Upper core plate ΔP(bar)		0.2	0.207
V25 - V041	Total core ΔP (bar)		1.	0.992
V041 - V111	Outlet nozzle ΔP(bar)		0.124	0.127

TABLE 4.5 : Summary of primary loop nodalisation volumes
- FIRST PRIMARY LOOP - (LOOP B)

HOT LEG

Component	Area	Length	Volume	Watermass	Name	Type
n°	m^2	m	m^3	kg	——	——
111	0.383	2.476	(0.948308)	653	HTLG 11	SNGLVOL
112	0.383	2.476	(0.948308)	653	HTLG 12	BRANCH
113 - 01	0.383	2.476	(0.948308)	653	HTLG 13	SNGLVOL
		7.428	2.844924	1959		

PUMP SUCTION LEG

131 - 01	0.487	1.806	(0.87952)	661	LSEAL B1	BRANCH
132 - 01	0.487	1.806	(0.87952)	661	B132	BRANCH
133 - 01	0.487	1.633	(0.79527)	598	LSEAL B2	PIPE
133 - 02	0.487	1.43	(0.69641)	523		
		6.675	3.25072	2443		

PUMP

140	(6.29627)	1.232	7.757	5830	PUMP B	PUMP
			7.757	5830		

COLD LEG

151 - 01	0.383	1.968	(0.754)	567	CLDLGB1	PIPE
02	0.383	1.968	(0.754)	567		
152	0.383	1.968	(0.754)	567	CLDLGB2	BRANCH
153	0.383	1.968	(0.754)	567	CLDLGB3	SNGLVOL
		7.872	3 015	2268		

( ) : data in brachets are not entered in input data, but are calculated by program from other intered data.

TABLE 4.6 : Summary of primary loop nodalisation volumes

- SECOND PRIMARY LOOP - (LOOP A)

HOT LEG

Component	Area	Length	Volume	Watermass	Name	Type
n°	m^2	m	m^3	kg		
211- 01	0.383	2.476	(0.948308)	653	HTLGA1	PIPE
02	0.383	2.476	(0.948308)	653		
03	0.383	2.476	(0.948308)	653		
——	——	7.428	2.844924	1959	——	——

PUMP SUCTION LEG

231 - 01	0.487	1.806	(0.879522)	661		PIPE
02	0.487	1.806	(0.879522)	661		
03	0.487	1.633	(0.795271)	598		
04	0.487	1.43	(0.696410)	523		
——	——	6.675	3.250725	2443	——	——

PUMP

240	(6.296267)	1.232	7.757	5831	PUMP	PUMP
——	——	——	7.757	5831	——	——

COLD LEG

251- 01	0.383	1.966	(0.754)	567	CLDLGA1	PIPE
02	0.383	1.968	(0.754)	567		
252	0.383	1.968	(0.754)	567	CLDLGA2	BRANC
253	0.383	1.968	(0.754)	567	CLDLGA3	SNGLV
——	——	7.872	3.015	2268	——	——

( ) : data in brackets are not entered in input data, but are calculated by program from other intered data.

TABLE 4.7: Summary of steam generater nodalization (volumes)

PRIMARY SIDE

Component n°	Area m²	Length m	Volume m³	Water mass kg	Name	Type
121 – 221	(2.607)	1.685	4.392	3024	INBOX	BRANCH (1)
125 – 225	(2.607)	1.685	4.392	3301	OUBOX	BRANCH (1)
122/01→10 222/01→10	0.99	10x0.908	(8.989)	6436	ÚUTUB 1	PIPE (10)
124/01→05 224/01→05	0.99	5x1.816	(8.989)	6697	DUTUB	PIPE (5)
———	———	———	26.762	19458	———	———

SECONDARY SIDE

612 – 712	8.048	0.735	(5.915)	4033	BG12	BRANCH
613 – 713	(8.029)	0.697	5.596	4318	FEEDMIX	SNGLVOL
615/01-715/01	2.589	1.938	(5.015)	3875	SGLDCOME1	ANNULUS (4)
615/02→04 715/02→04	0.4845	3x 2.550	(3x1.235)	2862	"	"
620/01→04 720/01→04	4.432	4x 1.816	(4x8.0485)	11225	SG PIPE	PIPE
621 – 721	4.432	2.324	(10.300)	1766	SG RISER	BRAUCH
622 – 722	4.	1.432	(5.728)	912	TOPRI1	BRANCH
611 – 711	8.048	2.424	(19.508)	5075	BYPASSB	BRANCH
623 – 723	4.	2.424	(9.696)	781	SEPARATOR	SEPARATR
625 – 725	4.	1.	(4.)	121	DRYER	BRANCH
627 – 727	8.56	1.	(8.56)	260	PLENUMB	BRANCH
630 – 730	12.56	2.093	(26.288)	797	SGDOME1	BRANCH
———	———	———	136.505	36025	———	———

STEAM LINES

640 . 01 02 03	0,288 " "	22,7171 " "	(6.54252) (") (")	197 197 196	SGLB1	PIPE
650 01 02 03	0,292 " "	32,61 " "	(9,52212) (") (")	284 283 282	SGLB2	PIPE
740 01 02 03	0,288 " "	22.7171 " "	(6.54252) (") (")	197 197 196	SGLA1	PIPE
750 01 02 03	0,292 " "	33,4646 " "	(9.77032) (") (")	291 290 290	SGLA2	PIPE
800	0.292	13.096	(3.82403)	113	COLLECTOR	BRANCH
810	2.	10.	(20.)	583	TURBIN	BRANCH
———	———	———	120.95647	3596	———	———

TABLE 4.8 : Summary of pressurizer nodalisation (volumes)

Component	Area	Length	Volume	Watermass	Name	Type
n°	m^2	m	m^3	kg	——	——
310	1.6964	0.3	(0.509)	302	PRES 310	BRANCH
311	1,6964	0.6	(1.018)	604	PRES 311	BRANCH
312	2.5164	1.766	(4.444)	2637	PRES 312	BRANCH
313	2.5164	1.766	(4.444)	2638	313	BRANCH
314	2.5164	1.539	(3.8727)	2299	314	BRAUCH
315	2,5164	1.515	(3.8123)	389	315	BRAUCH
316	2.5164	0.8	(2.0131)	205	316	BRANCH
317	2.5164	0.6	(1.5098)	154	317	BRANCH
320 - 01	2,5164	0.4	(1.0066)	103	PRES 320	PIPE
02	1.6964	0.3	(0.50892)	52		
03	1.6964	0.2	(0.33928)	35		
04	1,6964	0.15	(0.25446)	26		
05	1.6964	0.10	(0.16964)	17		
06	1.6964	0,10	(0.16964)	17		
330	1,6964	0.05	(0.08482)	9	PRES DCM	BRANCH
——	——	——	24.15626	9487	——	——

SURGE LINE

301 - 01	0.03875	6.3465	(0.24593)	169	SURGELN	PIPE
- 02	0.03875	6.3465	(0.24593)	166		
- 03	0.03875	4.07	(0.15771)	103		
——	——	——	0.64957	438	——	——

( ) : data in brachets are not entered in input data, but are calculated by program from other intered data.

FIG. 4·1

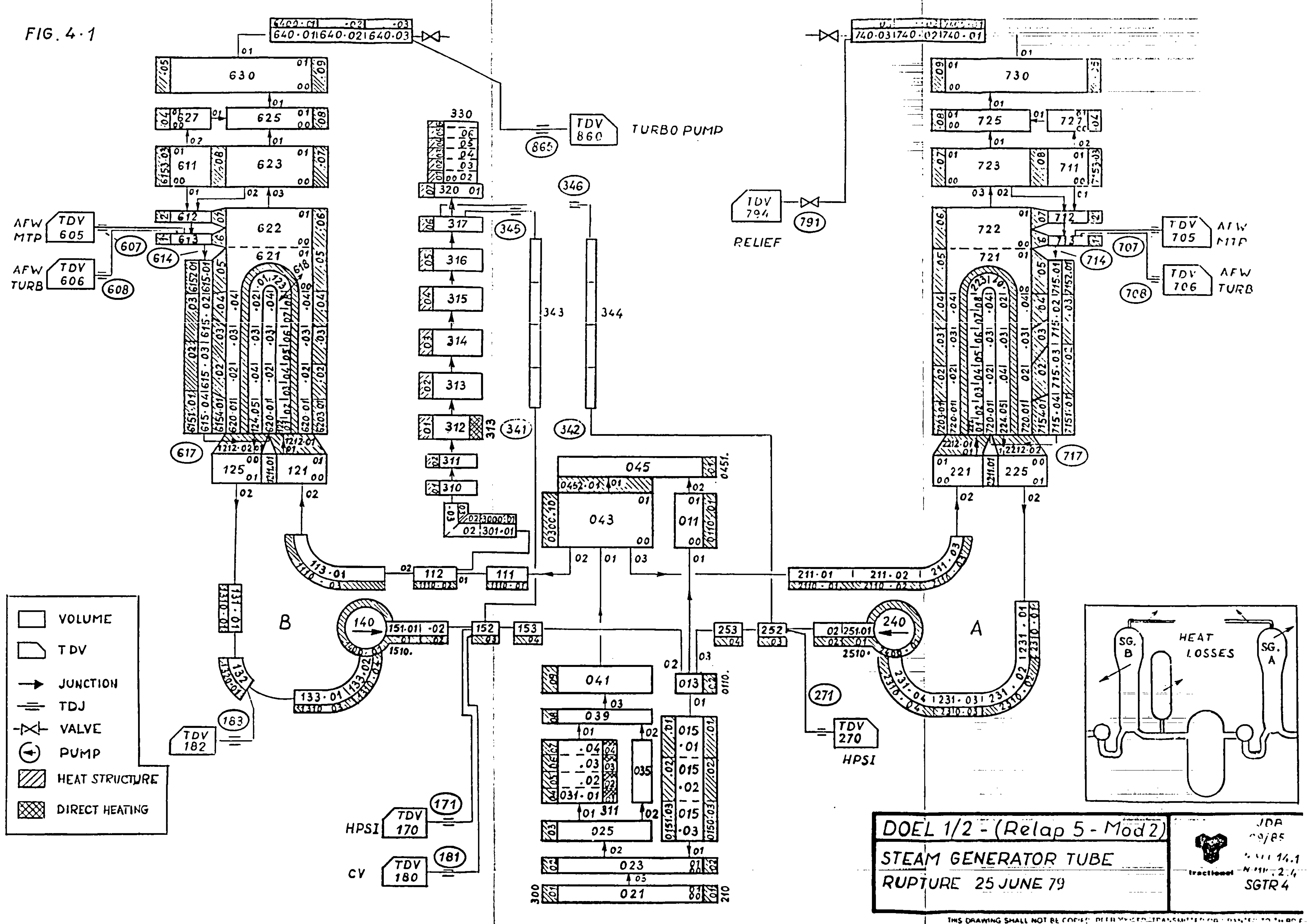

VOLUME
TDV
JUNCTION
TDJ
VALVE
PUMP
HEAT STRUCTURE
DIRECT HEATING
TURBO PUMP
RELIEF
AFW MTP
AFW TURB
HPSI
CV
B
A
HEAT LOSSES
SG. B
SG. A
DOEL 1/2 - (Relap 5 - Mod 2)
STEAM GENERATOR TUBE
RUPTURE 25 JUNE 79
SGTR 4

FIG 4.2 DOEL 1/2 REACTOR VESSEL NODALISATION

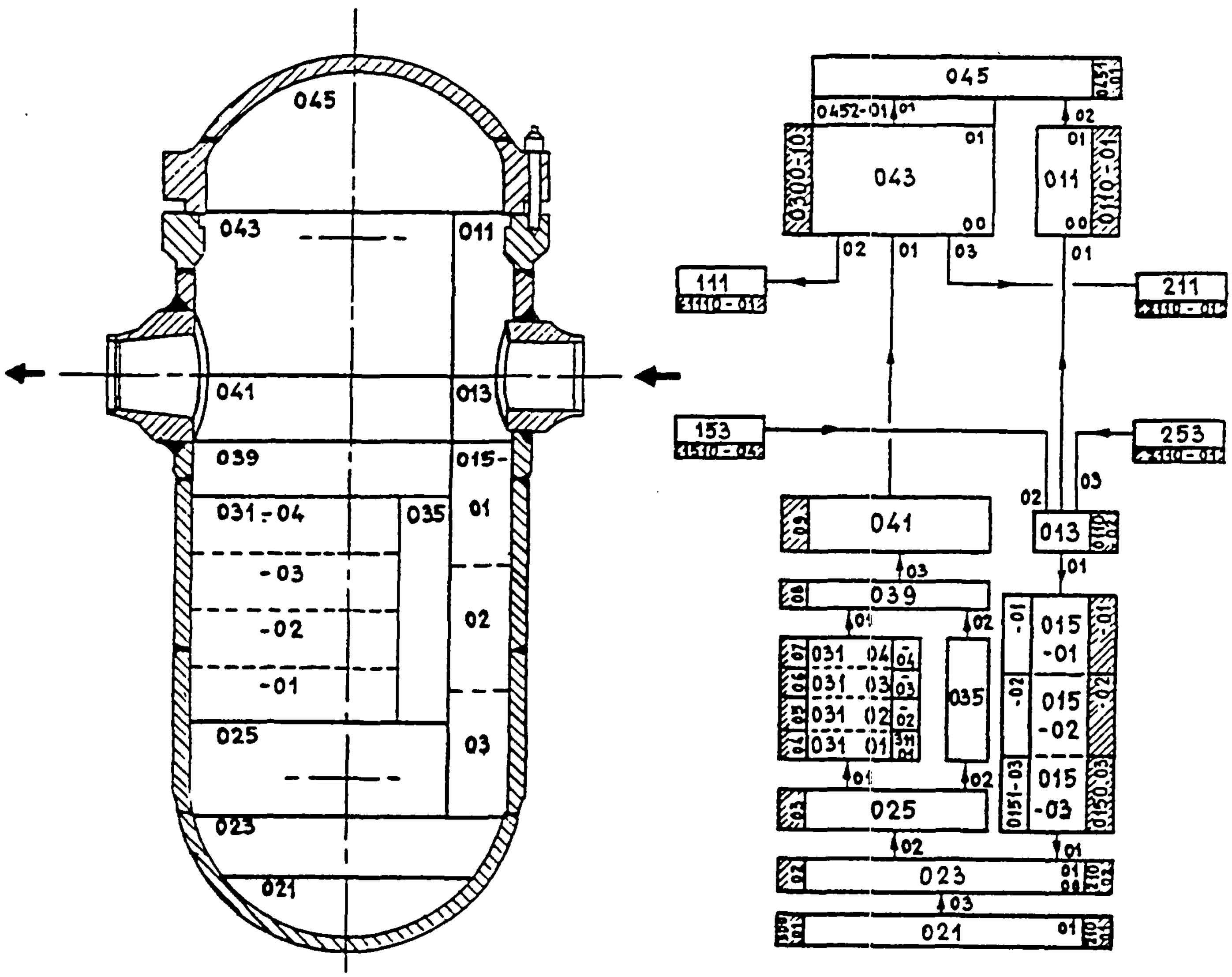


FIG. 4.3 DOEL 1/2 STEAM GENERATOR NODALISATION

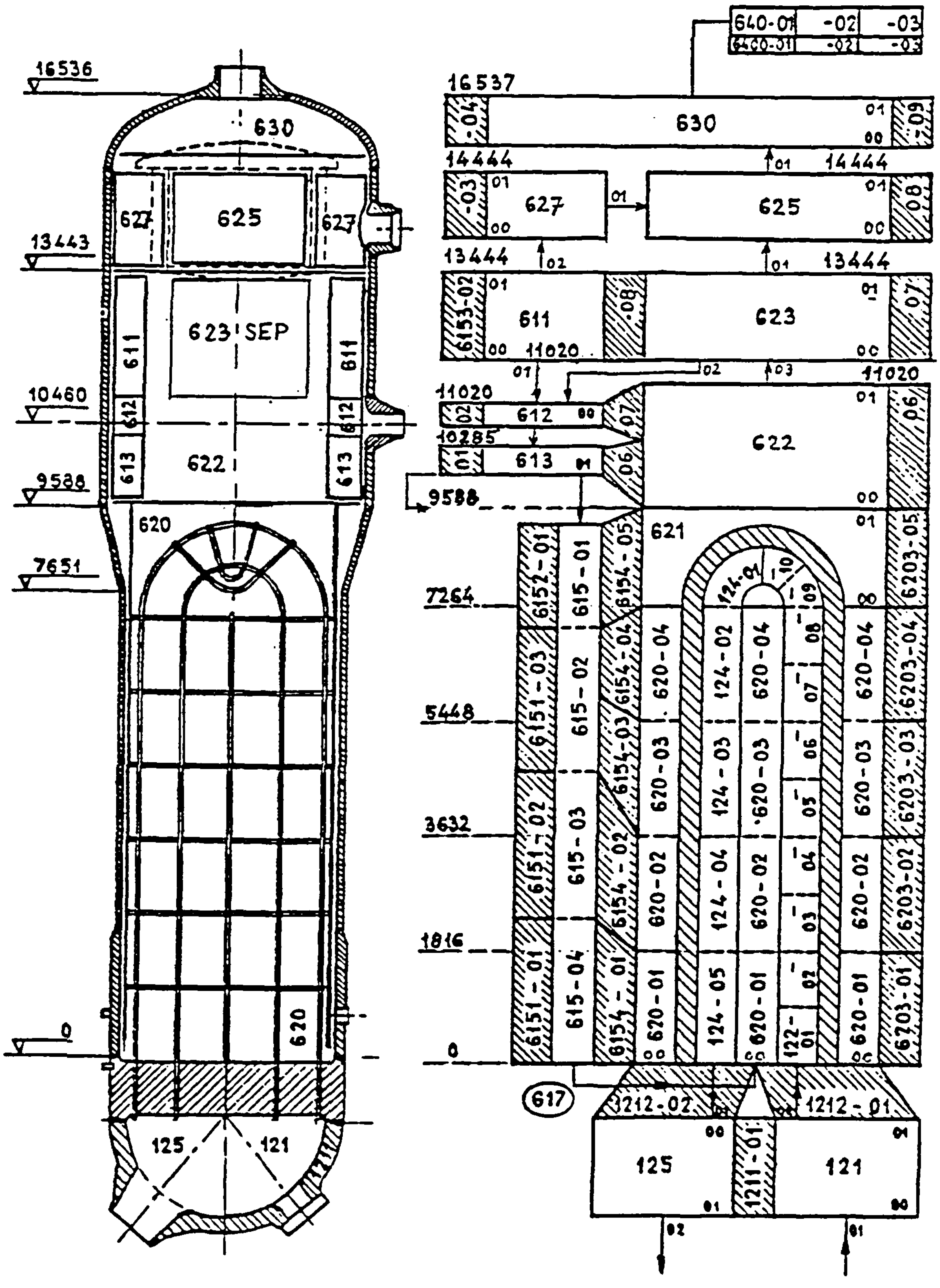


FIG4.4 PRESSURIZER LEVEL

- The level programmer is linear between given limits *

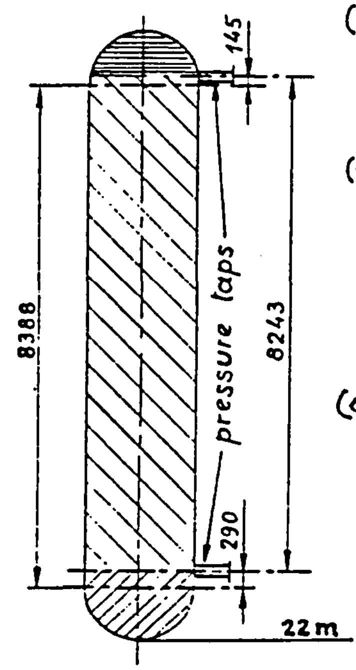
  Minimum level for a no-laod

  T_{avg} of 283.4°c (556.55°K) 24.65% of level span.

  Maximum level for a full laod

  T_{avg} of 299.6°c (572.75°K) 58% of level span.

- Level span **



(01) volume (below the pressure tap)

$V = 1.5268 + 0.7297 = 2.2565\ m^3$

(02) volume (between the pressure taps)

The section area variation along the 145mm has been neglected.

$V = 8,243 \times 2,5164 = 20.74346\ m^3$

(03) volume (above the pressure tap)

$V = 1.16192\ m^3$

volume surge line $V = 0.64957\ m^3$

The CONTROL VARIABLE 900 gives the collapsed water level particular values.

(- 0.109) indicates that only the pressurizer is empty

(- 0.14) indicates that both the pressurizer and the surge line are empty.

(+ 1.056) water solid conditions

---

* Set point study for the DOEL nuclear power station (WENX 73/49, november 30, 1973)

** Drawing COCKERILL 4306/9, 07.03.69, rev."K" 27.03.72.

RELATIONSHIP BETWEEN REAL COLLAPSED WATER LEVEL AND MEASURED LEVEL BY :

LEFT : COLD CALIBRATED ΔP CELL RIGHT : HOT CALIBRATED ΔP CELL

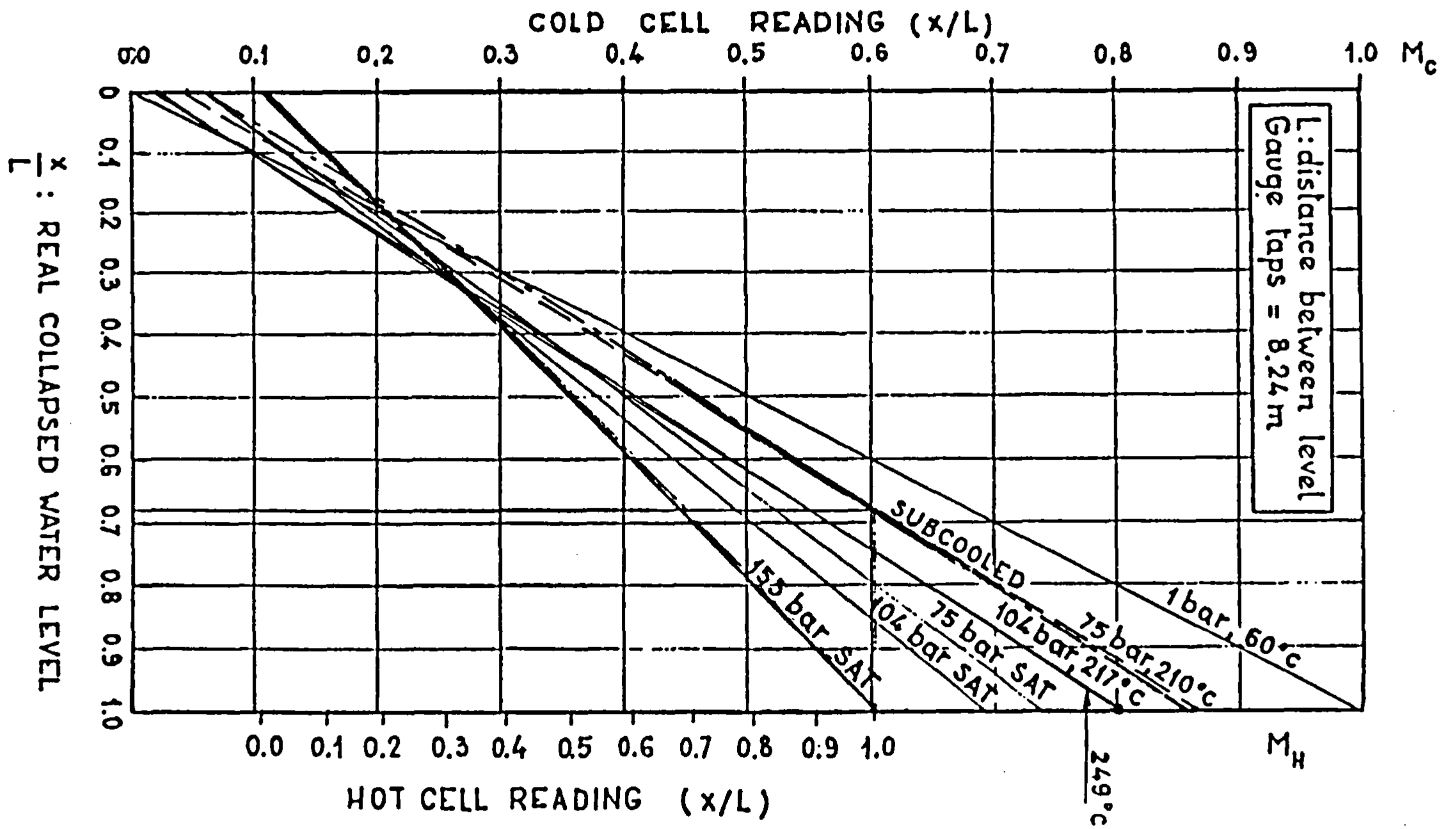
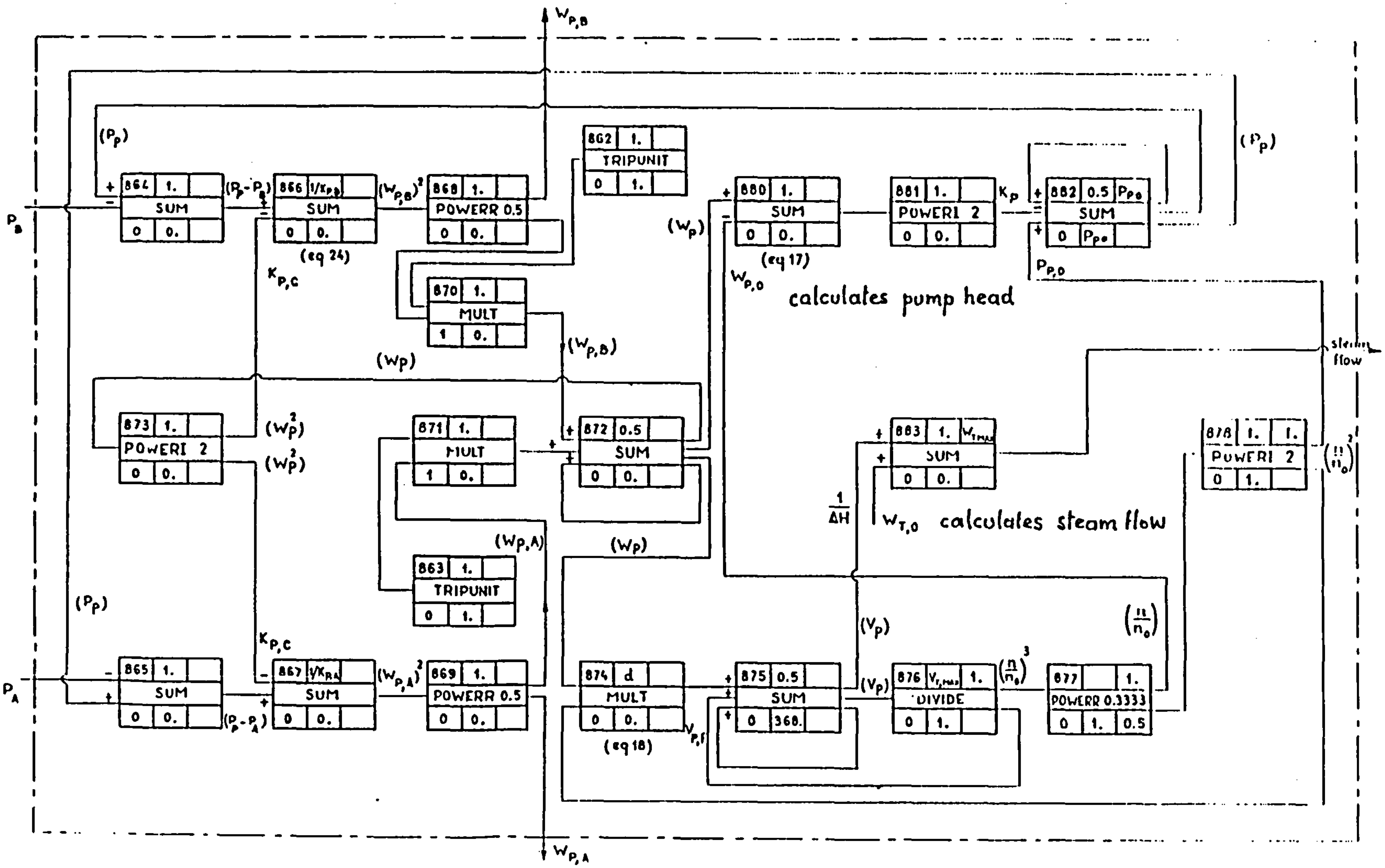


FIG 4.5

FIG. 4.6 TURBOPUMP CONTROL SYSTEM (R^'.A)



note: - 1) The values for scale factor (S) and multiplier constants (Ai) are given in table I - 2

2) Values in parenthesis ( ) are symbols of intermediate parameters for illustration only (are not multipliers)

5. BASE CASE RESULTS

The microfiches joined to this report contain the complete output file for this case.
The results are discussed on the basis of an exhaustive set of figures divided in several groups.
The numbering logic for these figures is as follows :

group 2 : pressuriser pressure
group 3 : pressuriser level
group 4 : primary coolant pressure
group 5 : primary coolant temperatures
group 6 : mass addition or depletion from primary system
group 7 : primary system energy parameters
group 8 : mass flow rates in RCS
group 9 : miscellaneous for RCS

group 10 : pressures in SG's
group 11 : water levels in the SG's
group 12 : temperatures in the SG's
group 14 : mass addition or depletion from SG's
group 15 : mass evolution in SG's

To be consistent with the numbering logic of the figures in this report, the chapter number (5) will preceed the figure number.
The main results of the base case will be described on the basis of these figures, whereby apparent anomalies will be discussion in detail in chapter 6.

. fig. 5.2.1. Pressure evolution in the pressuriser

For the initial depressurisation period (up to 900 s), the calculated pressure drop agrees well with the measured pressure drop (reconstructed from fig. 4 in annexe 1). When cooldown starts at 900, the depressurisation rate increases down to a pressure of 107 bar whereby the HPSI system stops the depressurisation slightly below the HPSI cut-off head of 108 bar, and compares to a measured plateau pressure of 107 bar (figure 3 in annexe 1).
When the operator actuated full spray at 2106 s elapsed time, a sharp pressure drop is calculated and observed, followed by

a repressurisation when the spray is stopped. The kinks in the repressurisation are probably caused by anomalous vapour condensation (or water evaporation) whenever the water level crosses a volume boundary in the pressuriser.

. Fig 5.3.1. and Fig. 5.3.2. Pressuriser water level.
The curves shown are respectively :

. The recorded water level (LRCA - PR11) in dash-dot line

. The collapsed water level $L_c = \left[\sum_i \alpha_{f_i} V_i - V_b\right] / \Delta V$ (CNTRLVAR 900)

. wherein Vi is the volume of component i of pressuriser
Vb is the volume below the lower level tap (fig. 4.4)
ΔV is the pressuriser volume between level taps (fig. 4.4)

. The hot ΔP cell level as calculated from expression b in paragraph 4.1.5.
. The cold ΔP cell level as calculated from expression a in par. 4.1.5.

The collapsed water level drops below the 0 % water level, meaning that the pressuriser drains below the lower level tap, down to the level of the hot leg connection.

The hot cell level, which is a ΔP measured with a ΔP cell calibrated at 100 % nominal condition, follows closely the recorded water level during initial depressurization, whereby the 0 level is reached at about 500 s. This close agreement confirms that the leak flowrate, estimated from a water level increase in the affected S.G., and the postulated charging minus letdown flow, are close to the plant values.

The cold calibrated water level measurement cell still records a finite level since it measures the normalised weight of the vapour in the pressuriser (see CONTROL VARIABLE 902).

During the period of pressuriser spray, the pressuriser fills up with water which is about 150°C colder than the temperature at which the ΔP level cells were calibrated.

From the calibration curves, shown in figure 4.5, one observes that for fluid temperatures in the pressuriser around 210°C, a hot cell reading of 100 % corresponds to a collapsed water level of about 68%, which in turn would show a reading of 60 % on the cold calibrated gange. These were also the values which were calculated in the very first simulation study (by means of RELAP-5 MOD-1). As will be seen further, the calculated cooldown is larger, resulting in a stronger depressurization during spray, and a faster fill-up of the pressuriser.

At 2500 s, the plant recorded level, the hot cell level and also the collapsed water level reach about 100 %, while the cold gauge indicates 80% water level. These calculated data are consistent for an average fluid density in the pressuriser of 800 kg/m^3 corresponding to an average fluid temperature of 249°C (522°K) (the fluid temperature in the pressuriser varies between 473°K and 588°K).
The calibration line for 249°C has been added in fig. 4.5.

. Fig. 5.3.2. compares the measured and calculated pressuriser level by means of the hot calibrated ΔP cell (the only two quantities that merit exact comparison). The agreement is good during the initial depressurization. For the remainder of the transient no conclusion can be drawn since the values are limited artificially between 0 and 100 %.

. Fig. 5.4.1. pressure evolution in hot leg A.
The calculated pressure drop agrees very well with the recorded pressure evolution except for two periods, respectively at the initiation of the cooldown (around 1000 s) and during the pressuriser spray period (between 2106 and 2287 seconds).

Since the exact timing and opening rate of the intact SG atmospheric steam relief valve are unknown (see also chapter 6.1) the discrepancy at the initiation of the cooldown must be attributed to unprecise boundary condition rather than code errors.

The excessive depressurization during the pressuriser spray activation is caused by excessive cooldown of the RCS as will be further discussed in chapter 6.2.

Figures 5.5.2. till 5.5.9. : Temperature evolution in the primary loops

figures 5.5.4, 5.5.5., 5.5.6 and 5.5.7., for which corresponding recordings exist, all manifest too strong a cooldown of the RCS by the intact steam generator, and will be discussed in chapter 6.2.
The temperature discontinuity at the time of the trip of the main coolant pump in the affected loop (at 1112 s), visible in figures 5.5.7 and 5.5.8, results from a flow reversal in the loop, whereby cold HPSI water, injected in the cold legs, is now redirected towards the pump and influences the temperature sensor (2RC29) located between the HPSI location and the pump.

This sudden temperature drop is not noticeable in the recordings. This may be caused by injection of all HPSI in both cold legs, while in the plant at least one injection line to the downcomer was open.

Fig. 5.5.9. illustrates clearly the increase in the vapour temperature at the pressuriser dome between 1200 s and initiation of pressuriser spray, due to structural heat release from the pressuriser walls to vapour, leading to a superheat of about 9°C. This structural heat compensates the vapour condensation at the steam/water interface and maintains a high pressuriser pressure, during the SI phase.

During the spraying period, the pressuriser temperature is following the saturation temperature. When the spraying is stopped, a water piston effect is seen whereby the vapour is compressed adiabatically to about 40°C superheat at which point the heat losses to the structure surrounding the pressuriser dome (VOL 320), leads to a final reduction in the vapour temperature from 635°K down to 622°K.

This figure may illustrate why the simulation of the structural heat of the pressuriser is important in order to understand the real pressuriser behaviour, and may explain why the pressuriser cannot be filled up due to the HPSI injection when heat is released from the structure to the vapour in an empty pressuriser, until spray is initiated. A volumetric balance shows that the HPSI water injected in the RCS compensates the primary coolant shrinking without increasing the water level in the pressuriser, as can be seen also from figs 5.3.1. and 5.8.3.

. The figures of group 5.6. illustrate various RCS inflow and outflow quantities.

Figures 5.6.1 and 5.6.2. illustrate the evolution of the break mass flow rate. While fig. 5.6.2. shows the break flow rate as calculated, fig. 5.6.1. shows the result of a integration differentiation operation intended to smooth out the calculated flowrate when the value oscillates from one cycle to the next (which was observed in a former calculation by means of the code RELAP-5 MOD-1).
Since no such oscillation are present, which is a remarkable improvement in MOD-2, both figures yield essentially identical results except close to time zero.

The mass flowrate clearly follows the pressure evolution except for a gradual increase between 1500 s and 1900 s due to a decrease in the affected SG pressure (see fig. 5.10.1), since the junction flowrate is not choked during this transient.

Fig. 5.6.5. shows the charging and the letdown flow rates. While the letdown closes at 41 s due to low pressuriser level,

the charging flow increases in order to maintain the pressuriser level. Since the breakflow exceeds the charging flow a second pump is started at 170 s, and the third charging pump starts at 900 s.

Fig. 5.6.6 illustrates the HPSI mass flow rate. With a compensation logic for the HPSI flow (see chapter 4.2.2) relative strong fluctuations are observed due to minor variations of the back pressure (fig. 5.4.1). For future runs, the lag due to the compensation, should be reduced.
Combining all inflow and outflow from the primary system, one obtains figure 5.6.3, illustrating a net coolant loss until the third charging pump was started around 900 s (when pressuriser was empty), and a net inventory increase when the HPSI pumps start injecting at 1200 s.

. Fig. 5.6.10. illustrates the variation of the primary coolant inventory (integral of fig. 5.6.3).

. Figures of group 5.7 illustrate various energy fluxes in the primary system.
The core thermal power is shown in fig. 7.1. The increase from 6 MWth to about 7 MWth between 900 and 1500 sec. results from the cooldown initiated via intact SG. The power spike at 2120 s coincides with the start of the second coolant pump whereby colder water ($\Delta T = 5°C$), accumulated in the cold leg of affected loop, reverses direction and is forced through the core.
The energy removed by the break is shown in figure 5.7.2.

. Fig. 5.7.3. illustrates the energy transferred from the primary to each steam generator (Heat input in the SG riser volume).
This figure illustrates many important phenomena (physical and numerical) which dominate the RCS behaviour.

In general, one observes that hardly any heat is transferred via the SG's until the cooldown is initiated at 900 s.
The intact SG acts as a heat sink during the remainder of the transient. The cooling power increases during the opening of the SG relief valve (900 - 1200 s), again at 1428 when the SG moto pumps, and at 1482 when the turbine driven auxiliary feedwater pump start injecting cold auxiliary feedwater in the intact SG.
The affected SG becomes a heat source which explains the asymmetric behaviour of a plant under SGTR conditions.
Even when the turbine driven auxiliary feedwater pump is started at 1482 s, the affected SG acts as a heat sink (contrary to expectation).

The sudden power reversal to the affected SG at the instant the turbine driven auxiliary feedwater pump is tripped (1900 s) is caused by an anomalous SG behaviour and will be explained in chapter 6.3.

The very large heat extraction by the affected SG between 1900 and 2100 s reinforces the excessive cooldown of the primary systém enhancing the discrepancies observed in the primary cooldown rate and the ensuing excessive depressurization during the spray period (e.g. fig. 5.4.1, 5.5.5, 5.5.8).

. Fig. 5.7.4. expresses the heat flux extracted from the SG tubes (primary side) and is basically identical to fig. 5.7.3 except for the sign, the structural heat in the SG tube bundle and possible heat exchanges between riser and surroundings.

. Fig. 5.7.5. illustrates the net energy balance in the primary system, and shows that the net energy balance is mostly negative (leading to a sustained depressurization) except during the spray period which is caused by the very large injection of HPSI water, with small but non negligible energy content. The large spike around 1900 s is caused by the sudden energy extraction by the affected SG (see chapter 6.3).

. Fig. 5.7.6. illustrates the structural heat input respectively in the pressuriser and the total primary system.

It is important to note that the core residual heat is about 6MW and at the end of the cooldown period, the structural heat input (before spray) also reaches a value of 6 MW, hence illustrating the importance of modelling structural heat release.
The sudden increase in structural heat release when spray is actuated results from a strong cooldown of the pressuriser shell in contact with cold water, combined with the actuation of the pressuriser heaters at 2230s.

. Figures of group 5.8 illustrate flowrates internal in the reactor coolant systems such as the loop flowrate (fig. 5.8.1.), the surgeline mass flow rate (fig. 5.8.3) and the pressuriser spray flow (fig. 5.8.5.).

The surgeline mass flow rate remains negative, indicating pressuriser emptying until the HPSI is actuated at 1200 s. However, the filling of the pressuriser does not start until the spray is actuated.

The miscellaneous figures of group 5.9. illustrate :

. the subcooling in the primary system (fig. 5.9.2.) :

The initial subcooling is very high corresponding to close to hot standby condition (about 90°C), and decreases due to the RCS depressurization. When cold SI water is injected, the pressure is stabilised while the cooldown continues leading to an increase in the subcooling.
The anomalous strong cooldown at 1900 s is caused by the excessive heat transfer to the affected SG (fig. 5.7.3.) and

causes a sudden increase in the subcooling around 1940 s. The subcooling reaches a constant value around 108°C, until a sharp drop occurs during the spray period; and increases again when the spray is stopped.

. status plot of downcomer fluid temperature versus downcomer pressure (fig. 5.9.3.).

On same plot is shown the limiting vessel integrity curve (Reference temperature for nil ductility transition) for a 40 year plant condition. This illustrates the PTS (Pressurized thermal schock) problem potential of such tansient.

- The integral mass balance in the primary system is shown in fig. 5.9.9. (Relative values)

Figures of group 5.10 illustrate the pressure evolution in both steam generators.

For the intact S.G. (fig. 5.10.2), while the calculated depressurization rate is acceptable, there is a constant lag between measured and calculated pressure. This discrepency may be attributed to misjudgment in the cooldown initiation time, or a time-shift problem in the recorded curves.

For the affected S.G. (fig. 5.10.3), several features show up :

. the calculated pressurization until 1482 s, is too high.
. When the auxiliary feedwater is initiated at 1482 s, steam taken from this SG to drive the turbine driven auxiliary feedwater pump creates a depressurization with a rate in good agreement with the observed rate.
. At 1710 sec, the vapour void fraction in volume 627 drops below 60 % and strong vapour condensation sets in producing a steeper pressure drop, until the turbine driven auxiliary feedwater pump is stopped at 1900s.
. The pressure anomalies observed after 1900 s are caused by condensation problems which will be discussed in chapter 6.3.

. Figures of group 5.11 illustrate different water levels in both steam generators.

Broadband collapsed water levels in the downcomer and the riser are shown in figure 11.1.

Since no broadband measurements were recorded at the plant, the plant comparison data in figures 5.11.6 and 5.11.7 are obtained by adding the distance between tube-plate and lower level tap of the narrow-band level measurement.
No strict comparison between plant data and calculated data should be attempted for these figures.

. Comparison of measured and calculated water level in the intact S.G. is shown in figure 5.11.8. When the cooldown is started by opening the atmospheric steam relief valve between 900 and 1200 s, an excessive level swell is observed in the riser (see also fig. 5.11.1) leading to a hold up of the water in the downcomer and the region located at the small band level measurement taps. This leads to an initial offset in the calculated water level followed by a level drop with a gradient which agrees well with the measured level gradient (see also chapter 6.2).

. Figure 5.11.9. illustrates the comparison between calculated and measured water level in the affected S.G. Since the leak flow rated was tuned to the level rise, good agreement is thus built-in as input to the code.

. Figures of group 5.12 illustrate temperature evolution in the steam generators
The steam temperatures in the SG domes reflect the pressure evolution in the steam generators (close to saturation).

. Figure 5.12.2. illustrates the evolution of the steam generator inlet and outlet (primary side) and the SGB riser, temperature.
When the B loop coolant pump in stopped at 1112 sec, flow reversal in this loop causes a temperature inversion at SG inlet and outlet (inlet temperature above outlet temperature) since the affected SG acts as a heat source.
When the auxiliary feedwater motordriven pump is stopped (1900 s), cold water hanging up in the SGB downcomer, enters the riser leading to a temporary very strong cooldown of the riser region and a strong drop in the primary SG inlet temperature (see also fig. 5.7.3.).
When the main coolant pump is started at 2105 s, the temperature inversion (inlet-outlet) is reversed.

. Fig. 5.12.3. illustrates the evolution of the temperatures in the intact SGA (primary inlet, outlet and SG bundle region). The closeness of the temperatures illustrates the high heat transfer efficiency during cooldown.

. Finally, fig. 5.12.4. gives an illustration of the strong fluid temperature stratification in the bottled-up affected S.G. after 2400 s.(see also figure 5.12.1 for dome vapour temperature).

The large temperature drop in the bottom of the riser around 1900 sec. is another illustration of the sudden cooldown when cold water, accumulated in the SG downcomer, suddenly falls down and cools the SG bundle region (see also chapter 6.2). This figure may give an indication of the challenges to the code to evaluate the correct flow and heat transfer regime under such conditions.

Figures of group 5.14 illustrate various mass addition and release rates from both steam generators.

. Figure 5.15.2 illustrates the net mass addition and depletion rates for both SG's.

. Figure 5.15.1 illustrates the total mass evolution in both SG's.

In conclusion one could state that the code calculation does present the overall macroscopic behaviour in primary and secondary system, except for three areas where large discrepancies are observed. These areas will be discussed in next chapter.

The following main phenomena, observed in the plant, are also simulated well by the code :

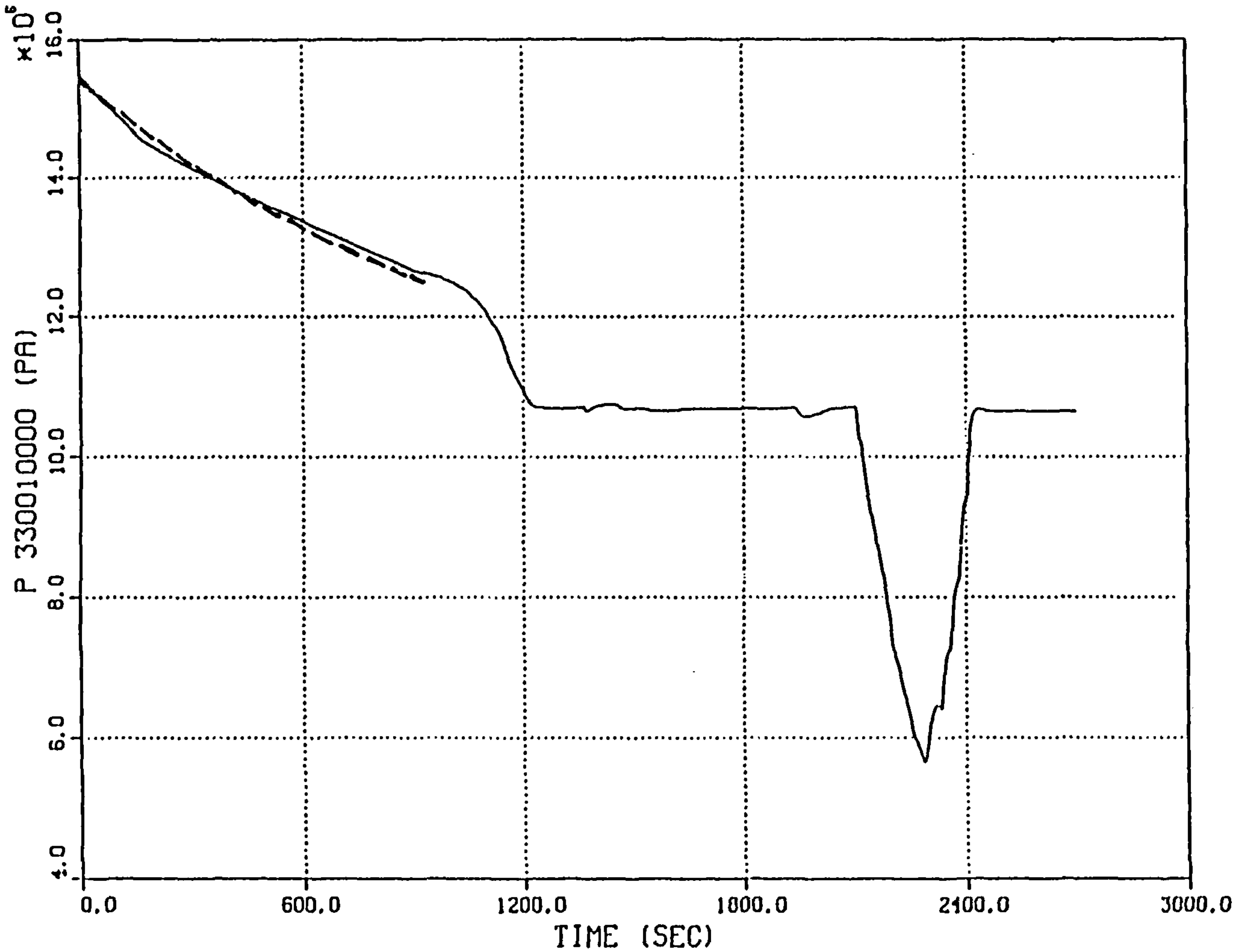
. Non-equilibrium pressuriser behaviour in voided and partially subcooled conditions.
. Couter current flow in the pressuriser during the spray period result in acceptable coolant distribution and depressurisation, in contrast to the RELAP-5 MOD-1 code (Ref. 2). Former calculations with RELAP-5 MOD-1 required artifical external steam recirculation to avoid hang-up of the spray water at top of pressuriser.
. Structural heat release to the voided pressuriser during cooldown leads to a situation whereby the water inventory in the pressuriser remains low, even when 4 HPSI pumps are operational.
. The cooldown gradient between 1200 s (fully opened relief valve) and start of the auxiliary feedwater system (1428 s) in the RCS matches with the plant cooldown gradient, which illustrates a correct heat transfer between RCS and both SG's (in direct and reverse direction).

PLOT 2100 04.13.59 SAT 28 SEP, 1985 JOB-A3GADYI , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 2.1 PRESSURE EVOLUTION IN PRESSURIZER

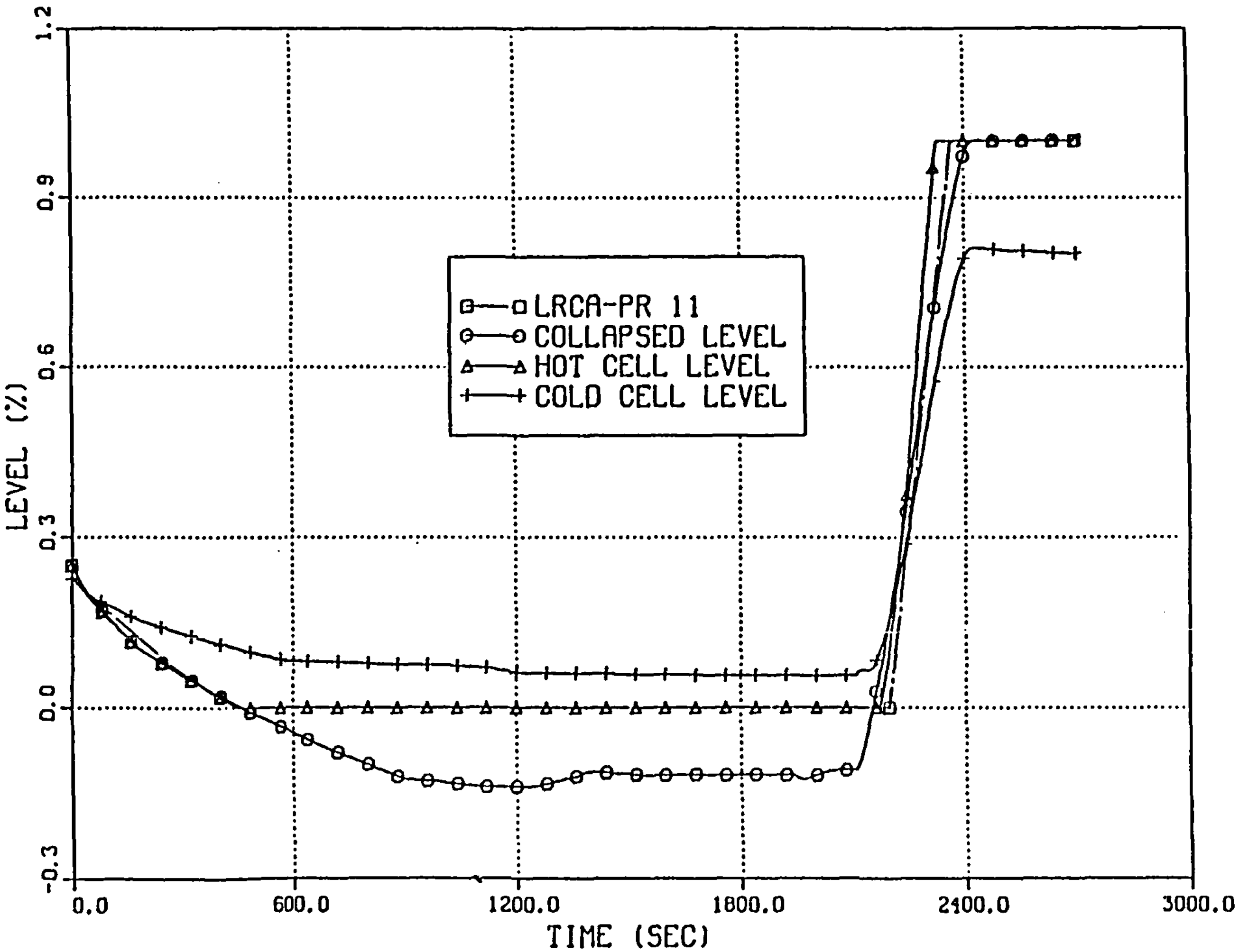


PLOT 3100 01.14.26 SAT 28 SEP, 1985 JOB-A3GRDYI , CYBER...I NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 3.1 WATER LEVEL IN PRESSURIZER

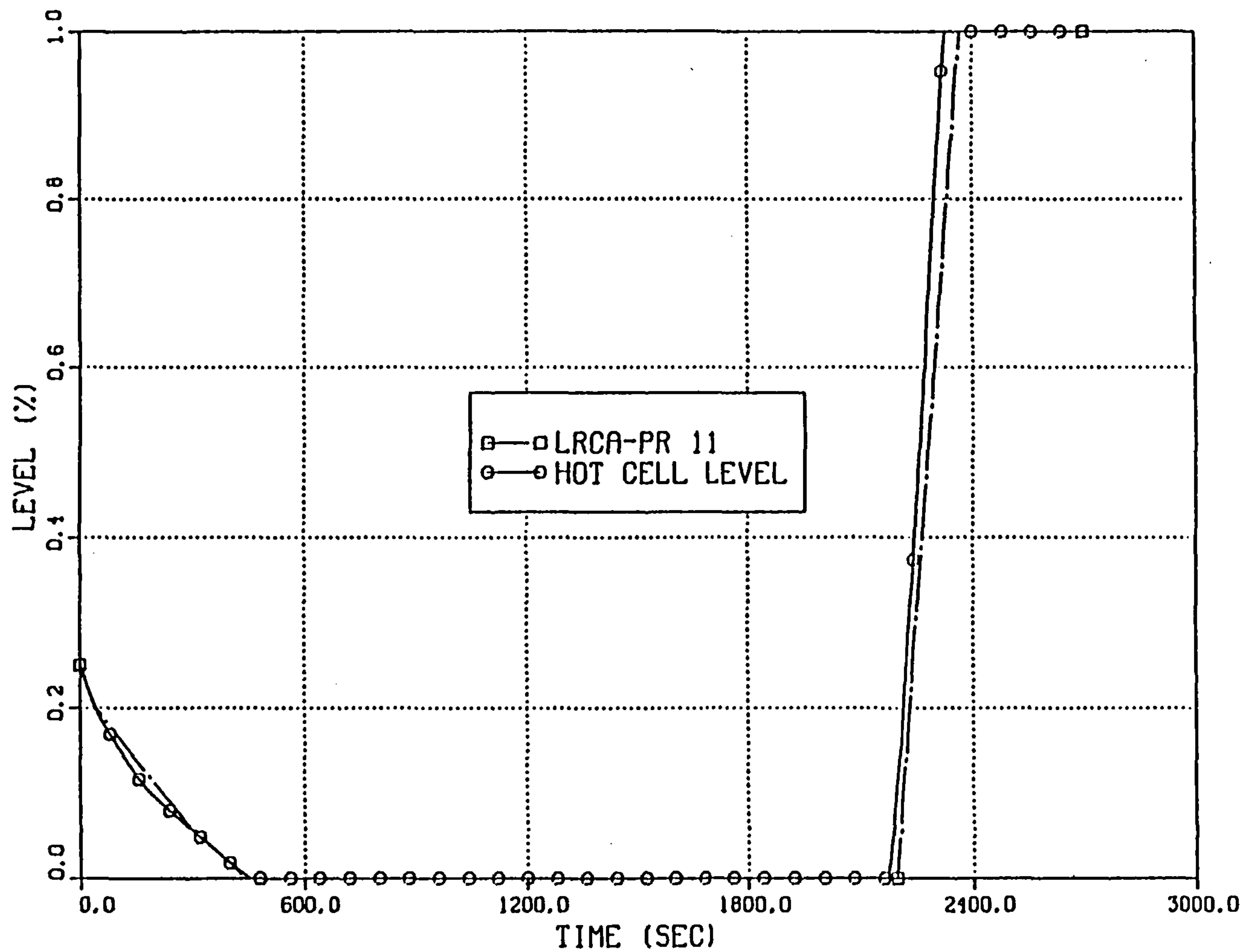


PLOT 3200 04.14.53 SAT 28 SEP, 1985 JOB-R3GRDYT , CYB...ET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28..

5. FIG 3.2 MEASURED WATER LEVEL IN PRESSURIZER



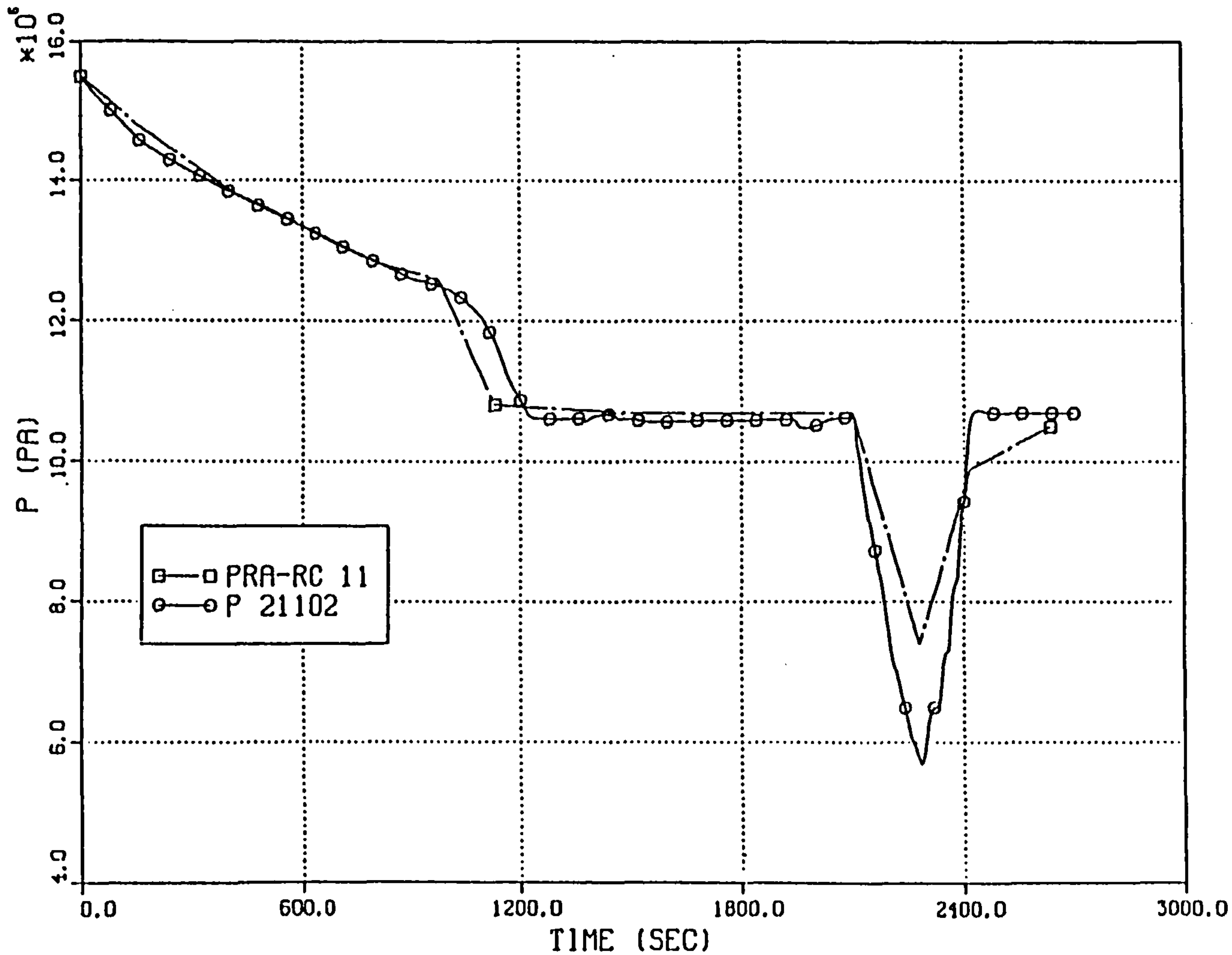
78

PLOT 4100 04.15.19 SAT 28 SEP, 1985 JOB-A3GRDYI , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 4.1 PRESSURE EVOLUTION IN HOT LEG A

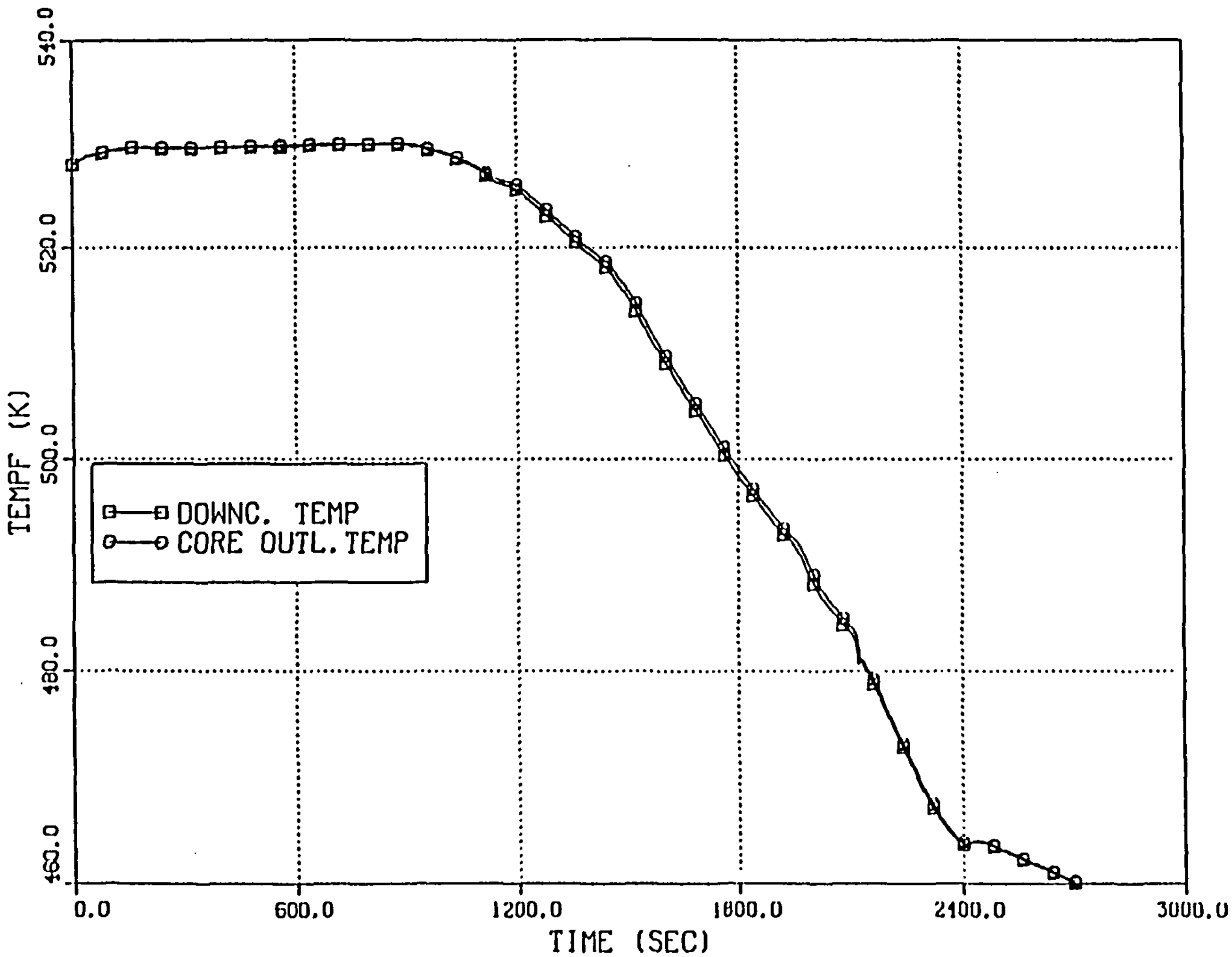


PLOT 5200 04.15.46 SAT 28 SEP, 1985 JOB-A3GAOYT , CYBER... NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28..

5. FIG 5.2 TEMPERATURE EVOLUTION IN REACTOR VESSEL

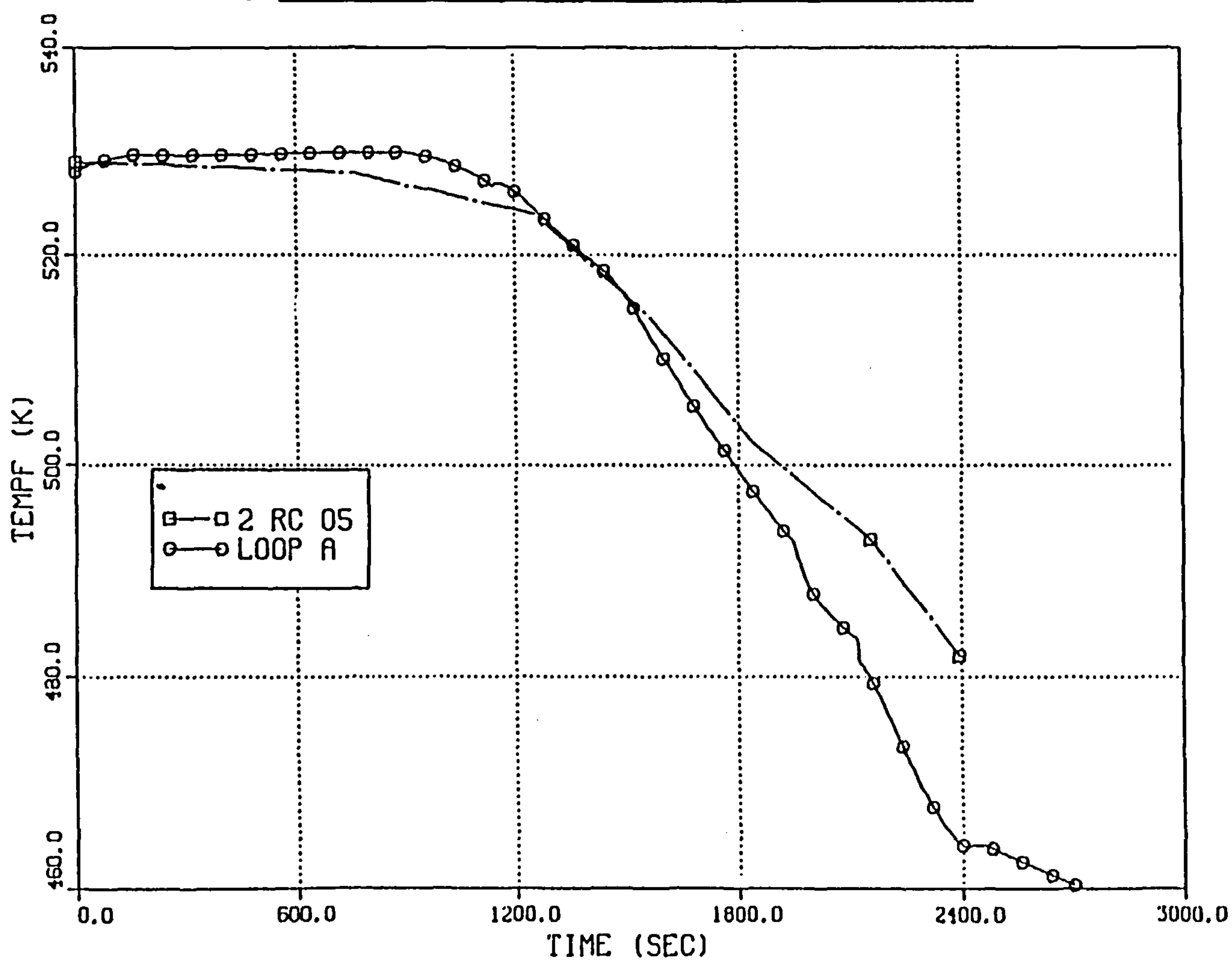


PLOT 5400 04.16.12 SAT 28 SEP, 1985 JOB-A3GROTT , CYB.. .I NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 5.4 TEMPERATURE EVOLUTION IN HOT LEG A

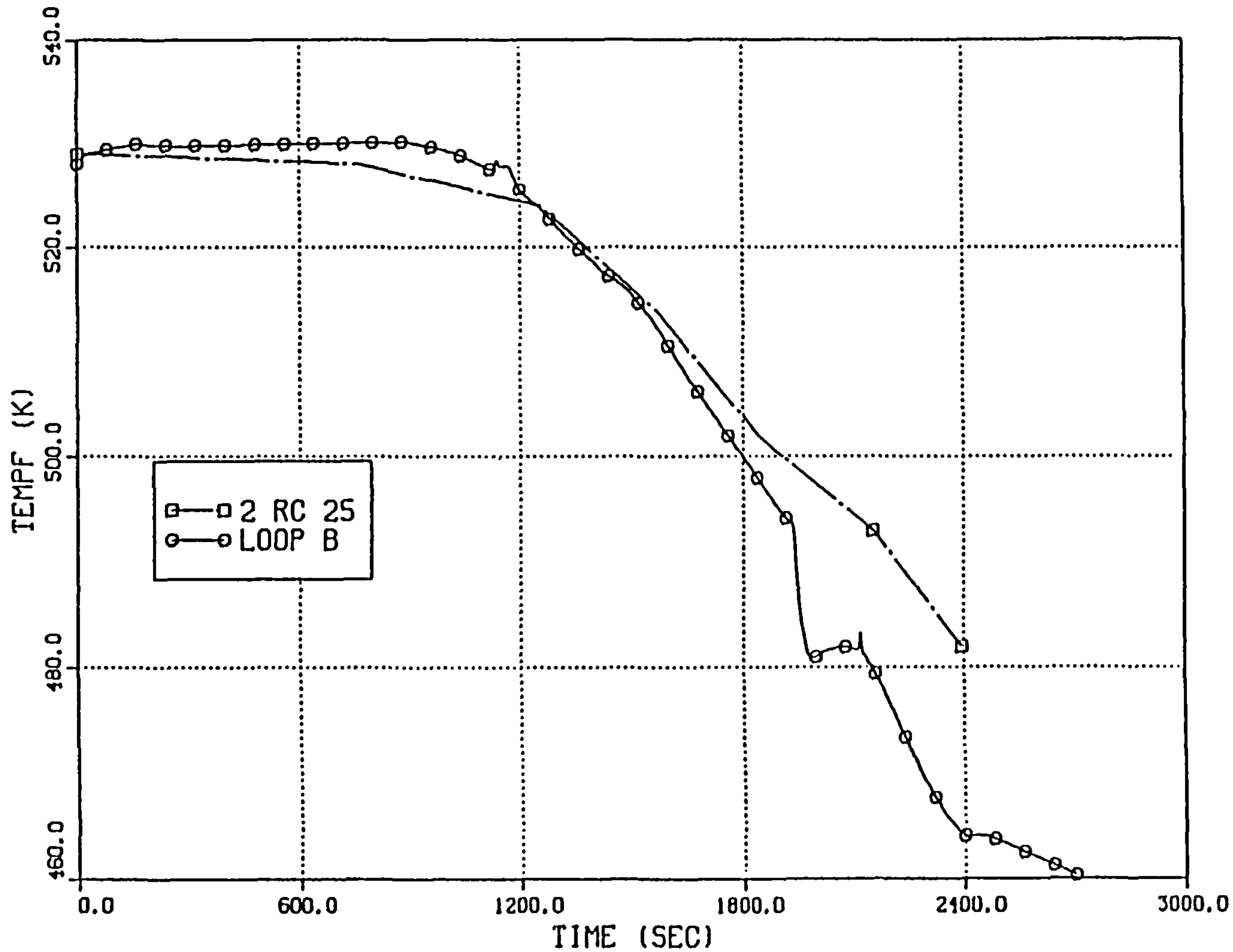


PLOT 5500 04.16.39 SAT 28 SEP, 1985 JOB-R3CRDYT , CYBER NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 5.5 TEMPERATURE EVOLUTION IN HOT LEG B

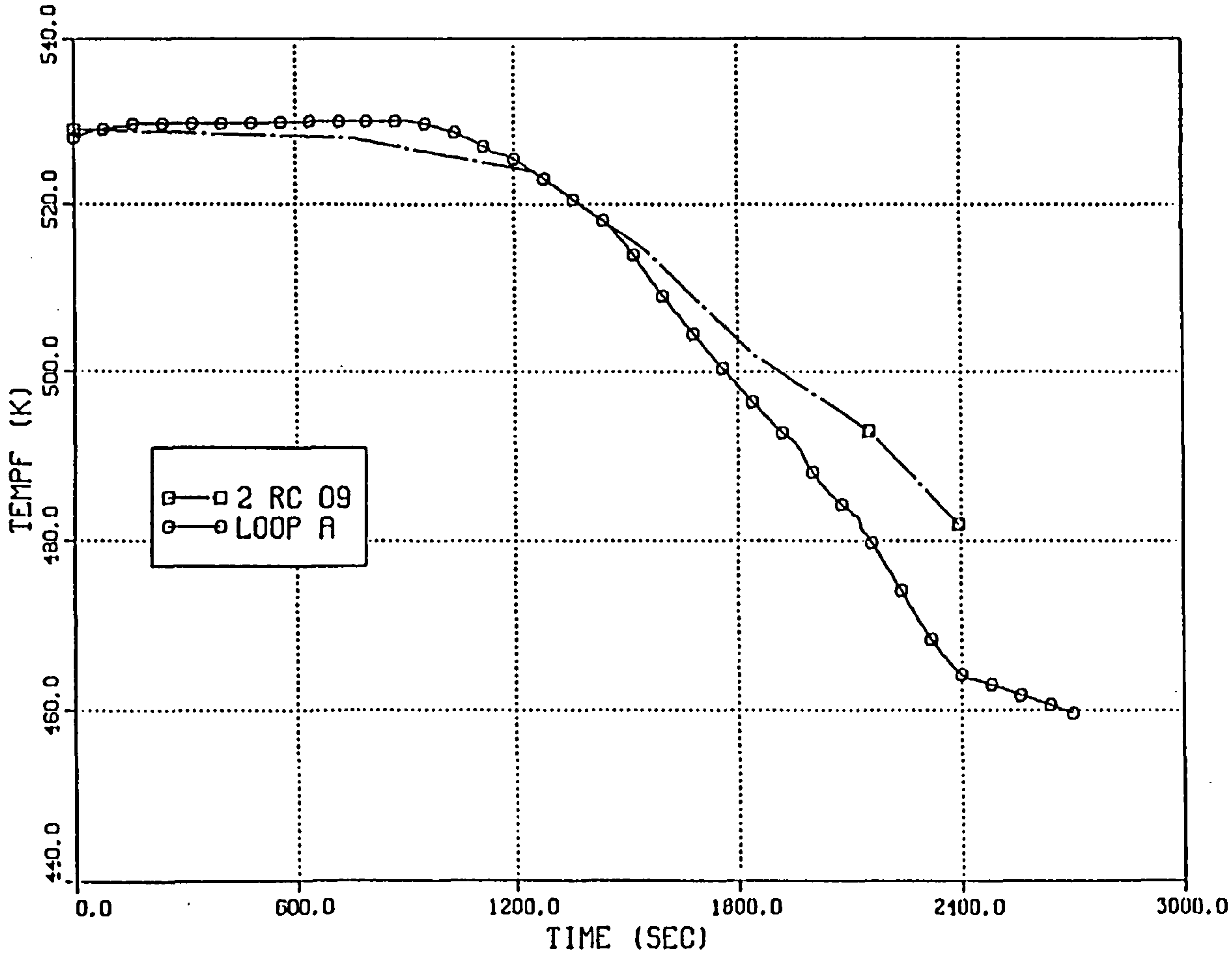


PLOT 5600 04.17.05 SAT 28 SEP, 1985 JOB-A3CRDYT , CYBERNL. .US 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 5.6 TEMPERATURE EVOLUTION IN COLD LEG A

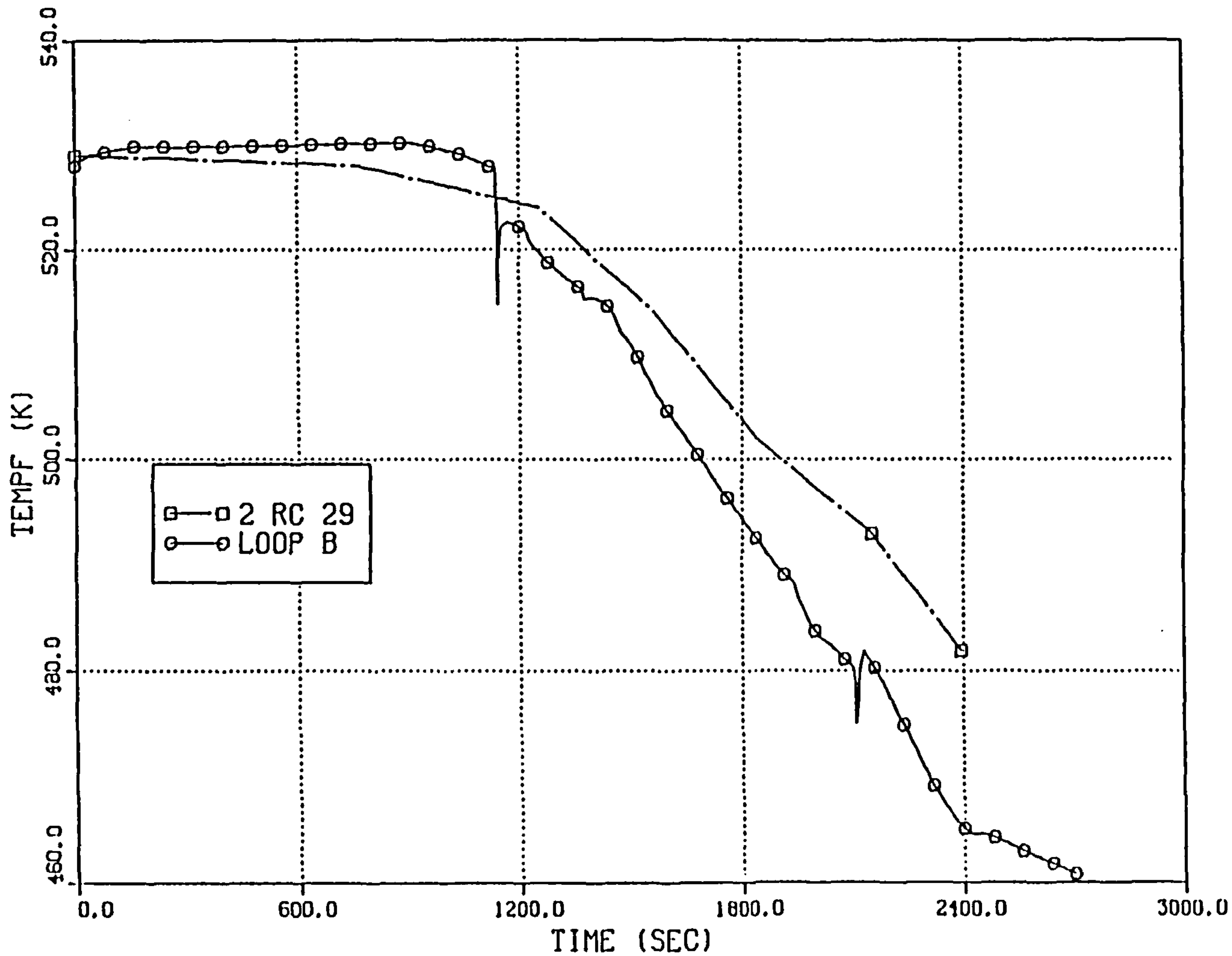


PLOT 5700 04.17.31 SAT 28 SEP, 1985 JOB-A3CRDYT , CYBE. ..I NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

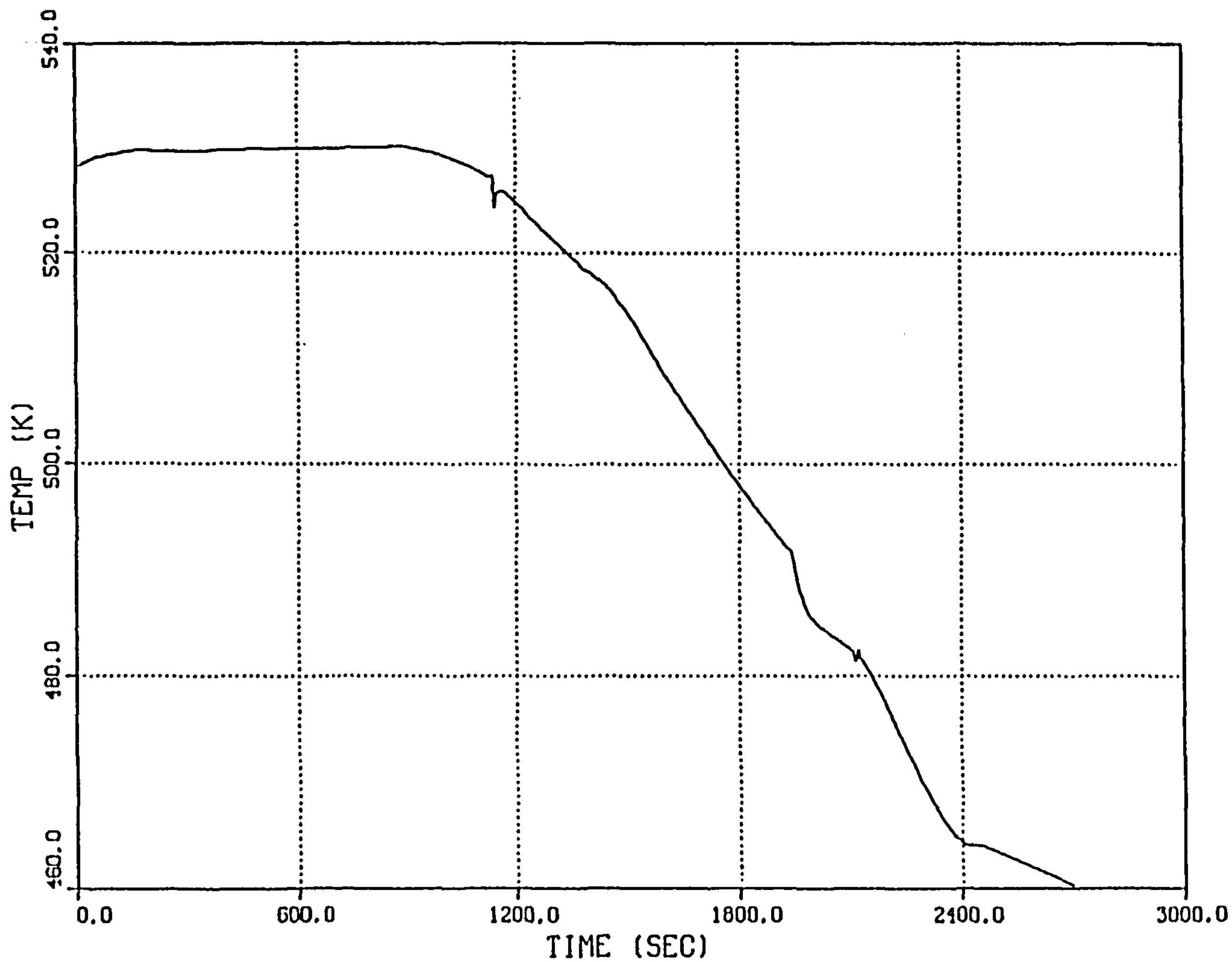
5. FIG 5.7 TEMPERATURE EVOLUTION IN COLD LEG B



RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28. .

5. FIG 5.8 AVERAGED PRIMARY TEMPERATURE EVOLUTION

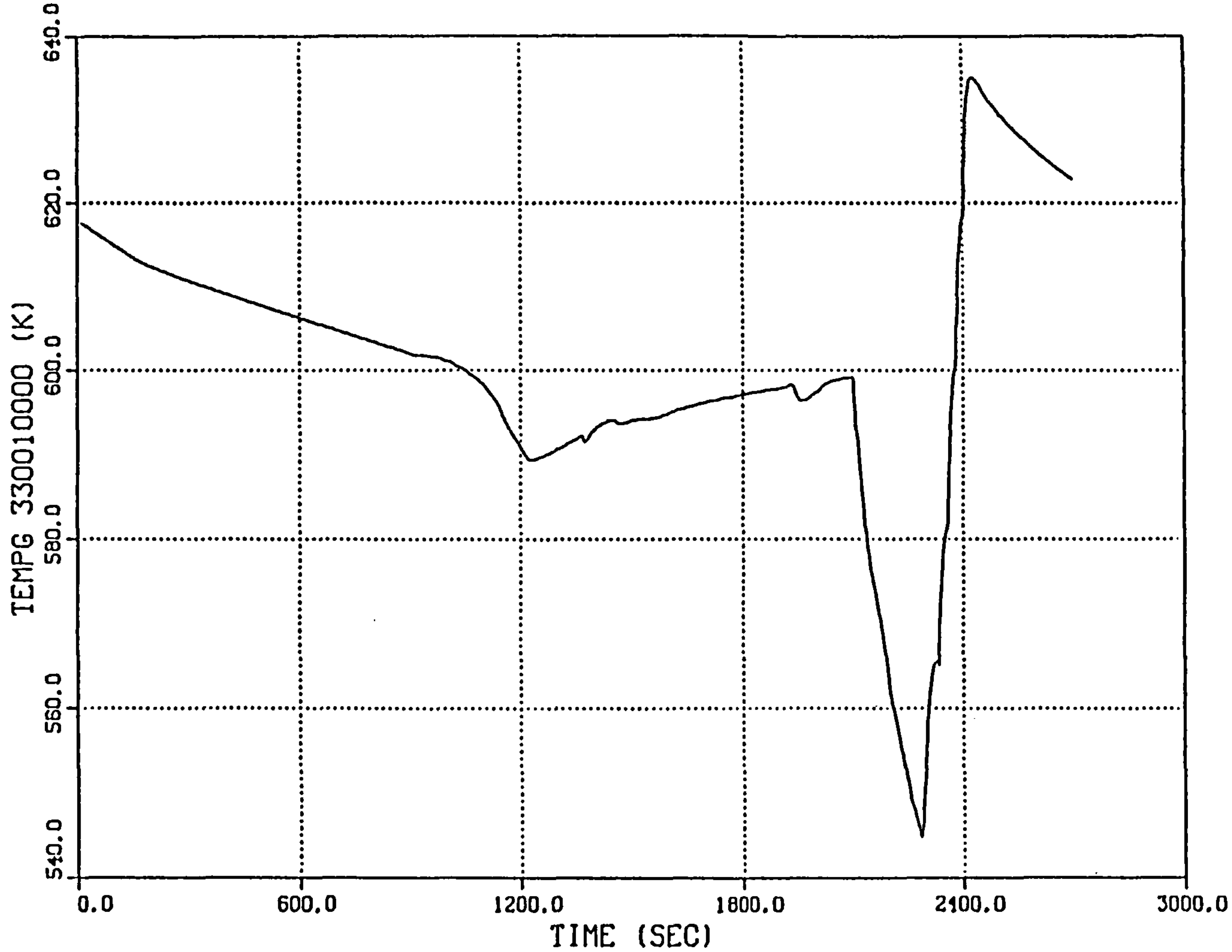


PLOT 5900 04.18.24 SAT 28 SEP, 1985 JOB-A3CROYT , CYBL...T NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28..

5. FIG 5.9 PRESSURIZER STEAM TEMPERATURE EVOLUTION

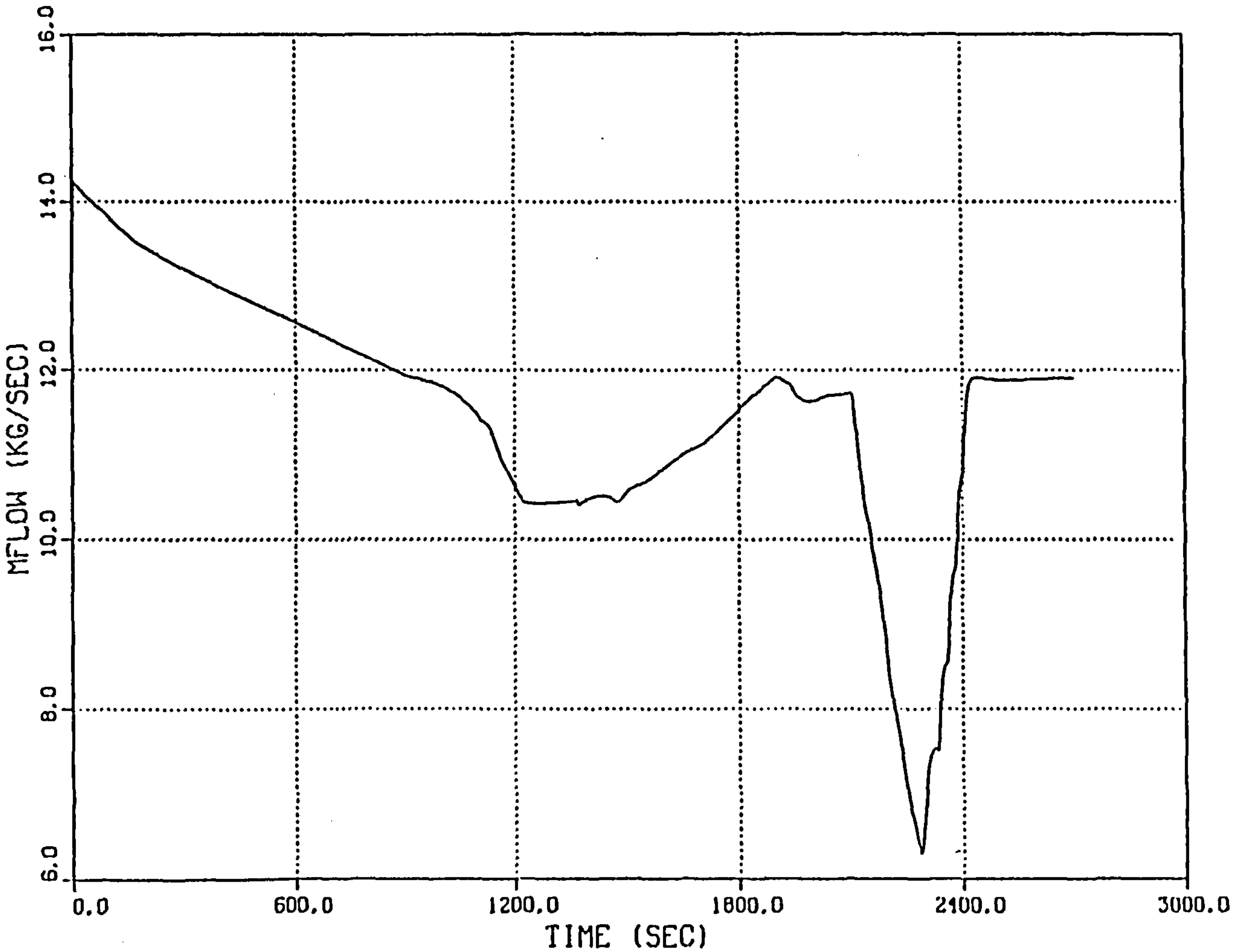


PLOT 6100 01.19.17 SAT 28 SEP, 1985 JOB-A3CROYT , CYB...CI NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 6.1 BREAK MASS FLOW RATE (CORRECTED)

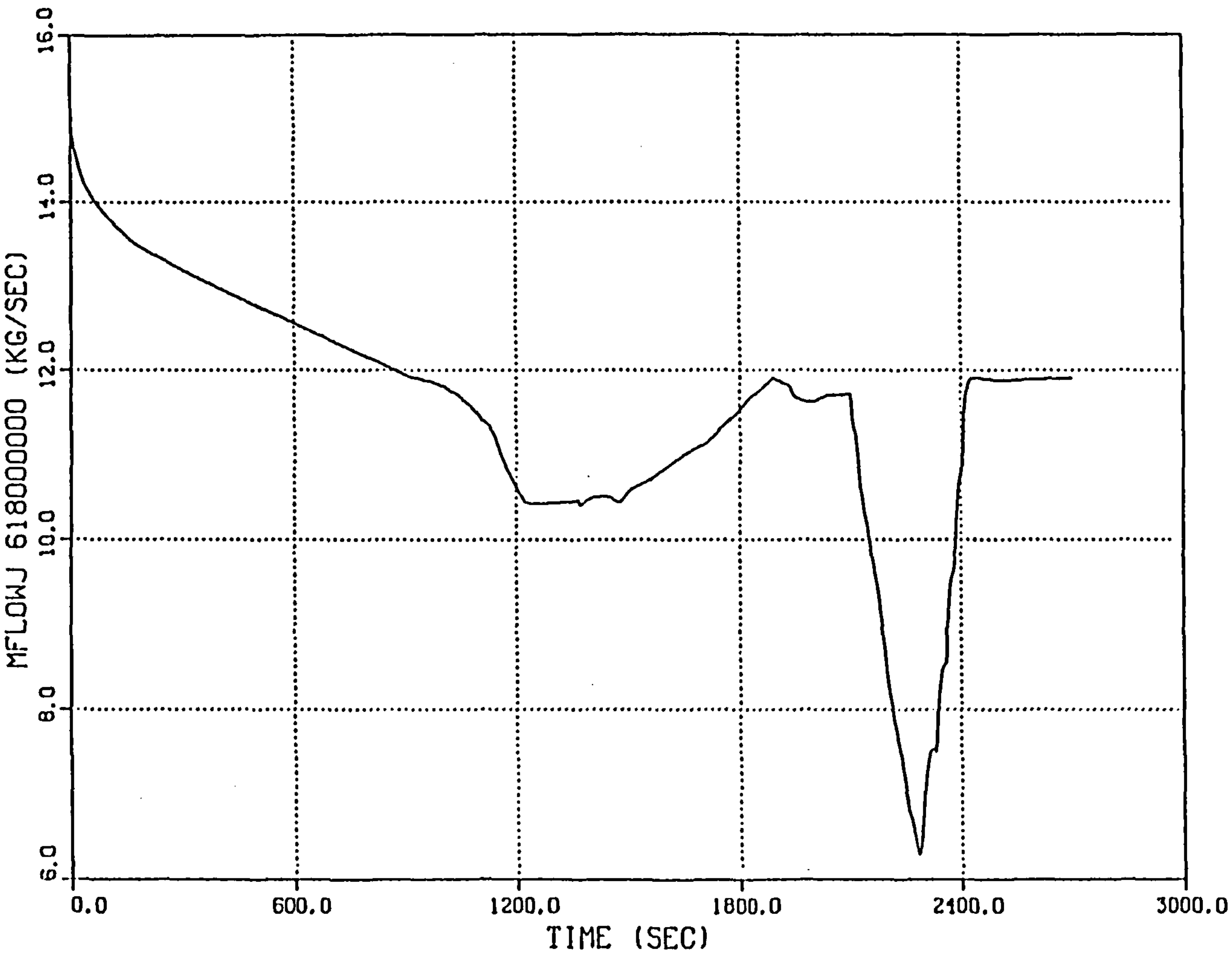


PLOT 6200 04.19.43 SAT 28 SEP, 1985 JOB-ASCROFT , CY...NET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 6.2 BREAK MASS FLOW RATE

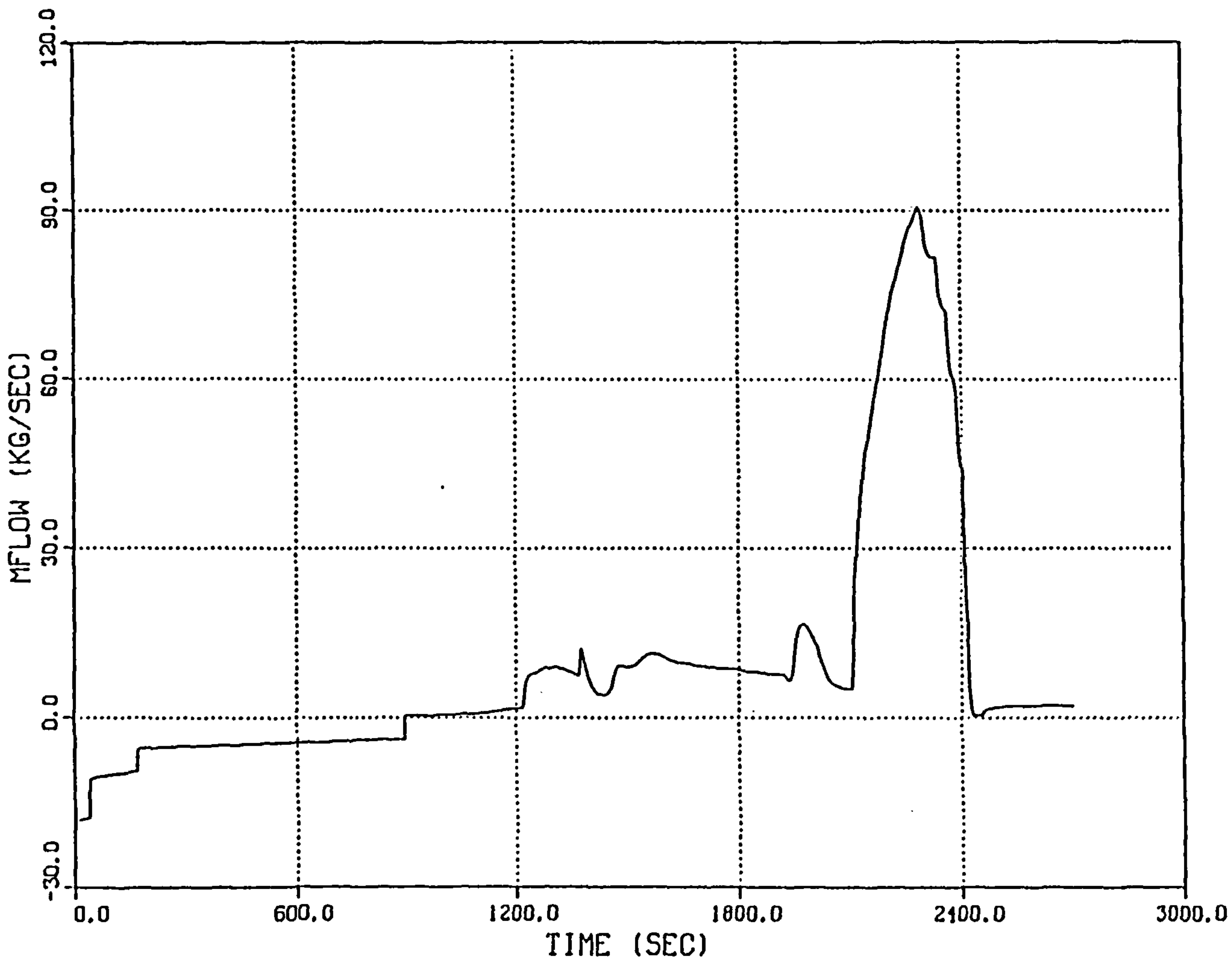


PLOT 6300 04.20.09 SAT 28 SEP, 1985 JOB-R3CROYT , CYBER NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 6.3 PRIMARY SYSTEM MASS ADDITION AND DEPLETION RATES

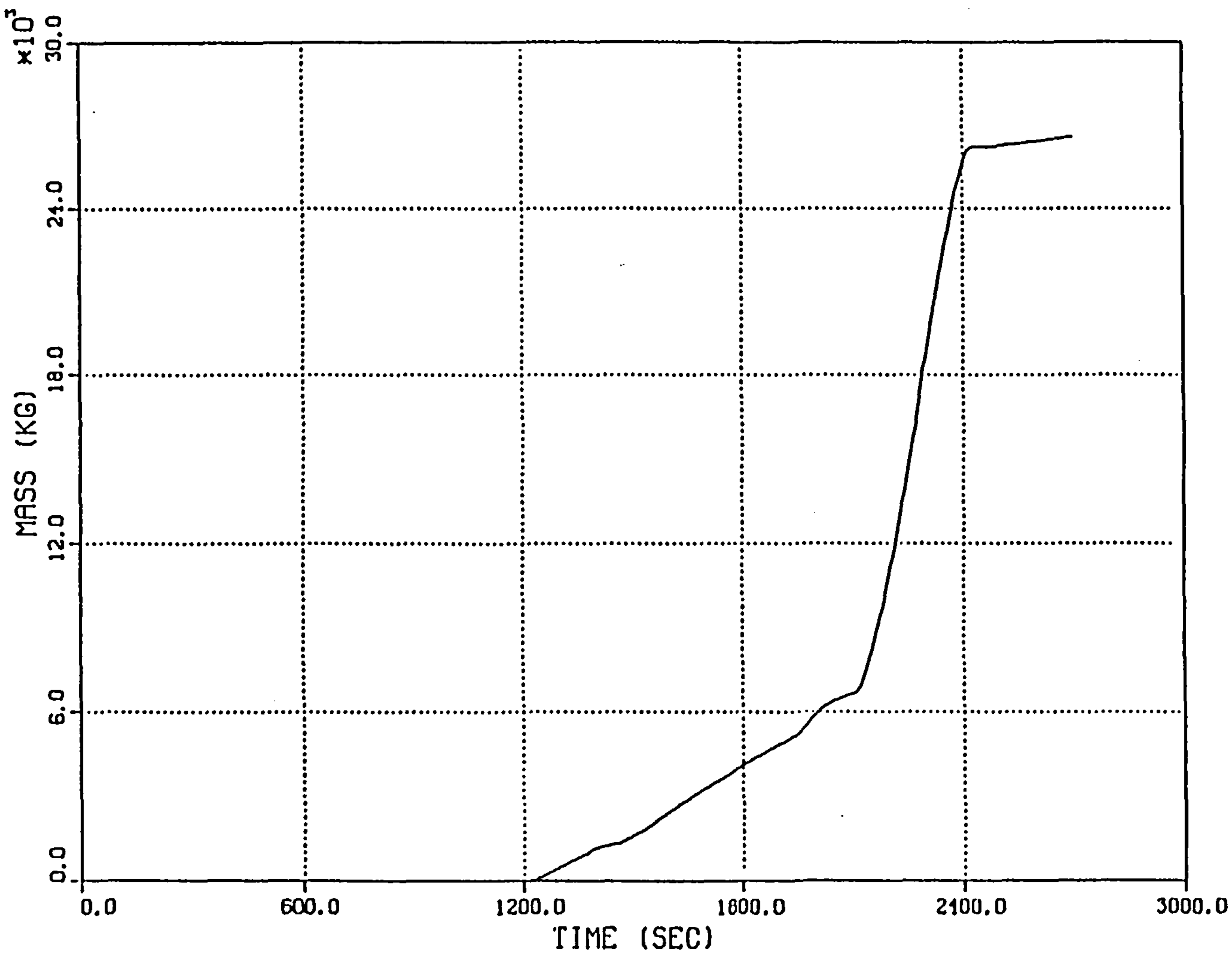


PLOT G100 04.20.35 SAT 28 SEP, 1985 JOB-A3CROYT , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 6.4 INTEGRAL OF HPSI MASS FLOW RATE

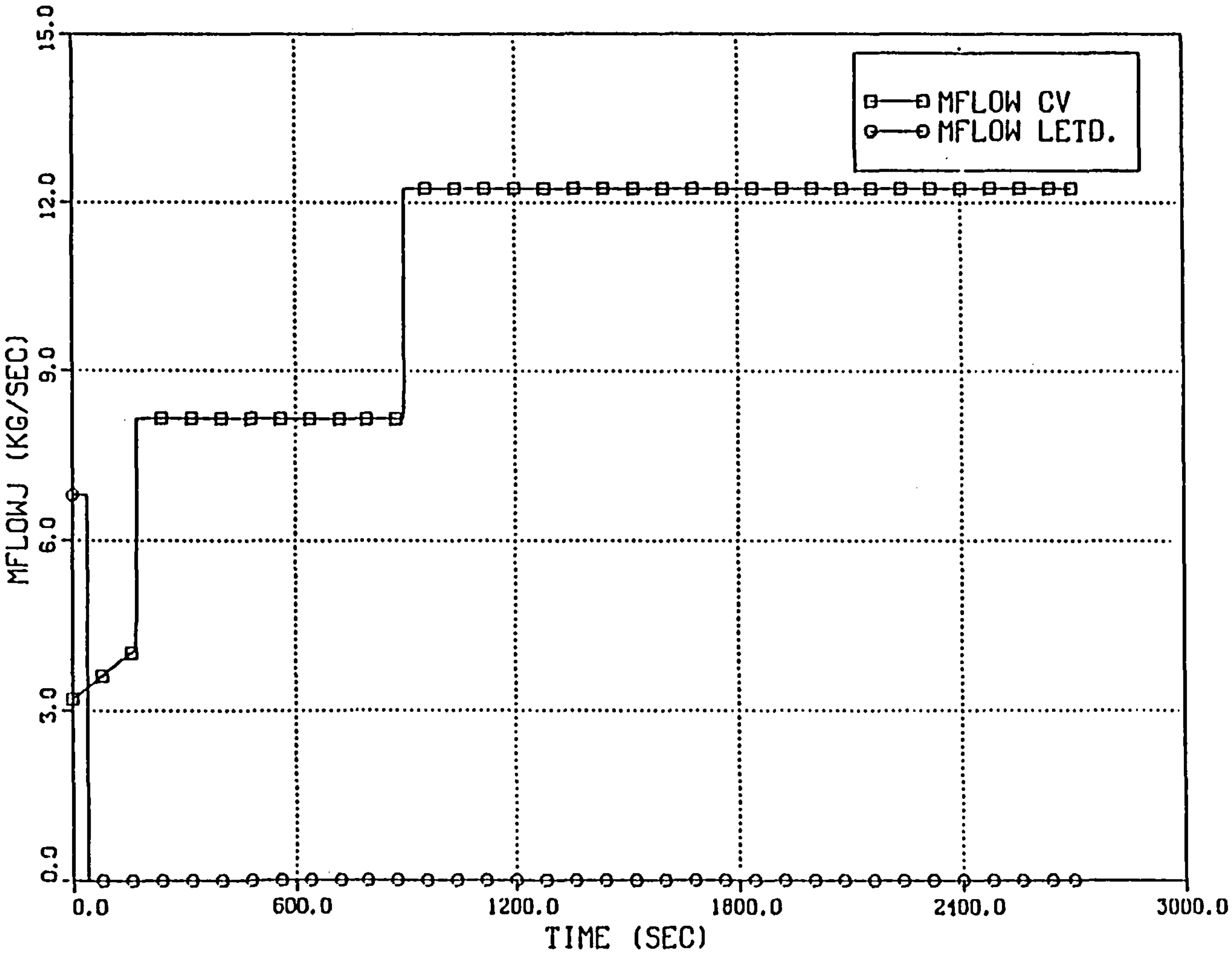


PLOT 6500 04.21.02 SAT 28 SEP, 1985 JOB-A3GRDYT , CYL. .CT NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 6.5 CHARGING AND LETDOWN MASS FLOW RATE

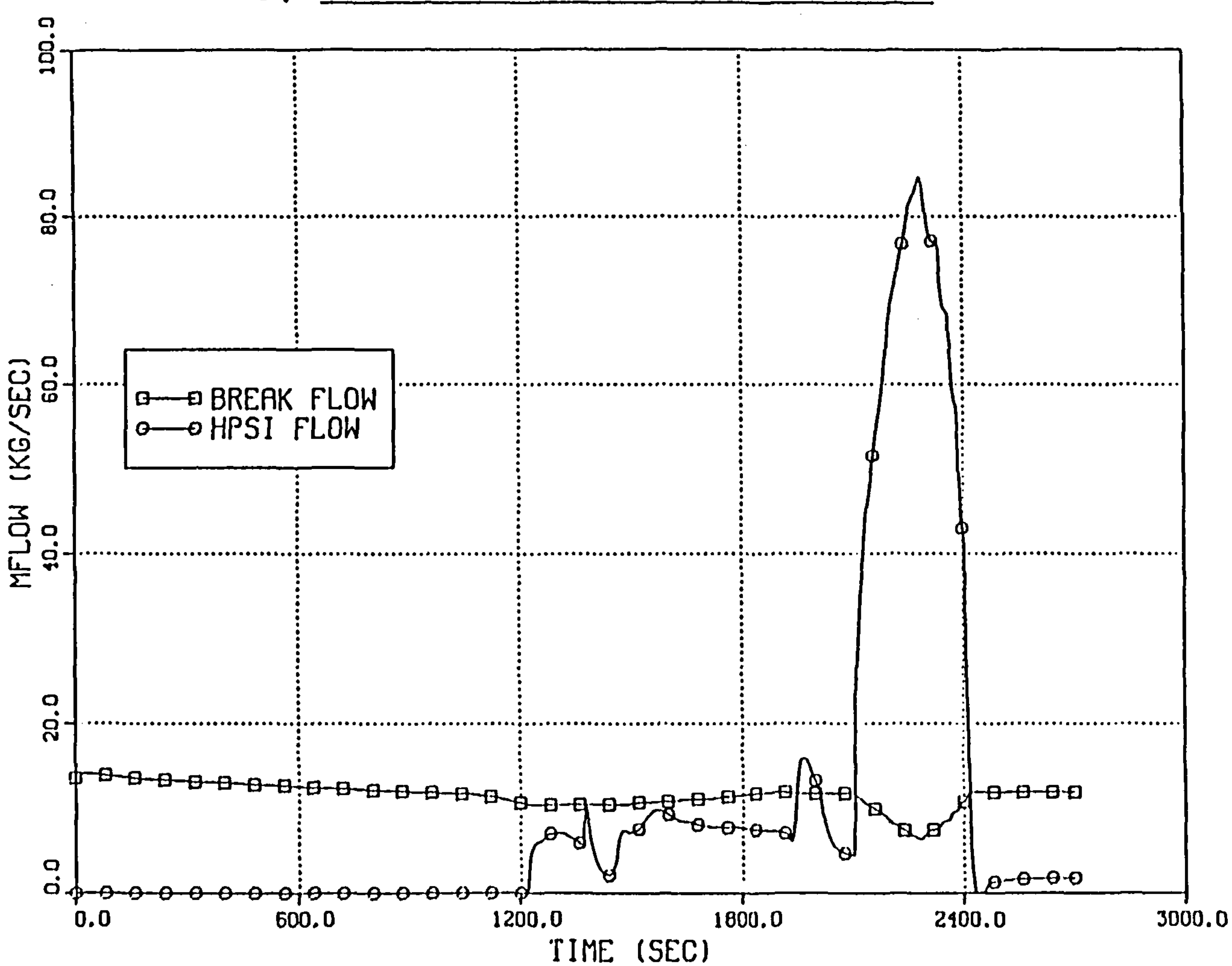


PLOT 6600 04.21.29 SAT 28 SEP, 1985 JOB-A3CRDYT , CYBERNE: NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 6.6 BREAK AND HPSI MASS FLOW RATE

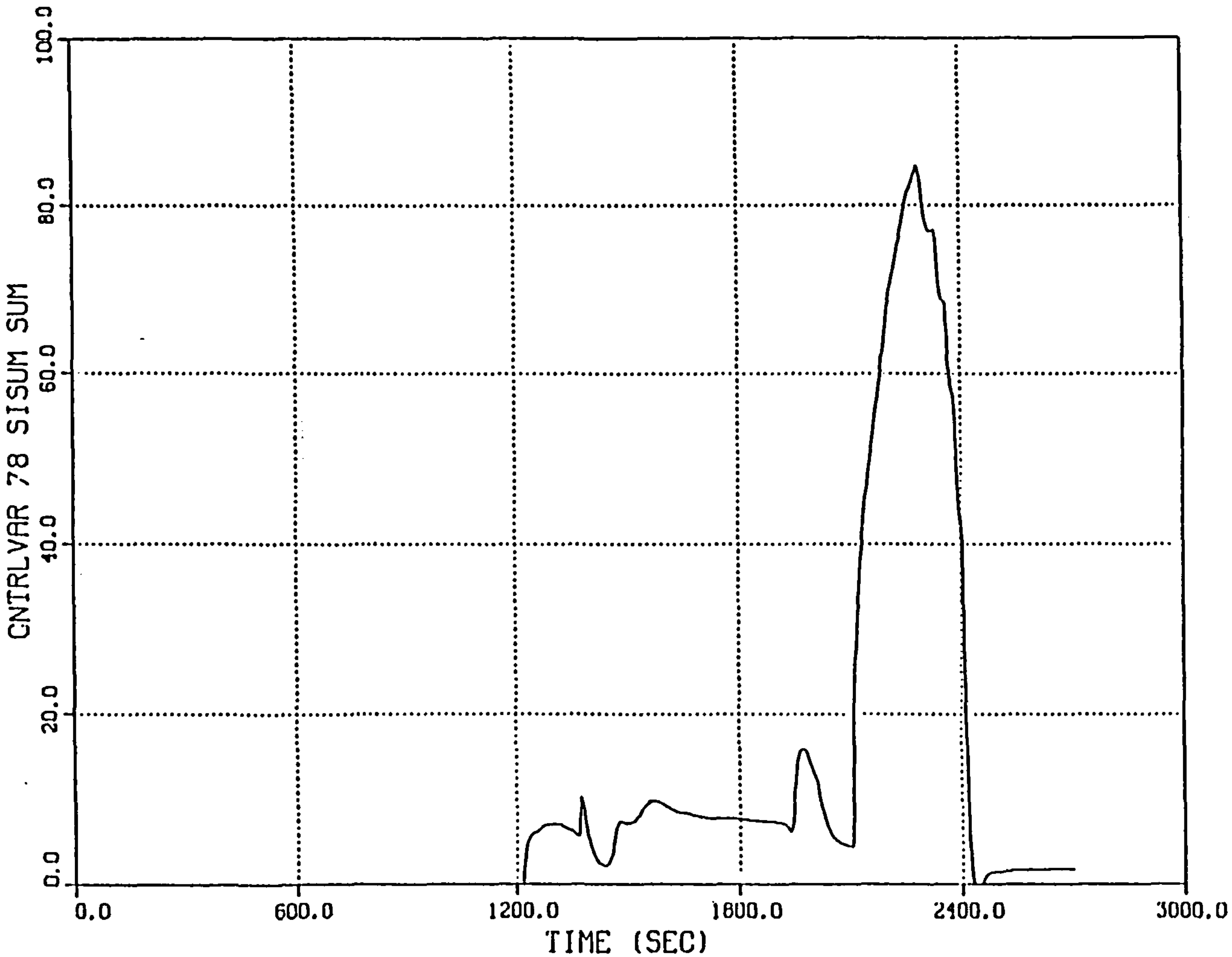


PLOT 6700 01.21.55 SAT 28 SEP, 1985 JOB-A3GRDYI , CYBF ~I NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 6.7 HPSI MASS FLOW RATE

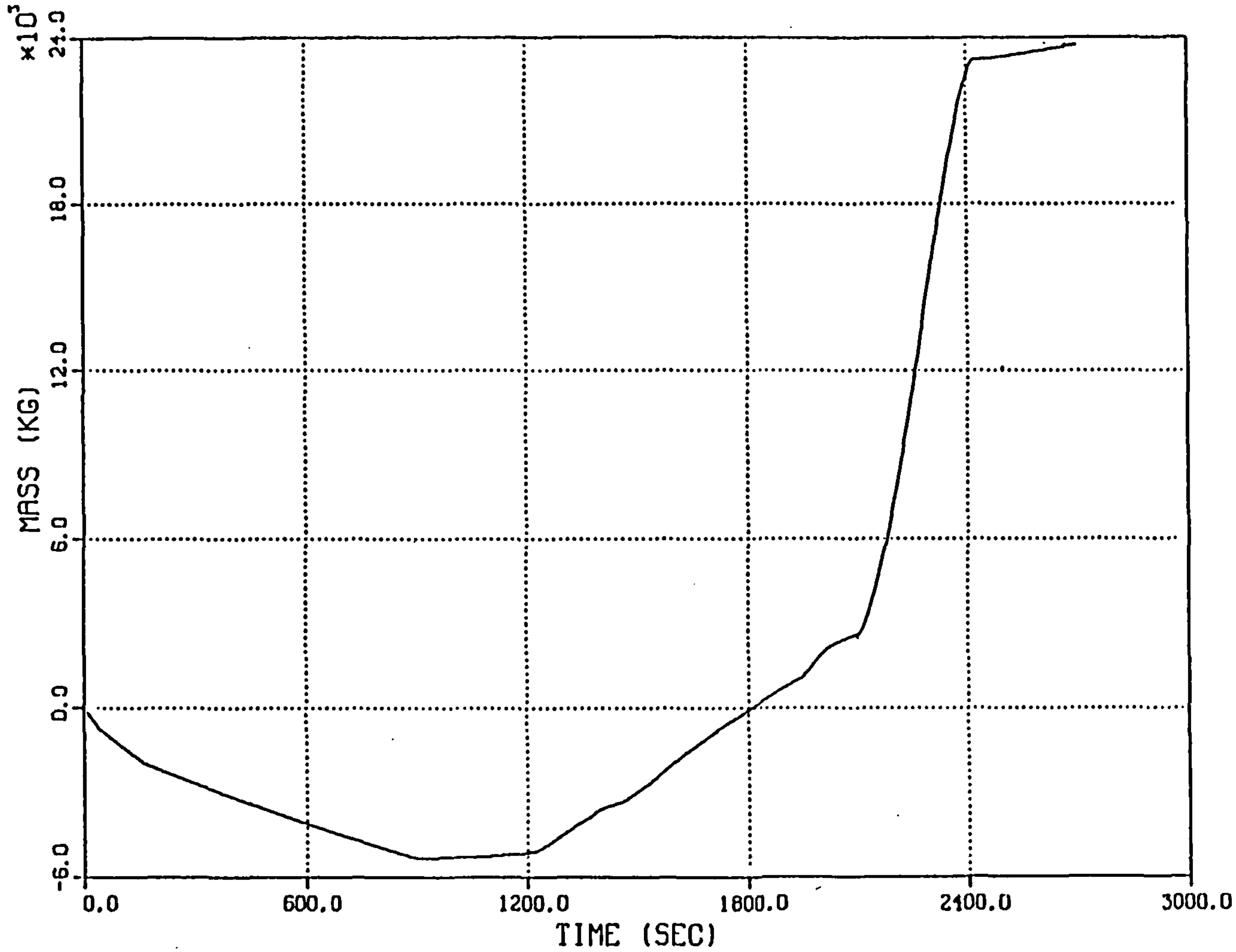


PLOT 6000 04.18.50 SAT 28 SEP, 1985 JOB-A3CRDYT , CYB...NET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 6.10 MASS BALANCE IN PRIMARY SYSTEM

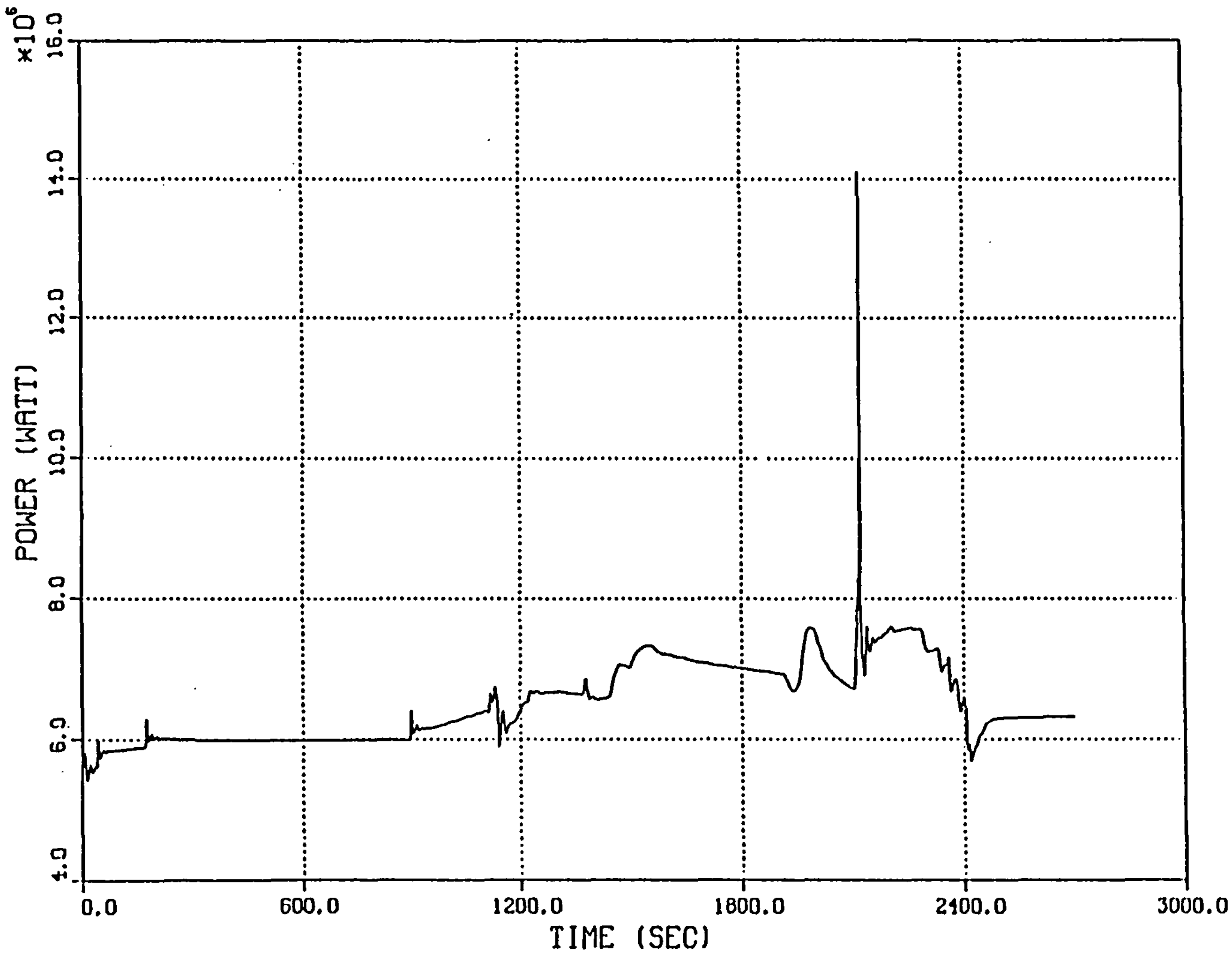


PLOT 7100 04.22.22 SAT 28 SEP, 1985 JOB-A3CROYT , CYBERNE, NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 7.1 CORE THERMAL POWER

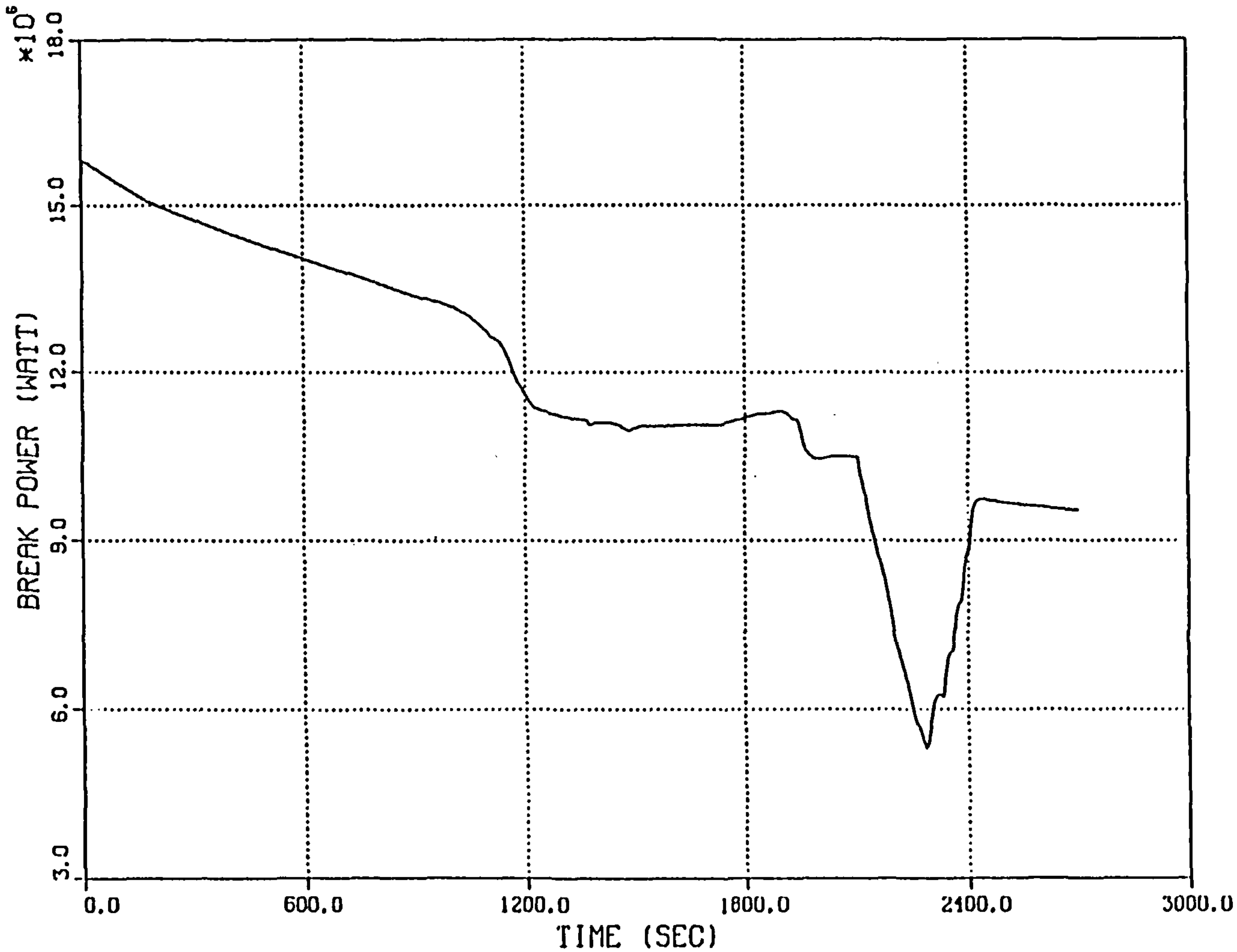


PLOT 7200 01.22.48 SAT 28 SEP, 1985 JOB-A3CROYT , CYBERNE, NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 7.2 BREAK ENERGY EVOLUTION



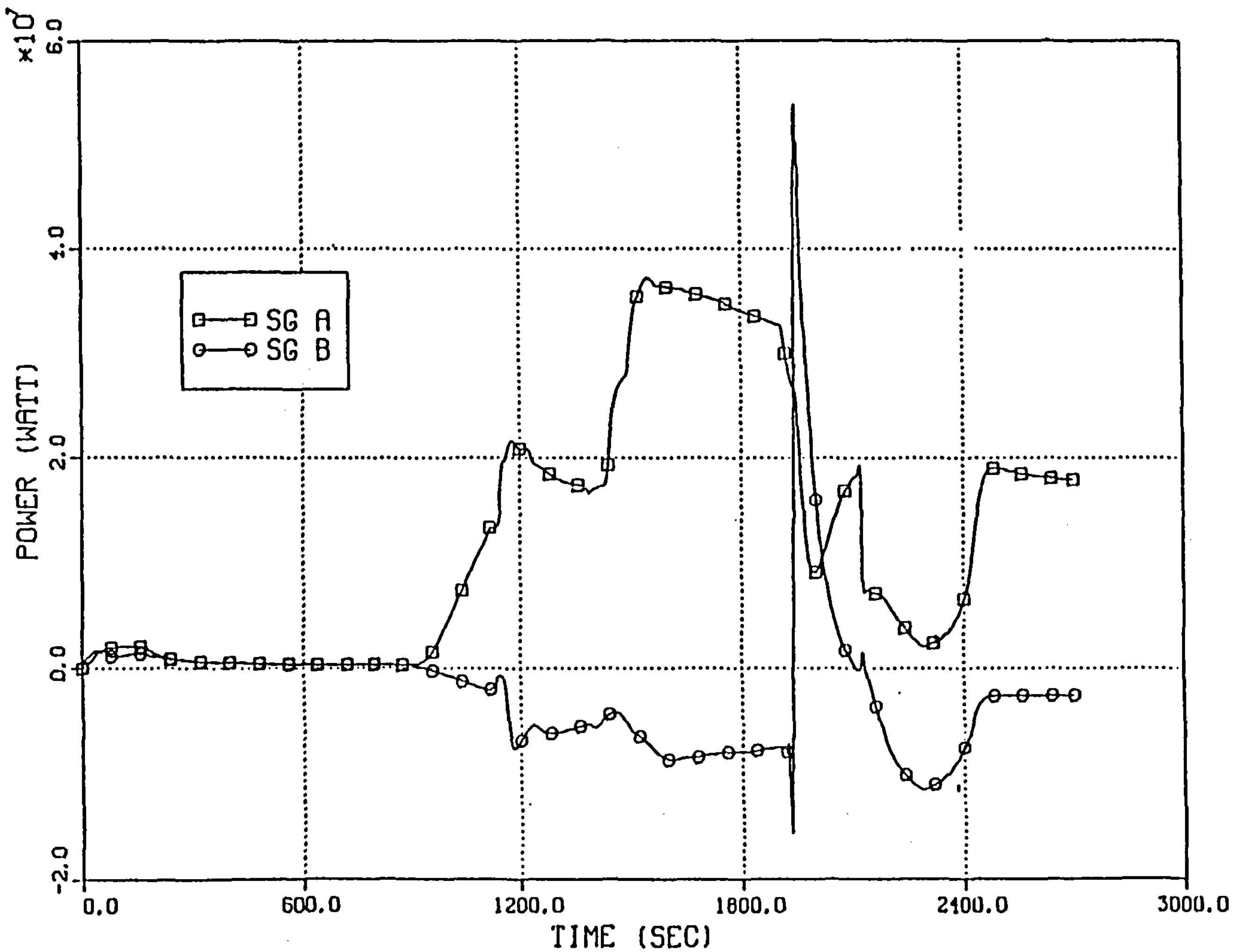
96

PLOT 7300 04.23.15 SAT 28 SEP, 1985 JOB-A3GROYT , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 7.3 HEAT TRANSFER RATE FROM PRIMARY TO SG

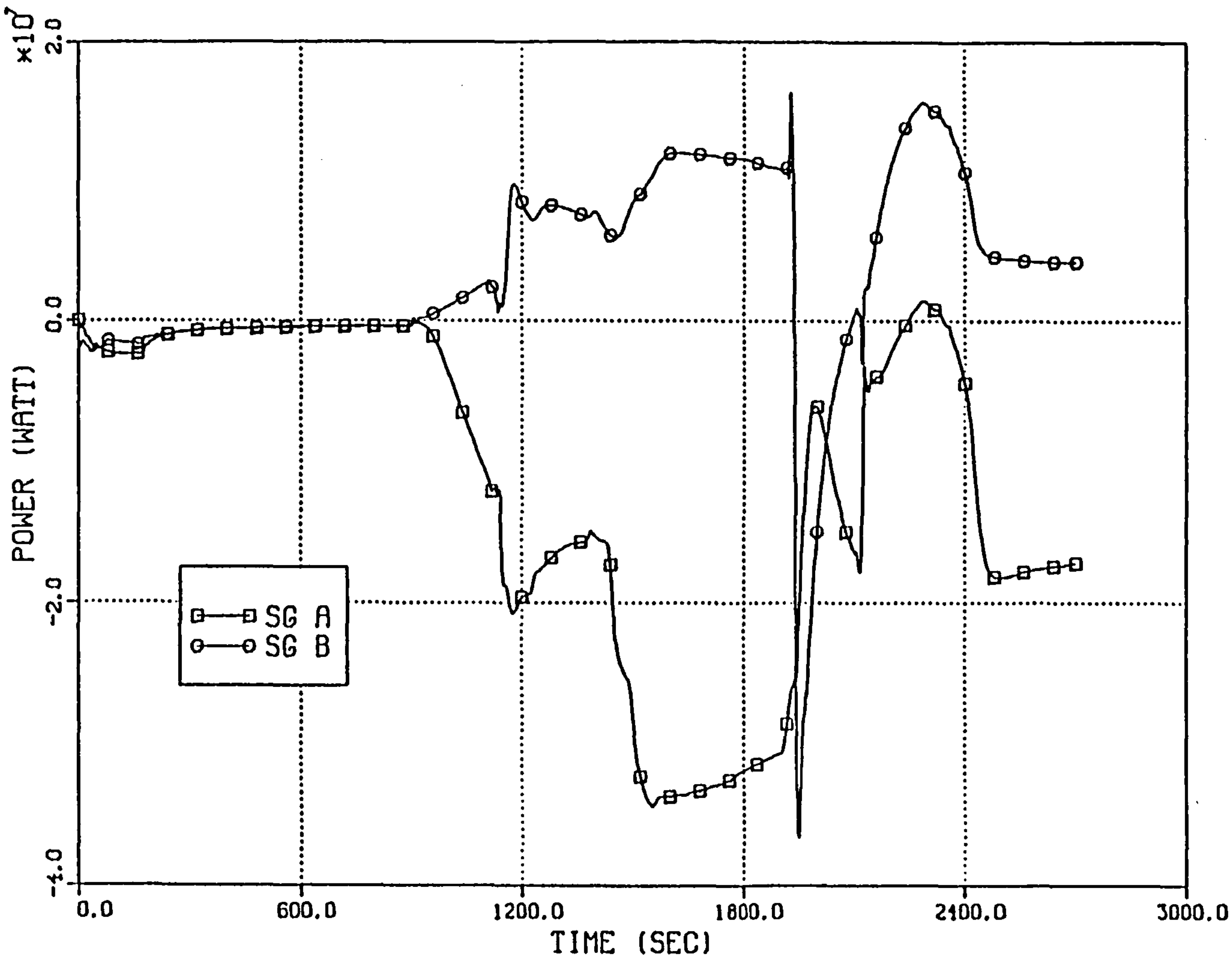


PLOT 7100 01.23.42 SAT 28 SEP, 1985 JOB-A3GADYT , CYDER..., NOS 1:0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 7.4 HEAT TRANSFER RATE FROM PRIMARY TO SG'S

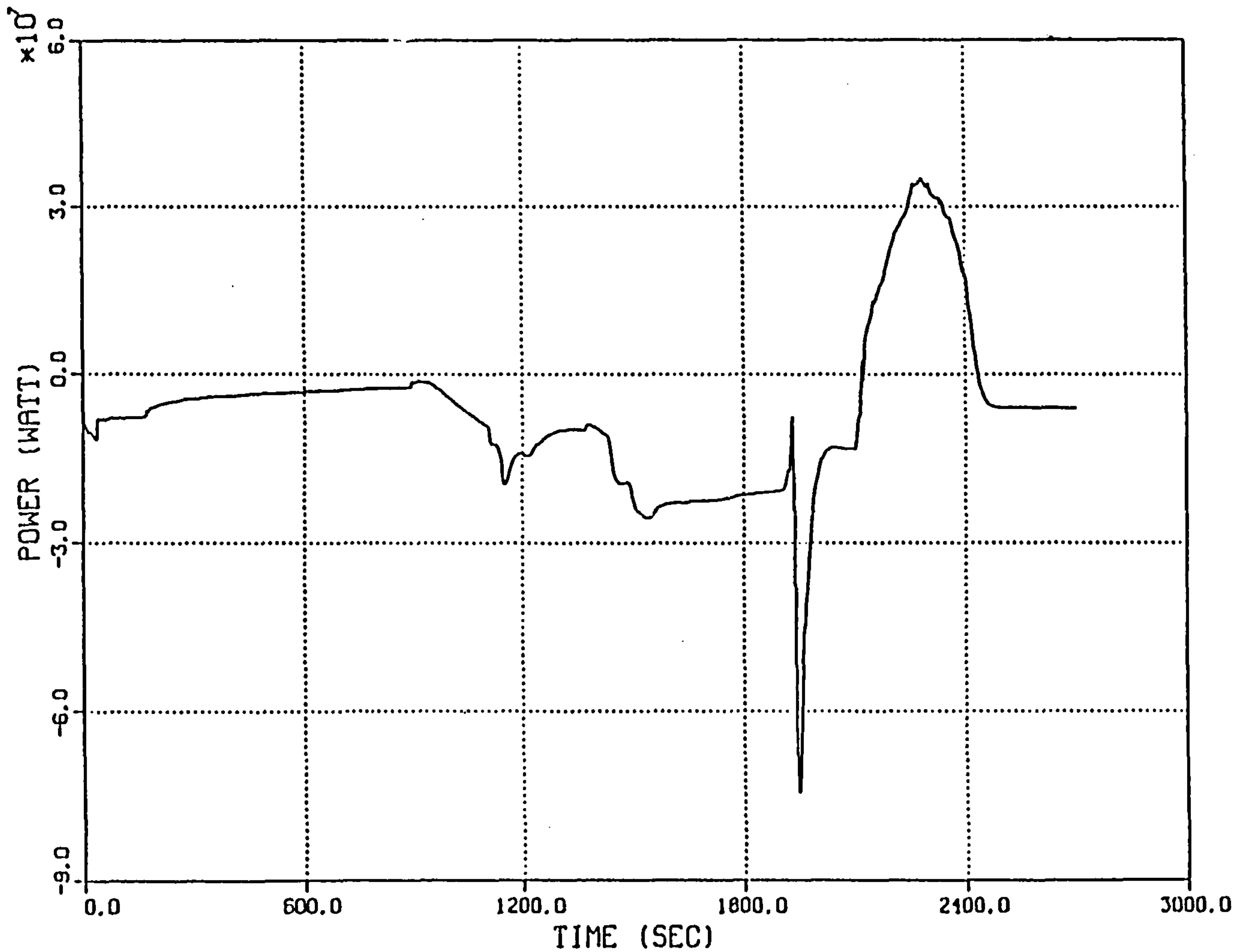


PLOT 7500 01.21.08 SAT 28 SEP, 1985 JOB-A3GRDYT , CYBL..CT NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 7.5 PRIMARY SYSTEM ENERGY BALANCE

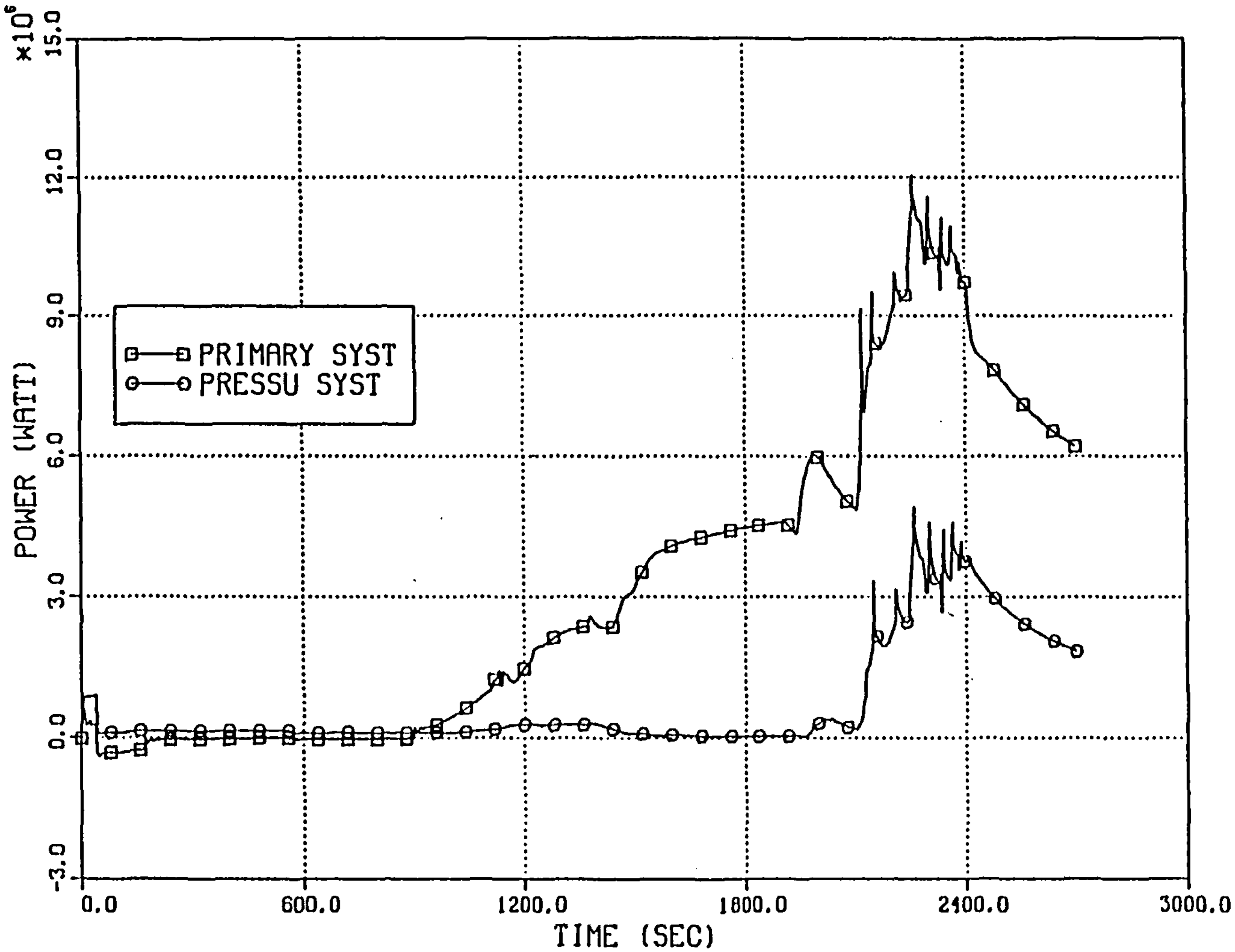


PLOT 7600 01.21.35 SAT 28 SEP, 1985 JOB-A3CRDYY , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 7.6 HEAT ADDITION RATE FROM PRIMARY METAL STRUCTURES

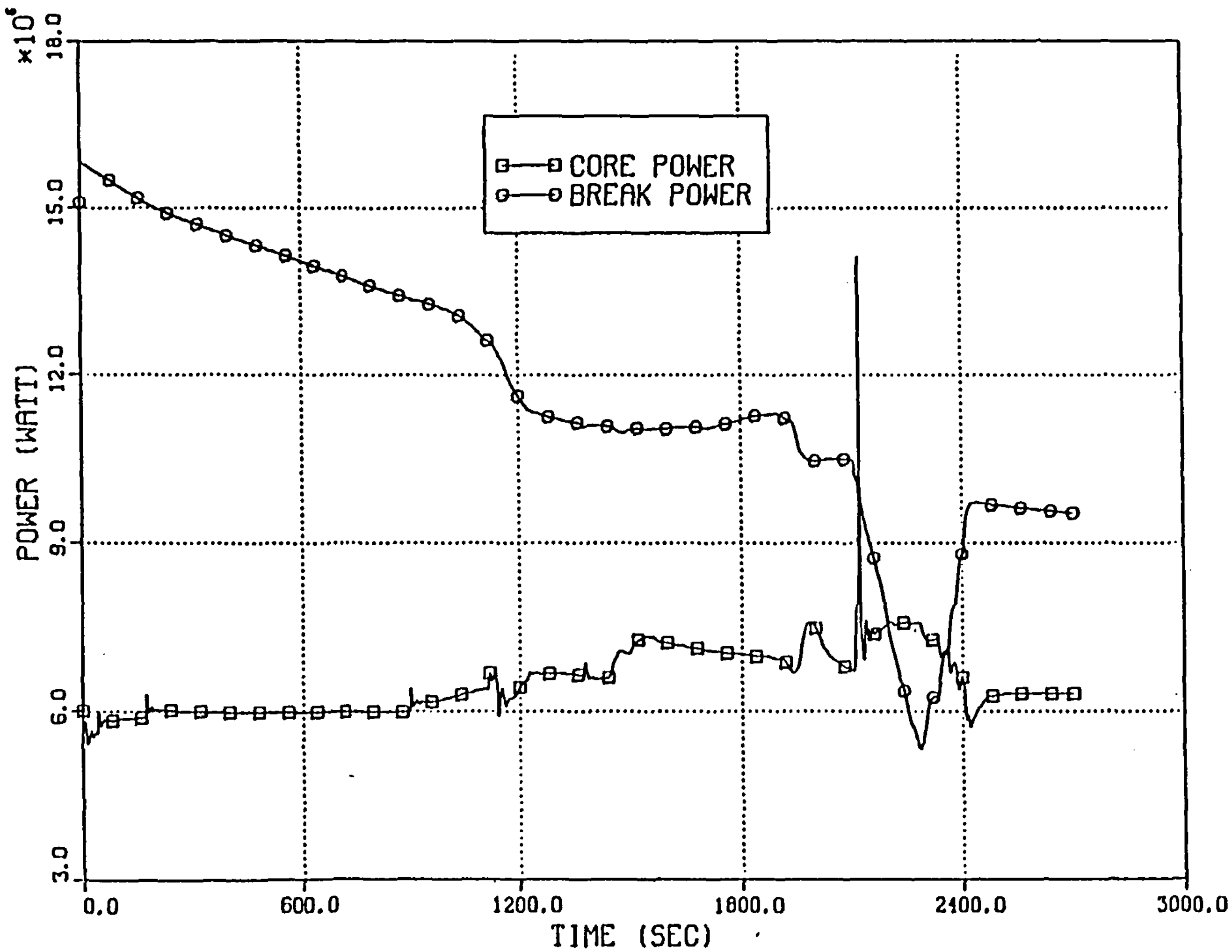


PLOT 7700 04.25.01 SAT 28 SEP, 1985 JOB-A3GROYT , CYBER... NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 7.7 THERMAL CORE AND BREAK POWER

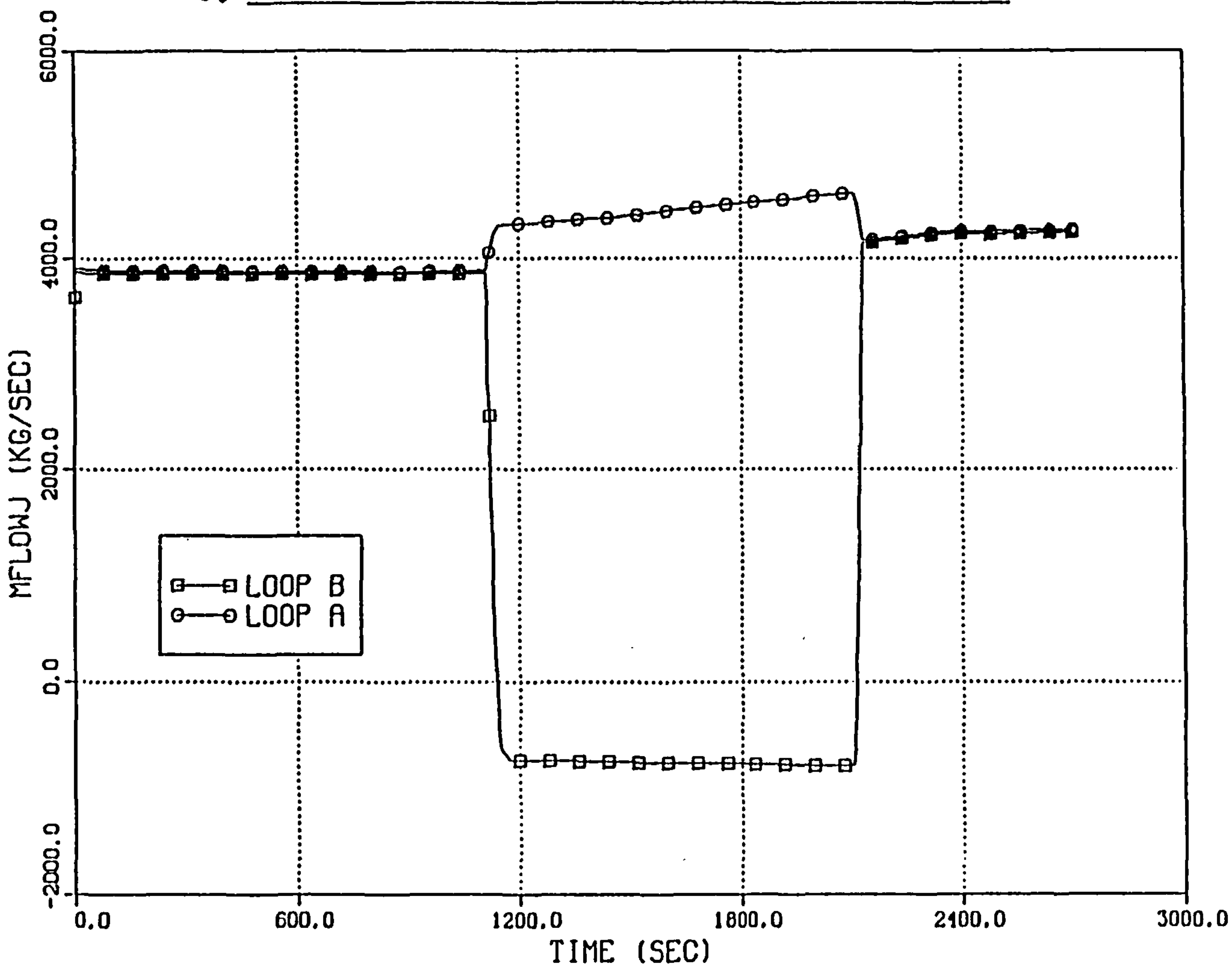


PLOT 8100 01.25.28 SAT 28 SEP, 1985 JOB-AJGRDYT , CYBER NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 8.1 COLD LEG MASS FLOW RATE (VESSEL INLET)

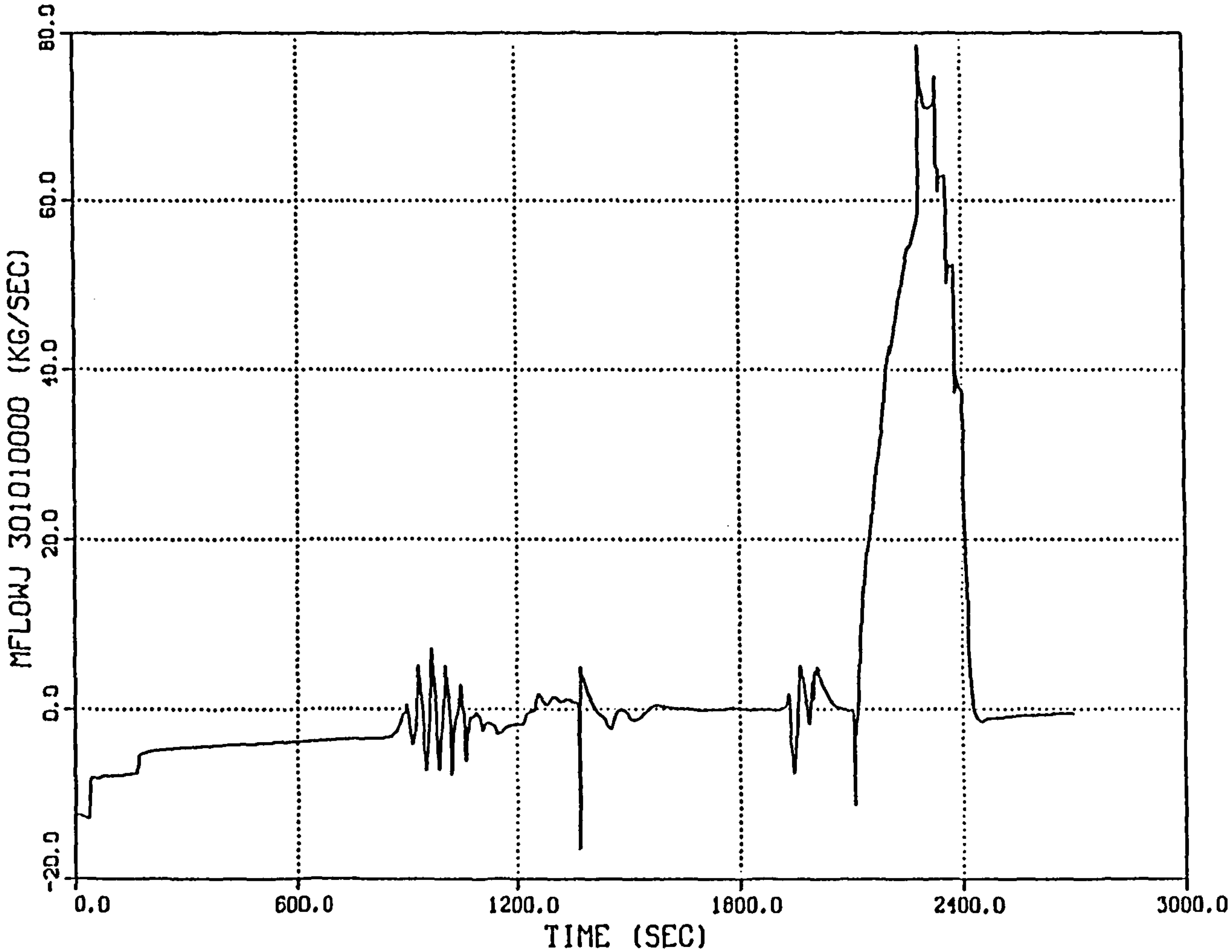


PLOT 8300 04.25.55 SAT 28 SEP, 1985 JOB-A3CRDYT , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 8.3 SURGELINE MASS FLOW RATE

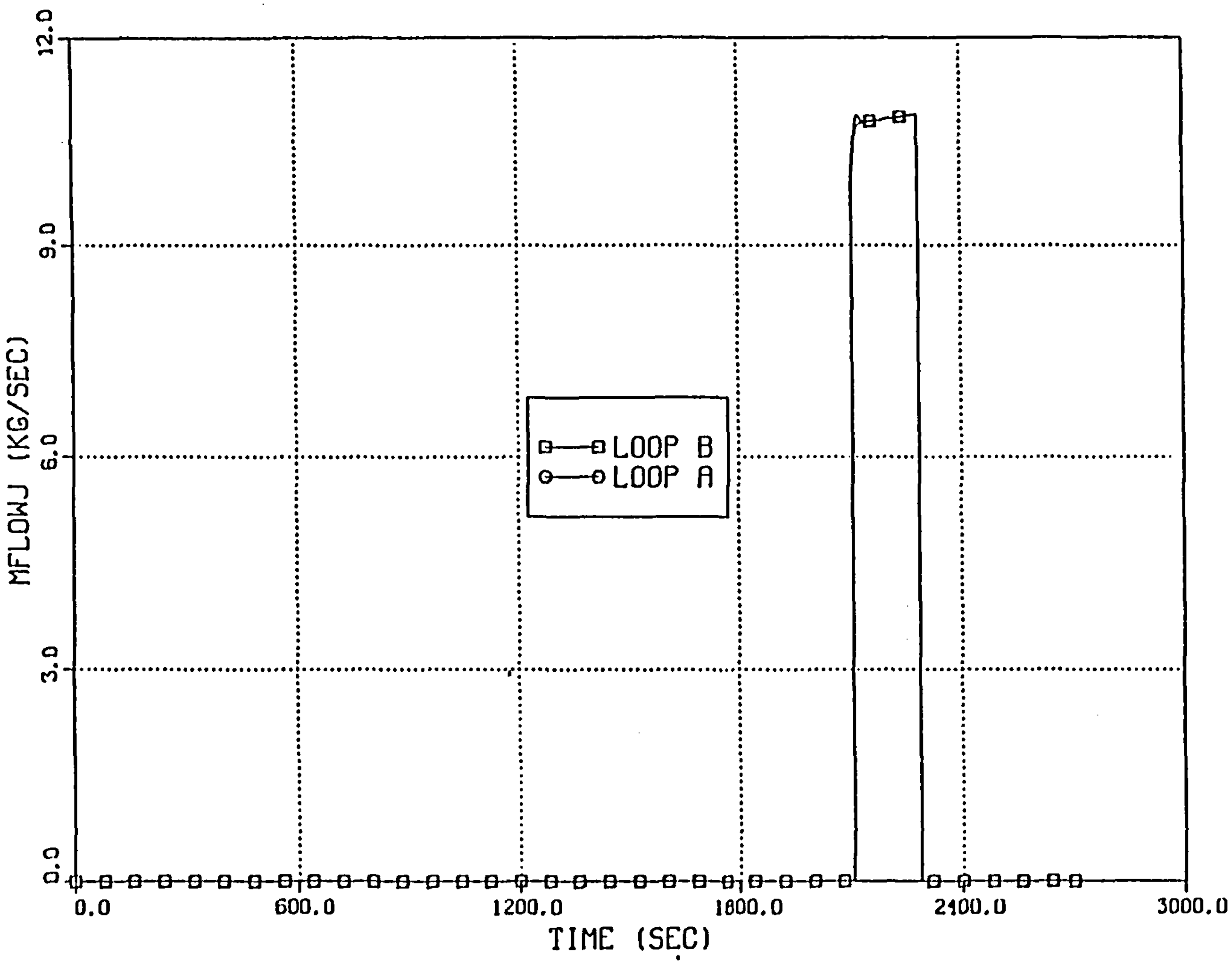


PLOT 6500 01.26.18 SAT 28 SEP, 1985 JOB-A3GRDYT , CYBER . NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 8.5 SPRAY MASS FLOW RATE



PLOT 9200 04.27.14 SAT 28 SEP, 1985 JOB-A3GROYT CY NET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

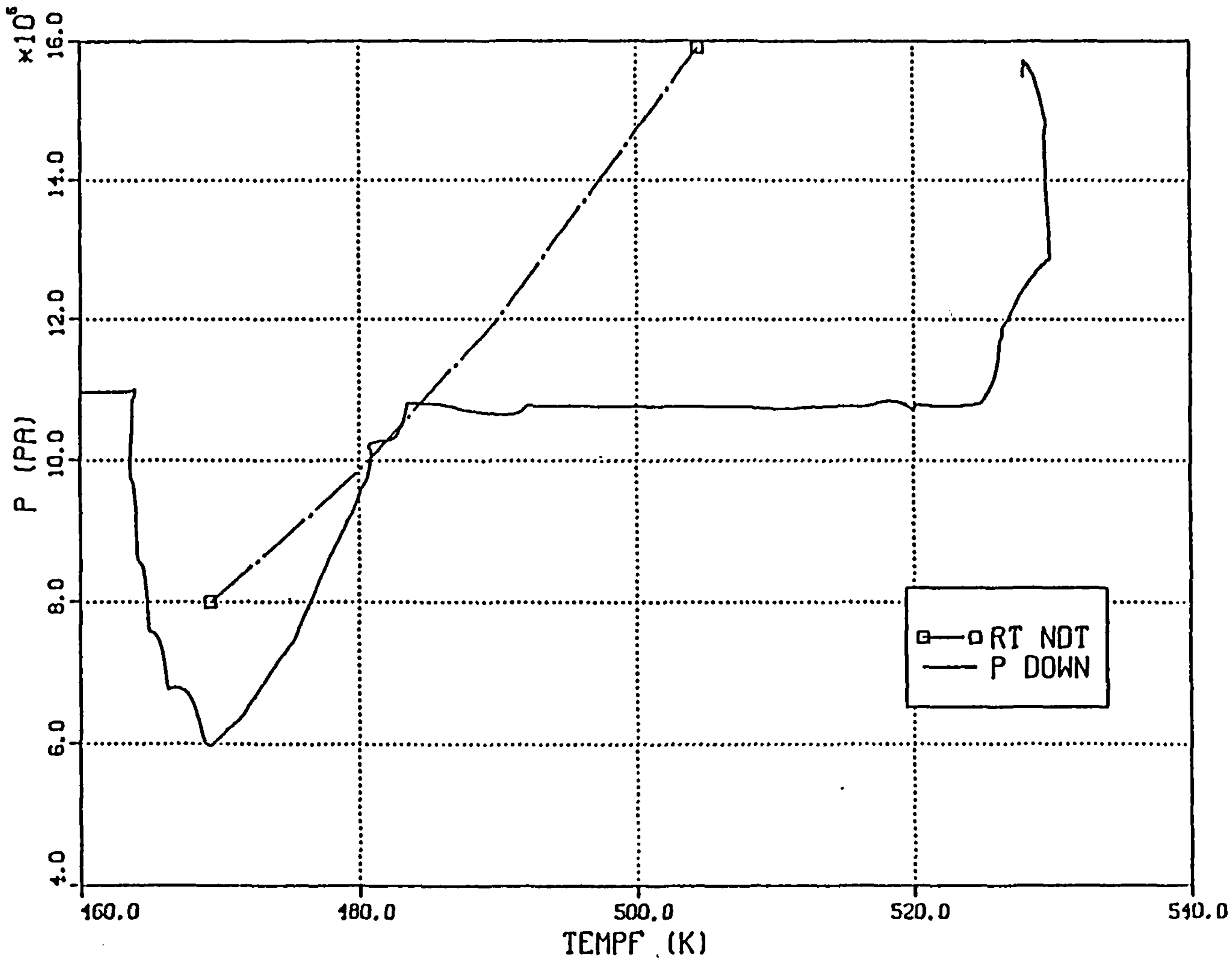
5. FIG 9.2 SUBCOOLING IN PRIMARY SYSTEM

PLOT 9300 01.27.41 SAT 28 SEP, 1985 JOB-A3GRDYT , CYBE I NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 9.3 PRESSURE VERSUS TEMPERATURE IN DOWNCOMER

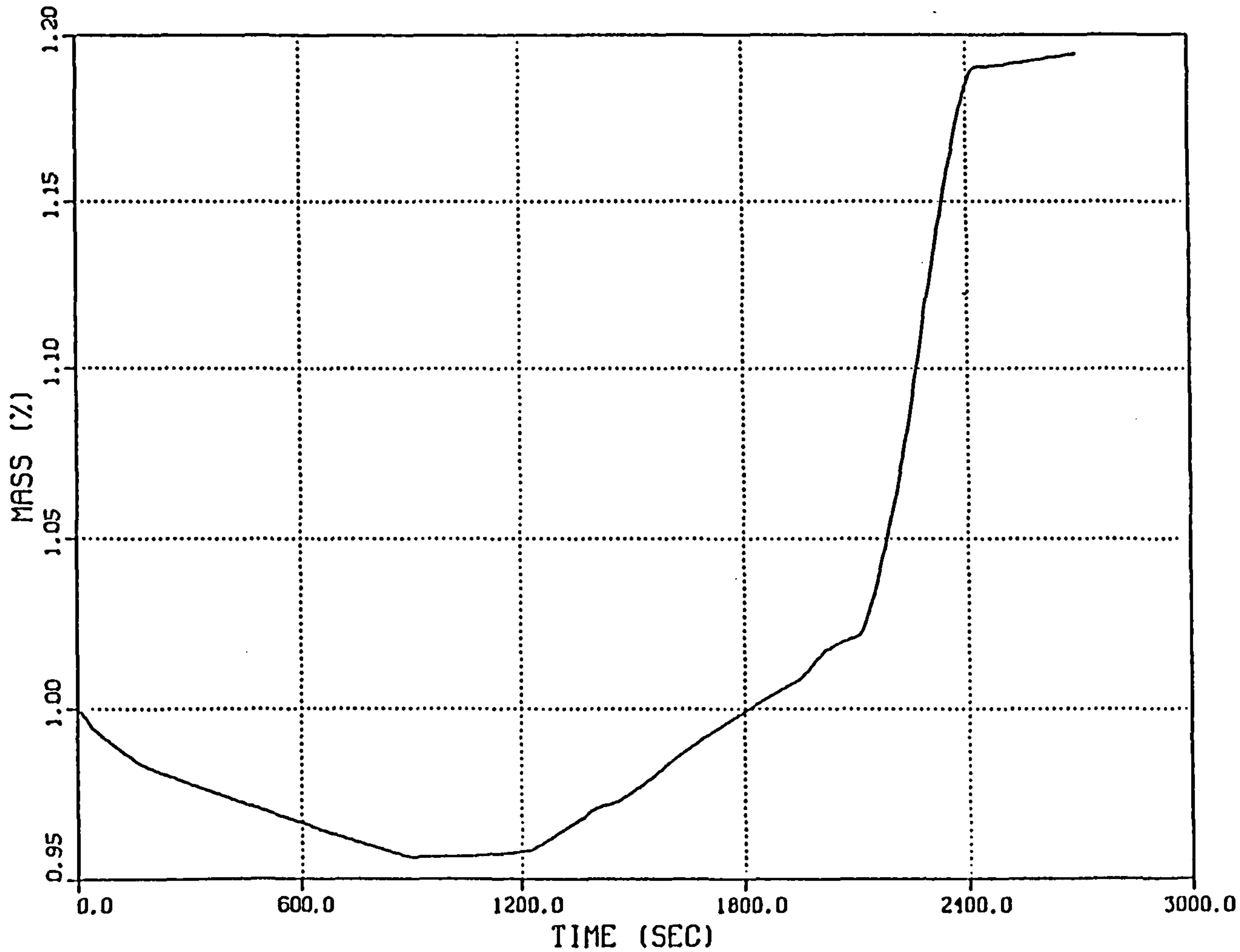


PLOT 9900 04.28.07 SAT 28 SEP, 1985 JOB-A3CRDYT , CYBI .T NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 9.9 MASS BALANCE IN PRIMARY SYSTEM

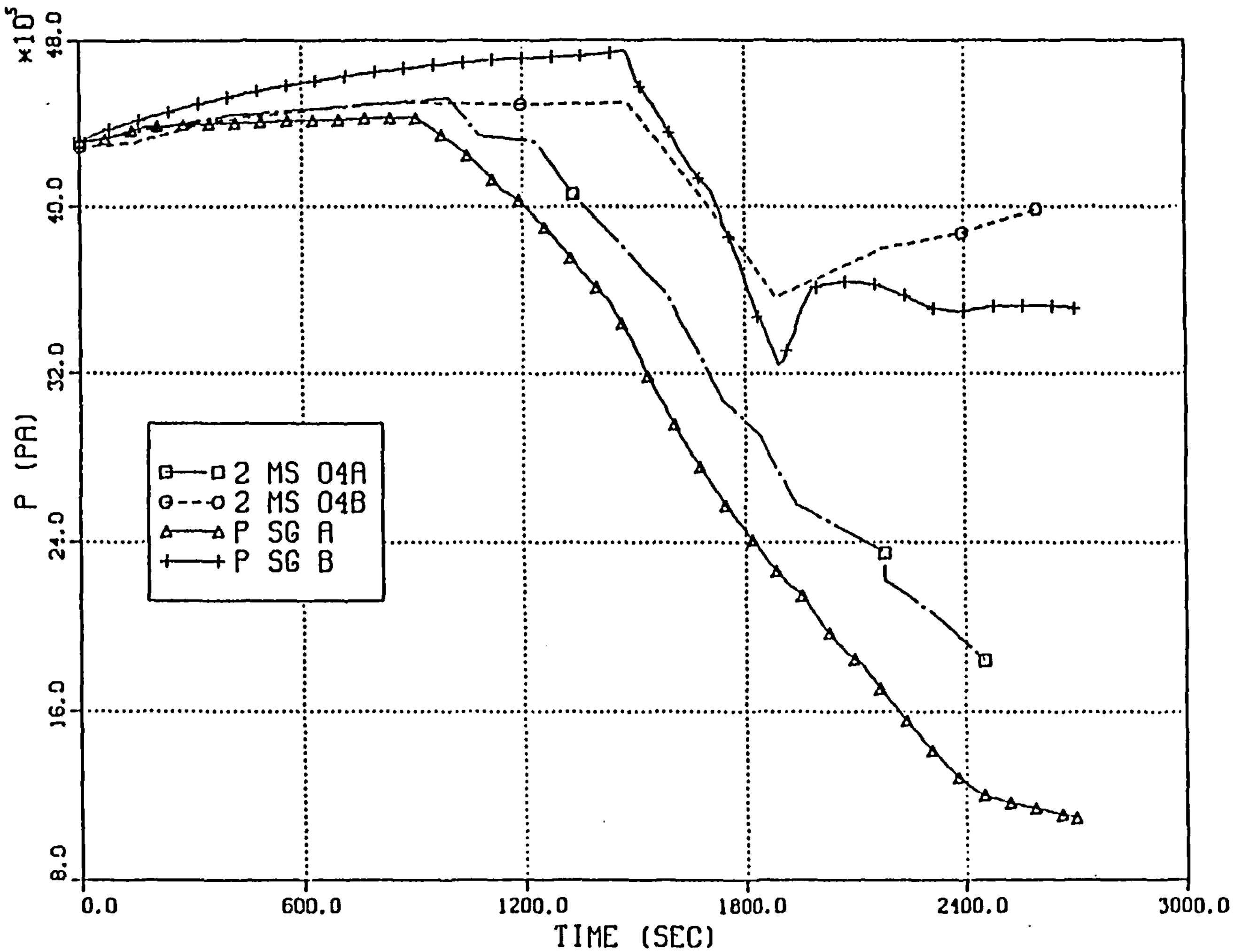


PLOT 0 01.28.34 SAT 28 SEP, 1985 JOB-A3GRDYT , CYBE I NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 10.1 PRESSURE EVOLUTION IN STEAM GENERATOR (DOME)

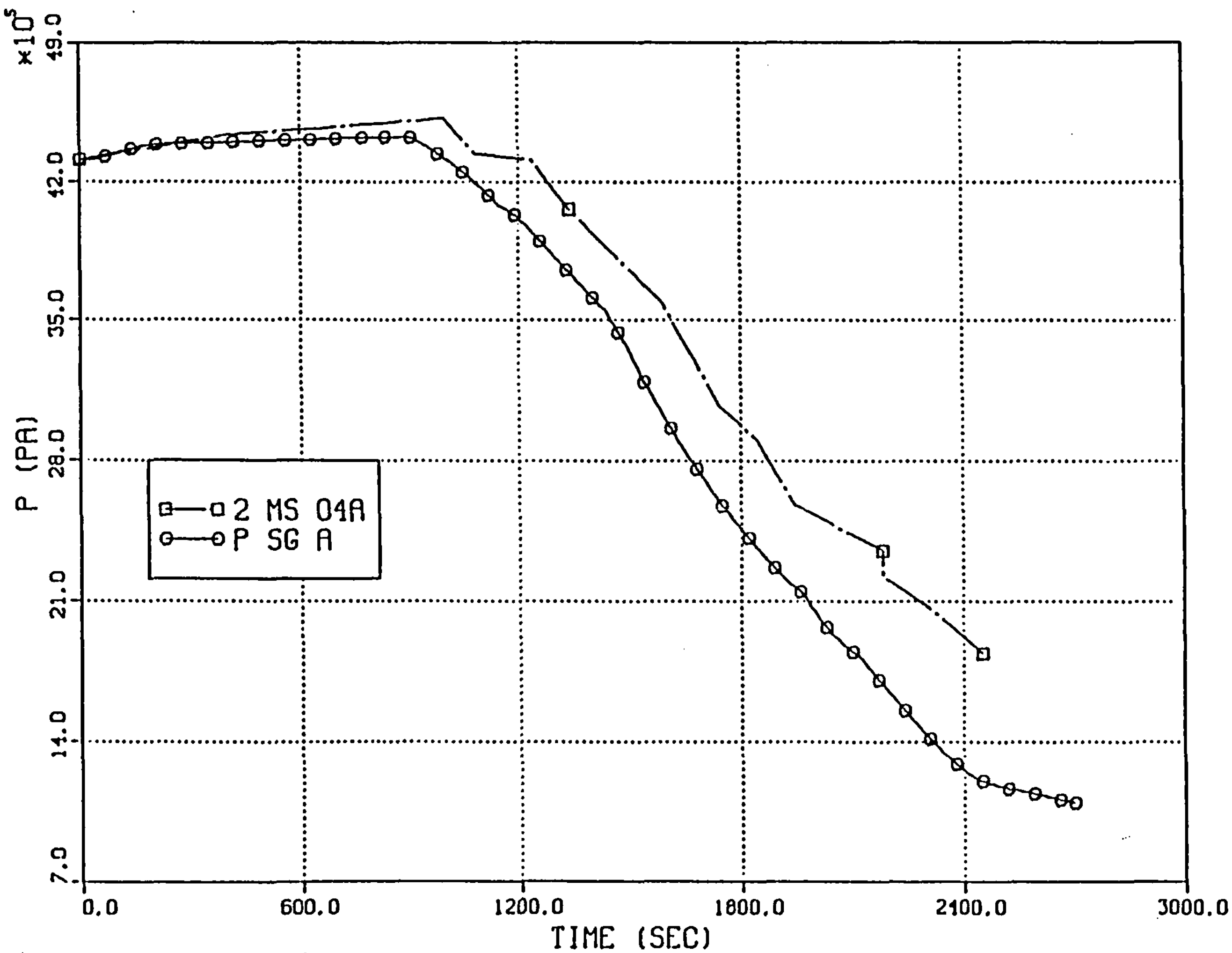


PLOT 0 04.29.00 SAT 28 SEP, 1985 JOB-A3GADYT , CYB :T NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 10.2 PRESSURE EVOLUTION IN STEAM GENERATOR A(DOME)

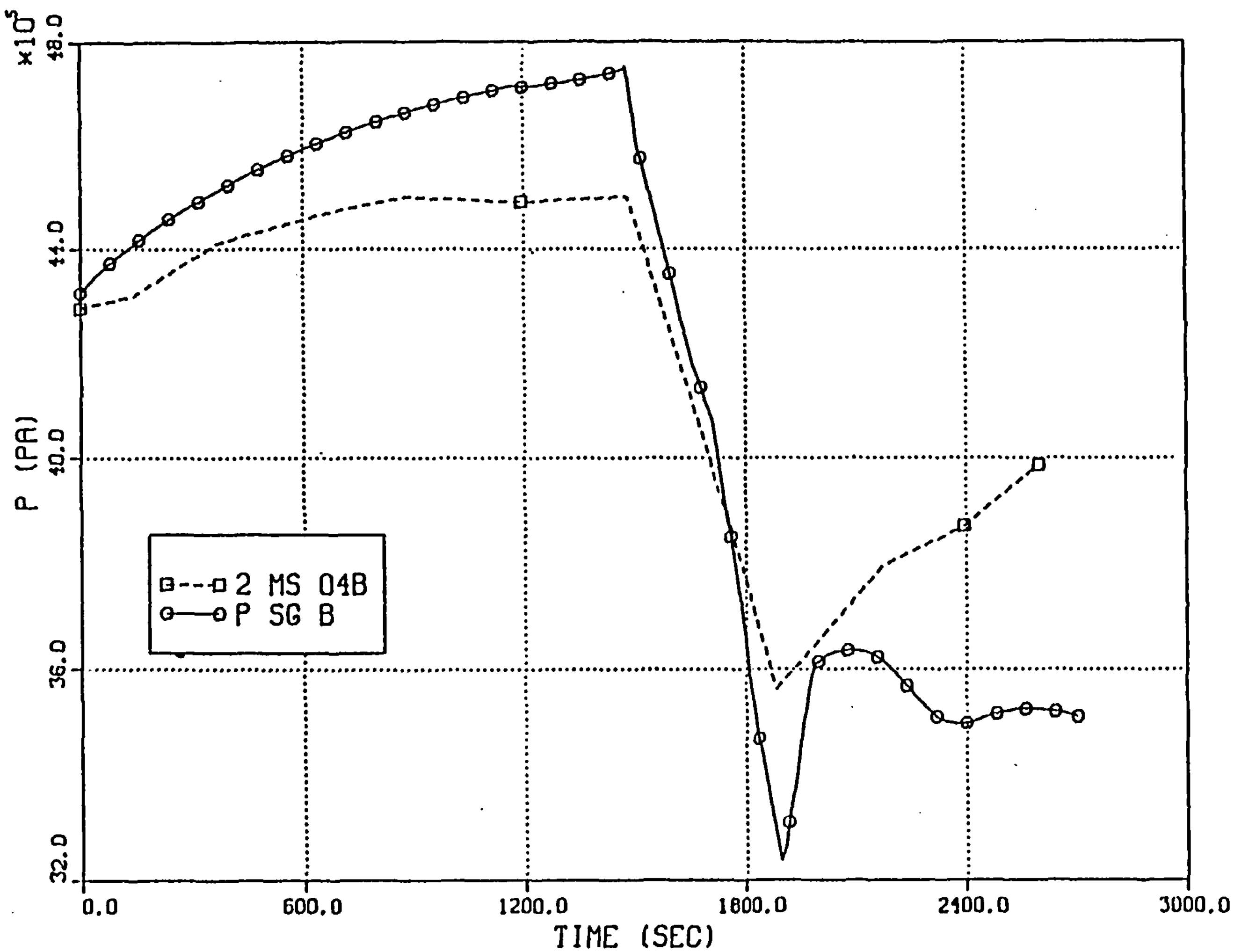


PLOT 0 01.29.27 SAT 28 SEP, 1985 JOB-AJGRDYT CTR' ET NOS 1.0 DISSPLA VER 9.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 10.3 PRESSURE EVOLUTION IN STEAM GENERATOR B(DOME)

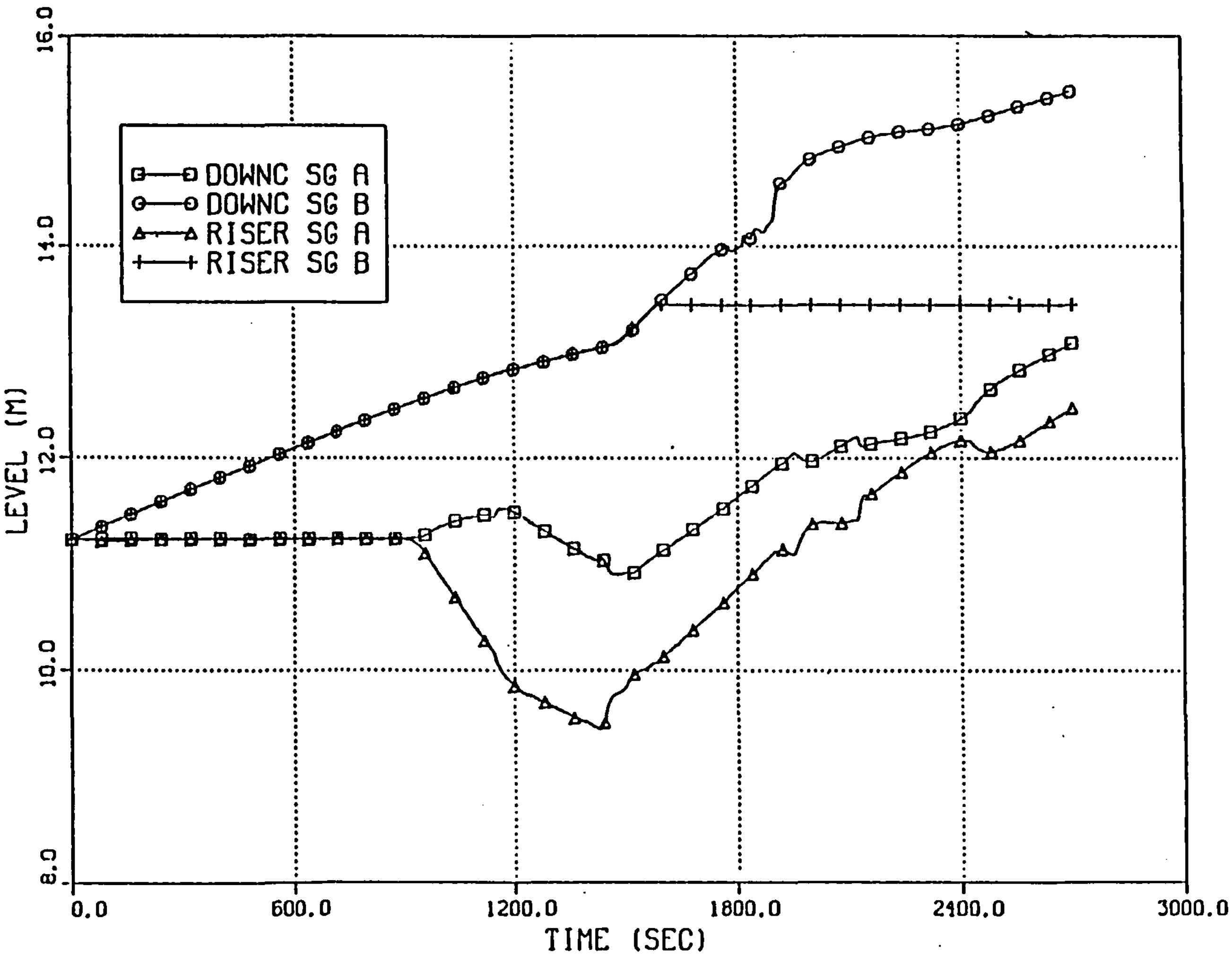


PLOT 0 04.29.55 SAT 28 SEP, 1985 JOB-ASGROTT , ...ERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 11.1 COLLAPSED WATER LEVEL IN STEAM GENERATORS

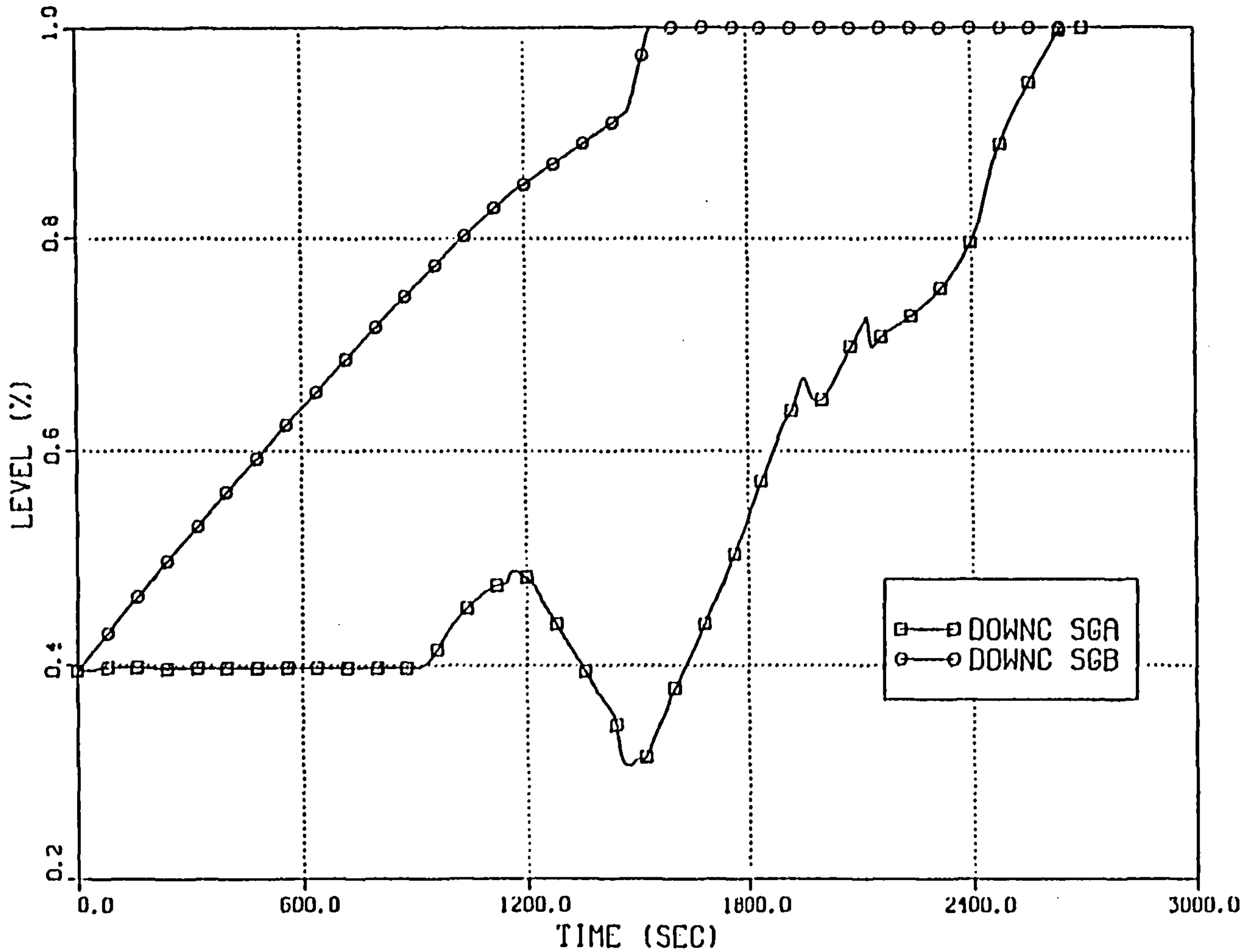


PLOT 0 01.30.22 SAT 28 SEP, 1985 JOB-A3GRDYT , CYb .T NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 11.5 MEASURED WATER LEVEL IN STEAM GENERATORS

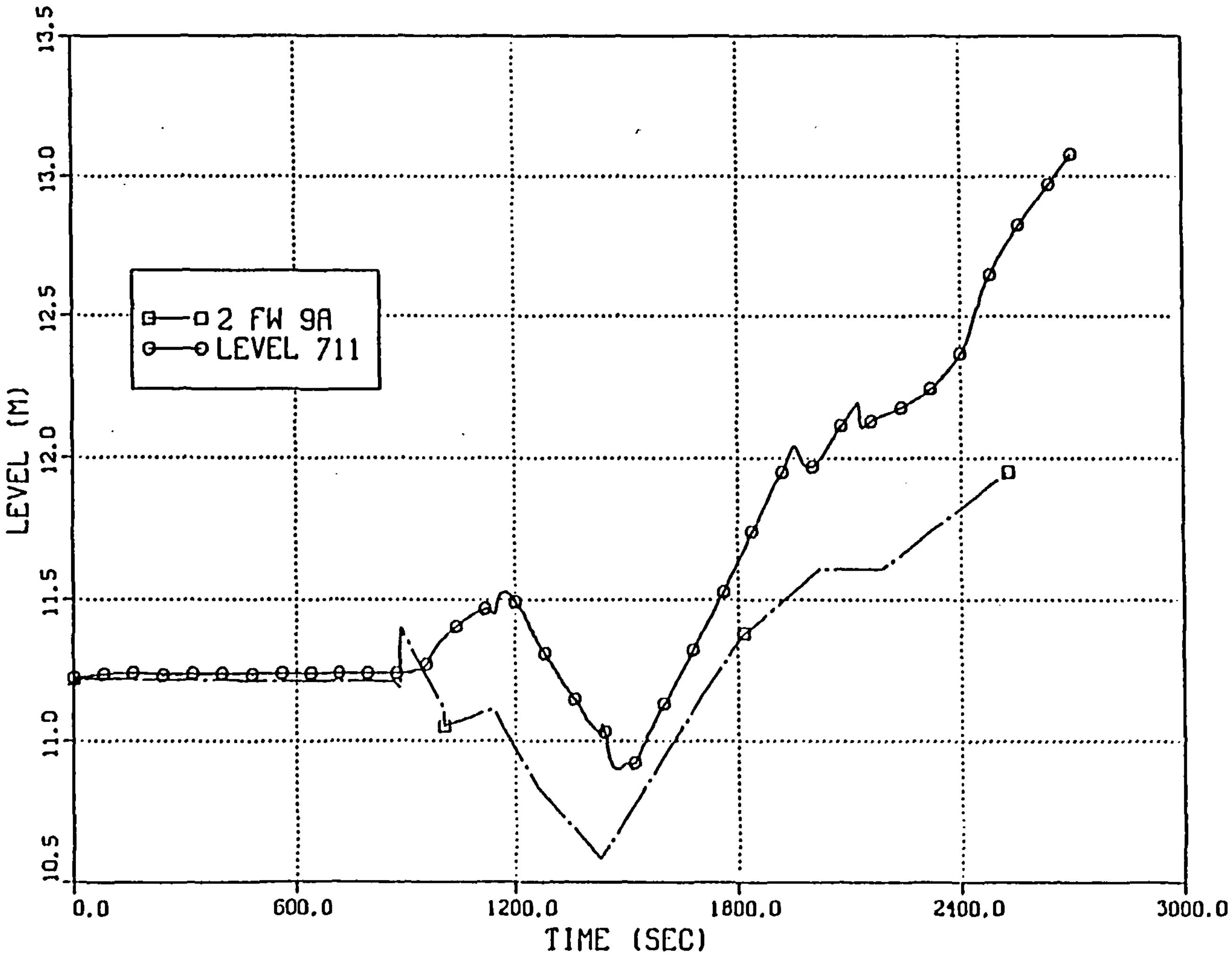


PLOT 0 01.30.18 SAT 28 SEP, 1985 JOB-A3GRDYT , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 11.6 COLLAPSED WATER LEVEL IN STEAM GENERATOR A

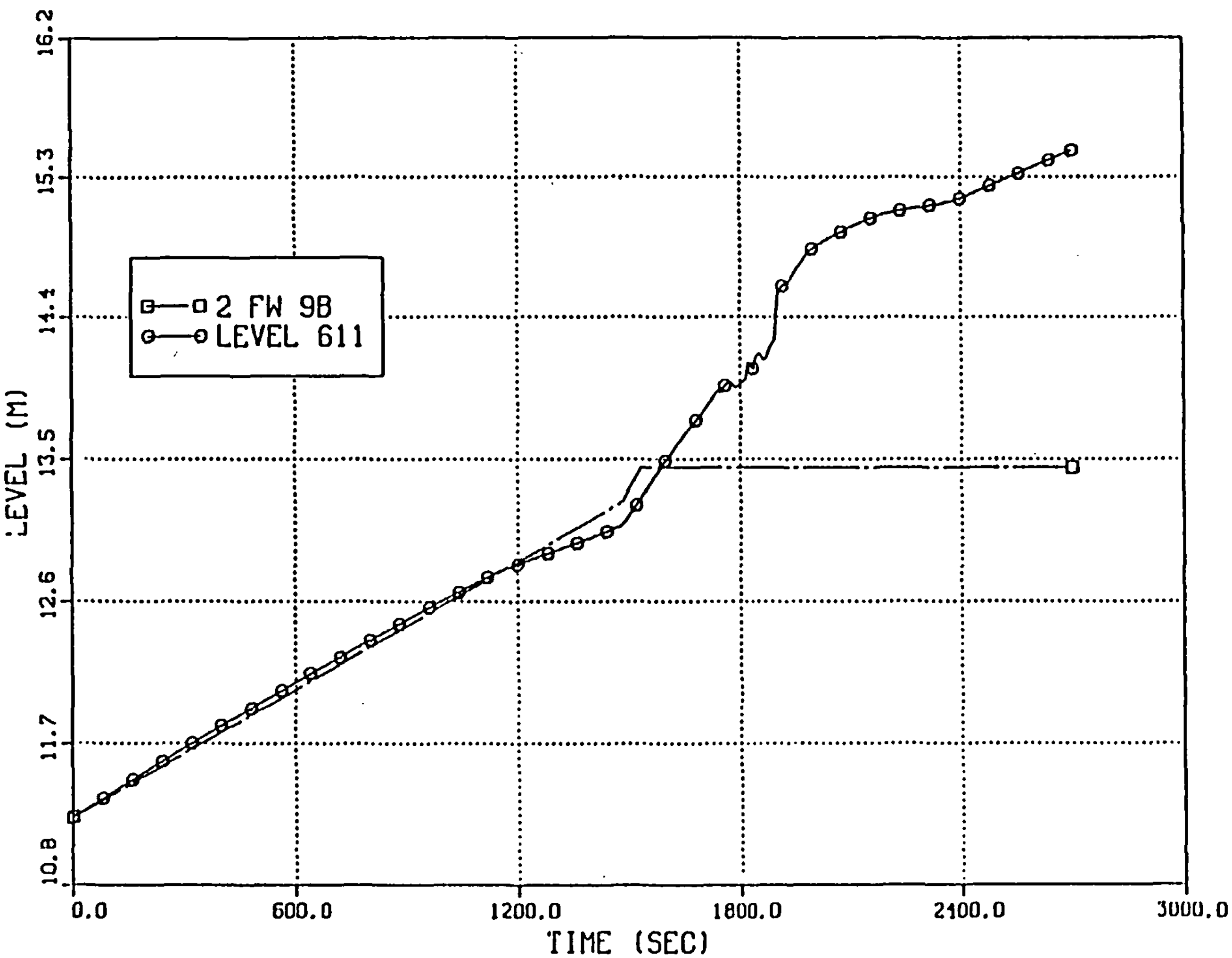


PLOT 0 01.31.15 SAT 28 SEP, 1985 JOB-A3GRDYI , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 11.7 COLLAPSED WATER LEVEL IN STEAM GENERATOR B

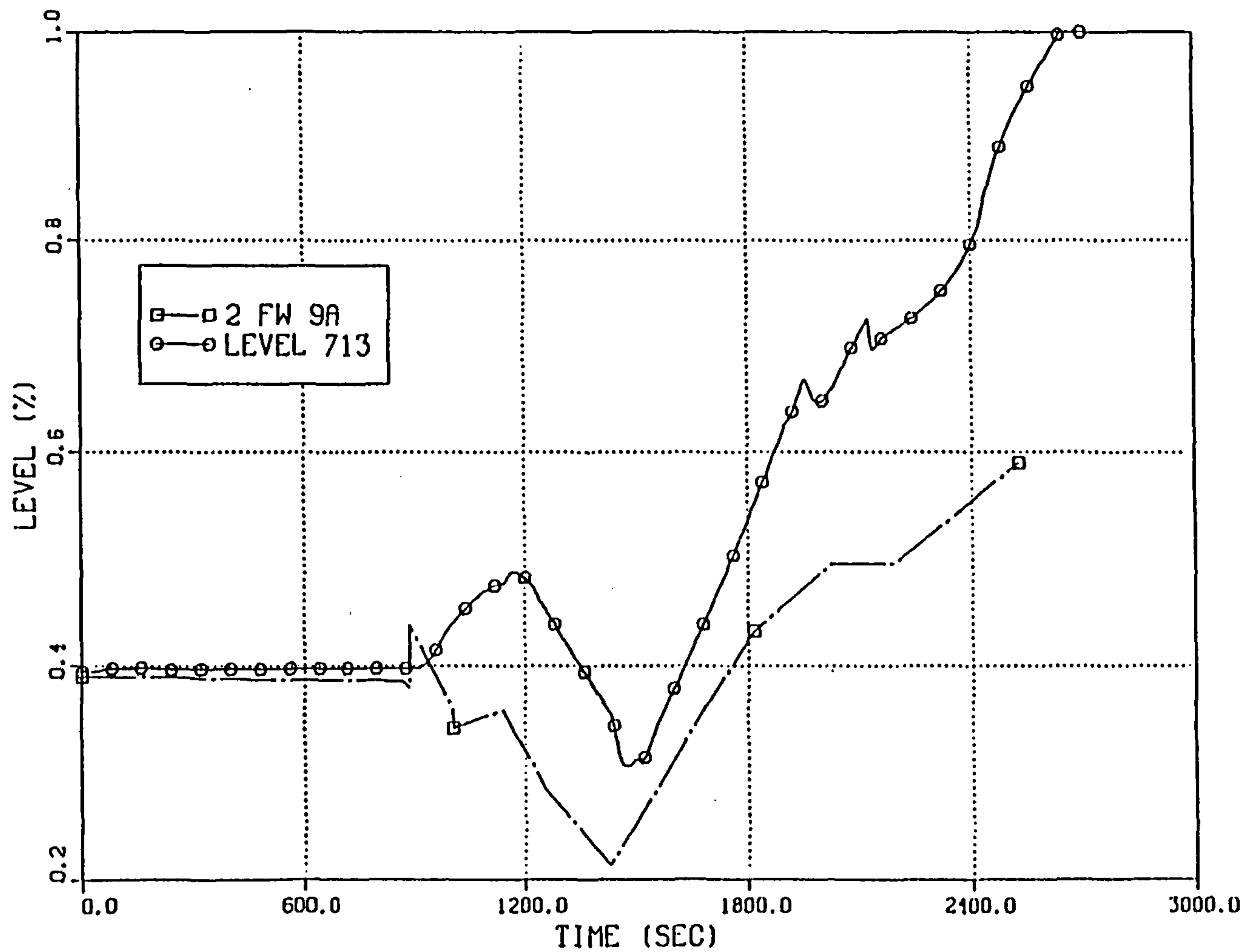


PLOT 0 01.31.41 SAT 28 SEP, 1985 JOB-AJGRDYT , C" JHCT NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 11.8 MEASURED WATER LEVEL IN STEAM GENERATOR A

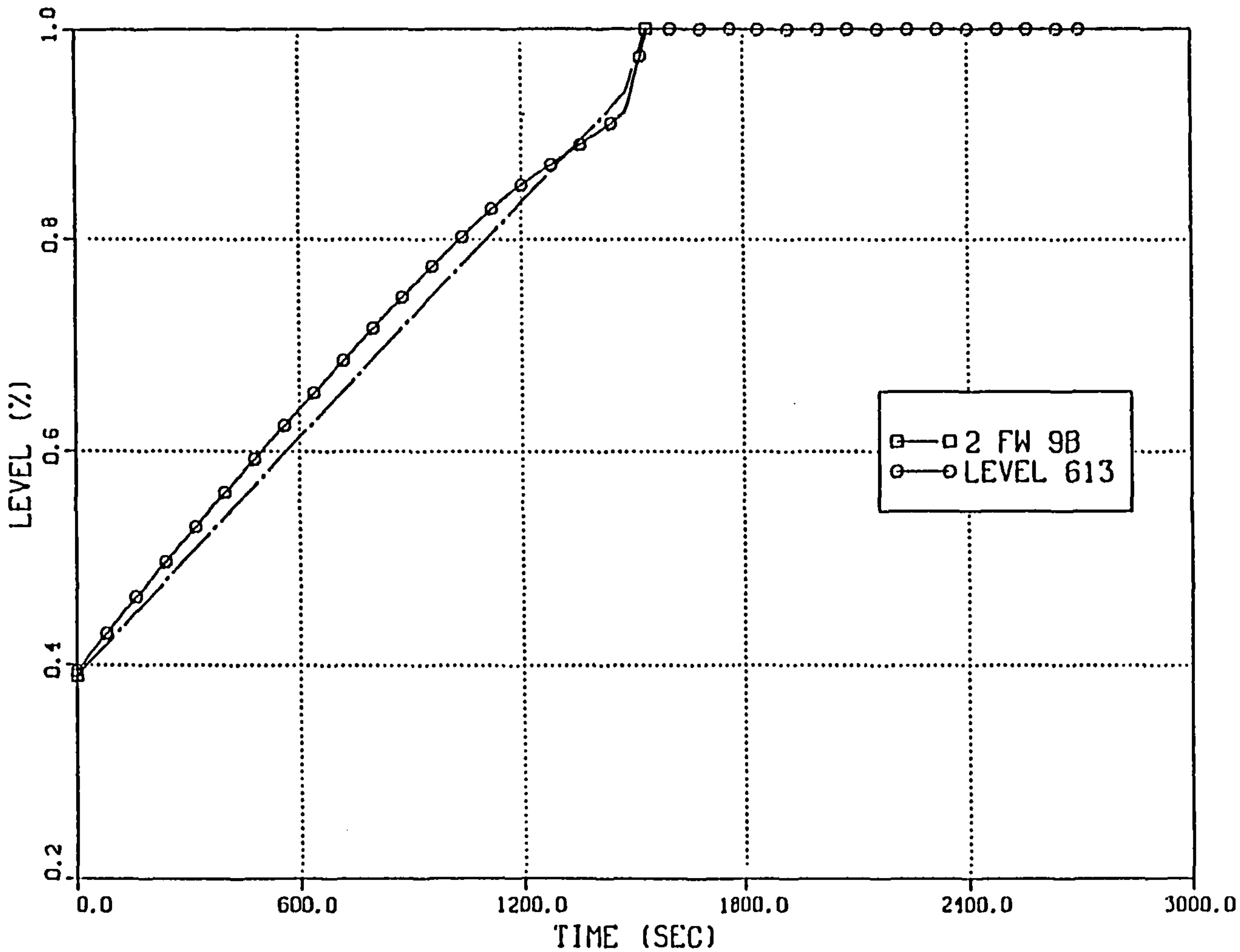


PLOT 0 01.32.07 SAT 28 SEP, 1985 JOB-A3GRDYT , ι ..RNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

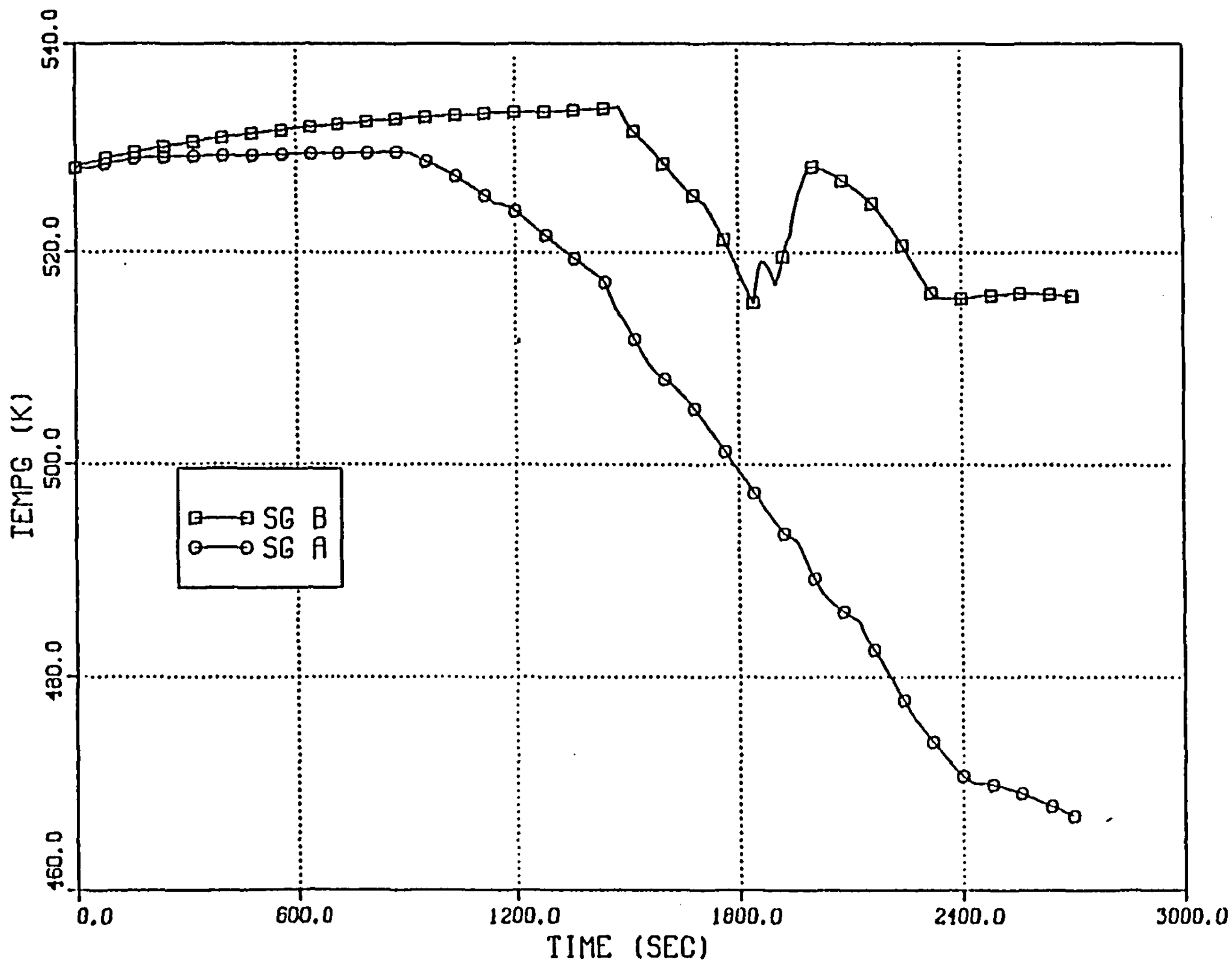
5. FIG 11.9 MEASURED WATER LEVEL IN STEAM GENERATOR B



RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 12.1 STEAM TEMPERATURE IN STEAM GENERATORS(DOME)

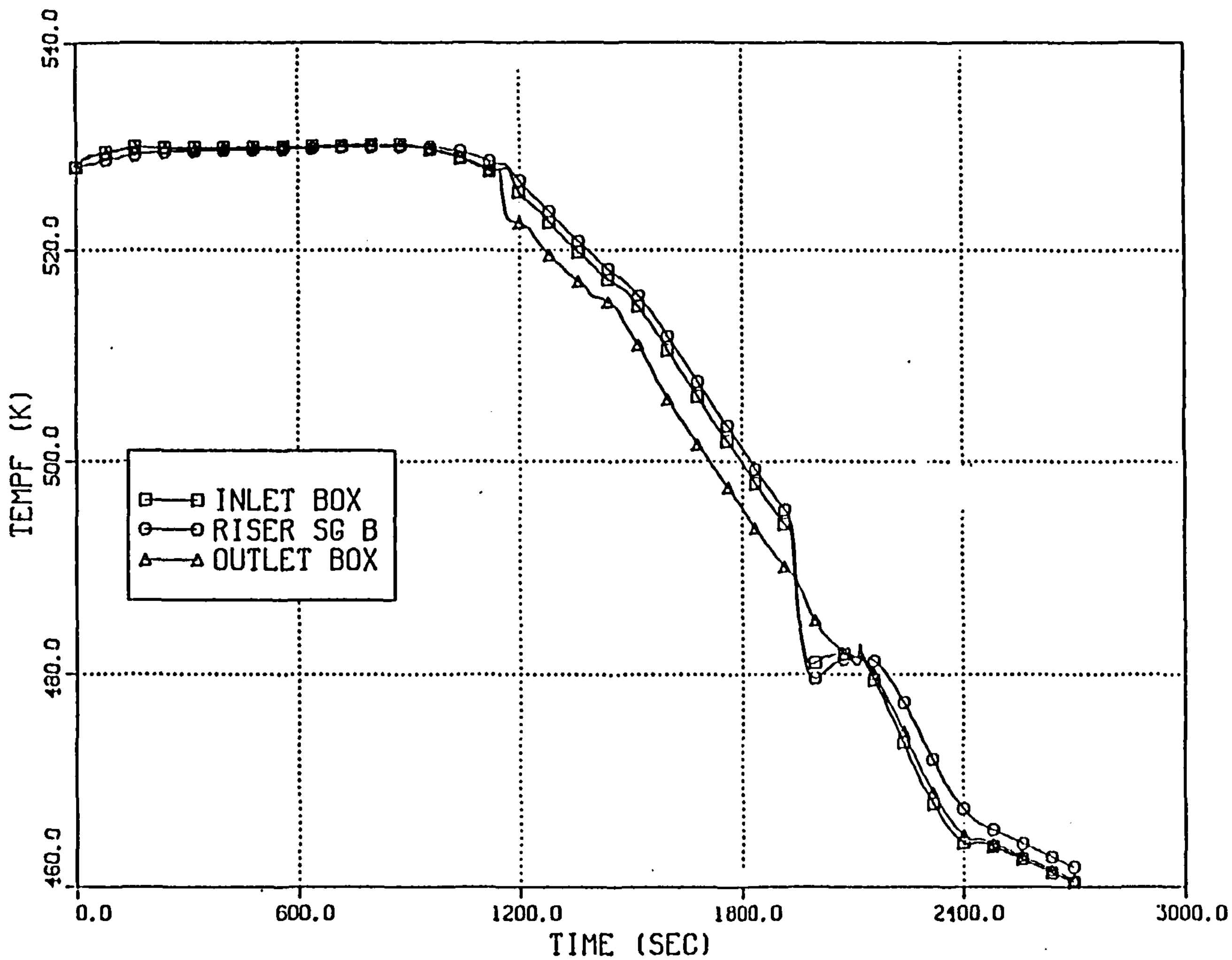


PLOT 0 01.33.02 SAT 28 SEP, 1985 JOB-A3CRDYT , CYBE. .F NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 12.2 LOOP B AND SG B TEMPERATURES

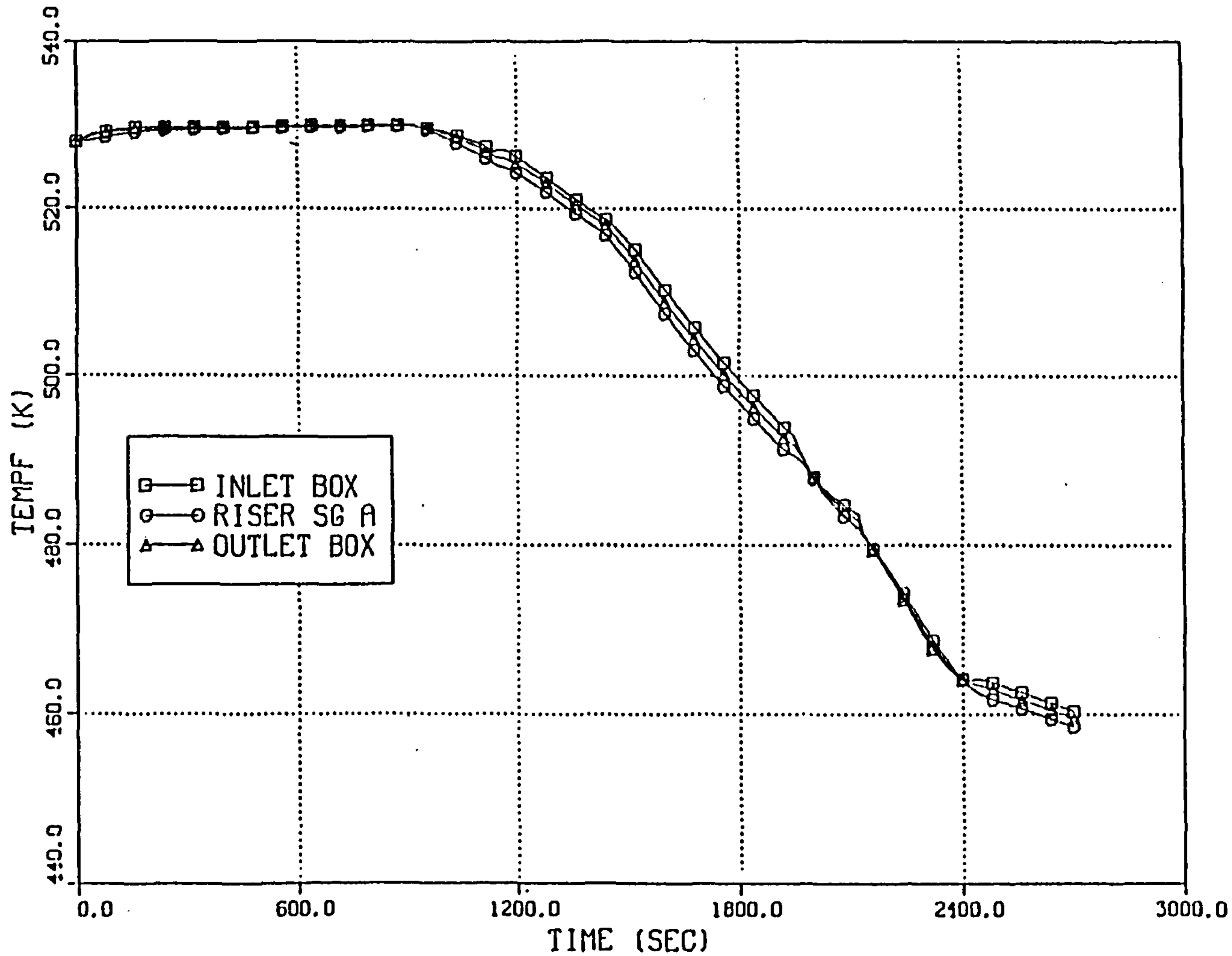


PLOT 0 04.33.29 SAT 28 SEP, 1985 JOB-A3CRDYT , CYB. ..T NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28;

5. FIG 12.3 LOOP A AND SG A TEMPERATURES

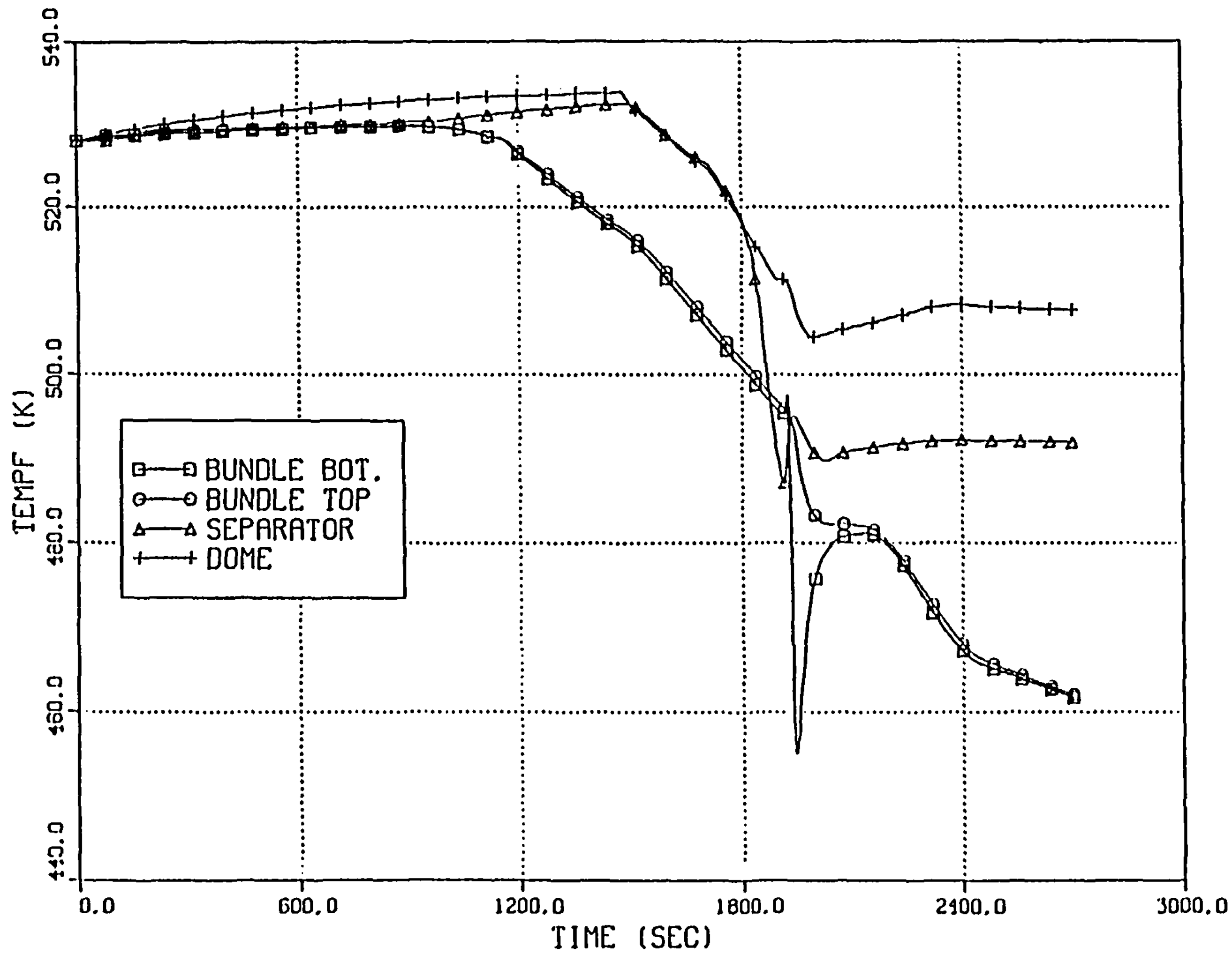


PLOT 0 04.33.57 SAT 28 SEP, 1985 JOB-A3CRDYT , CYBERNET NOS 1.0 DISSPLA VER 9.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 12.4 TEMPERATURE STRATIFICATION IN SG B

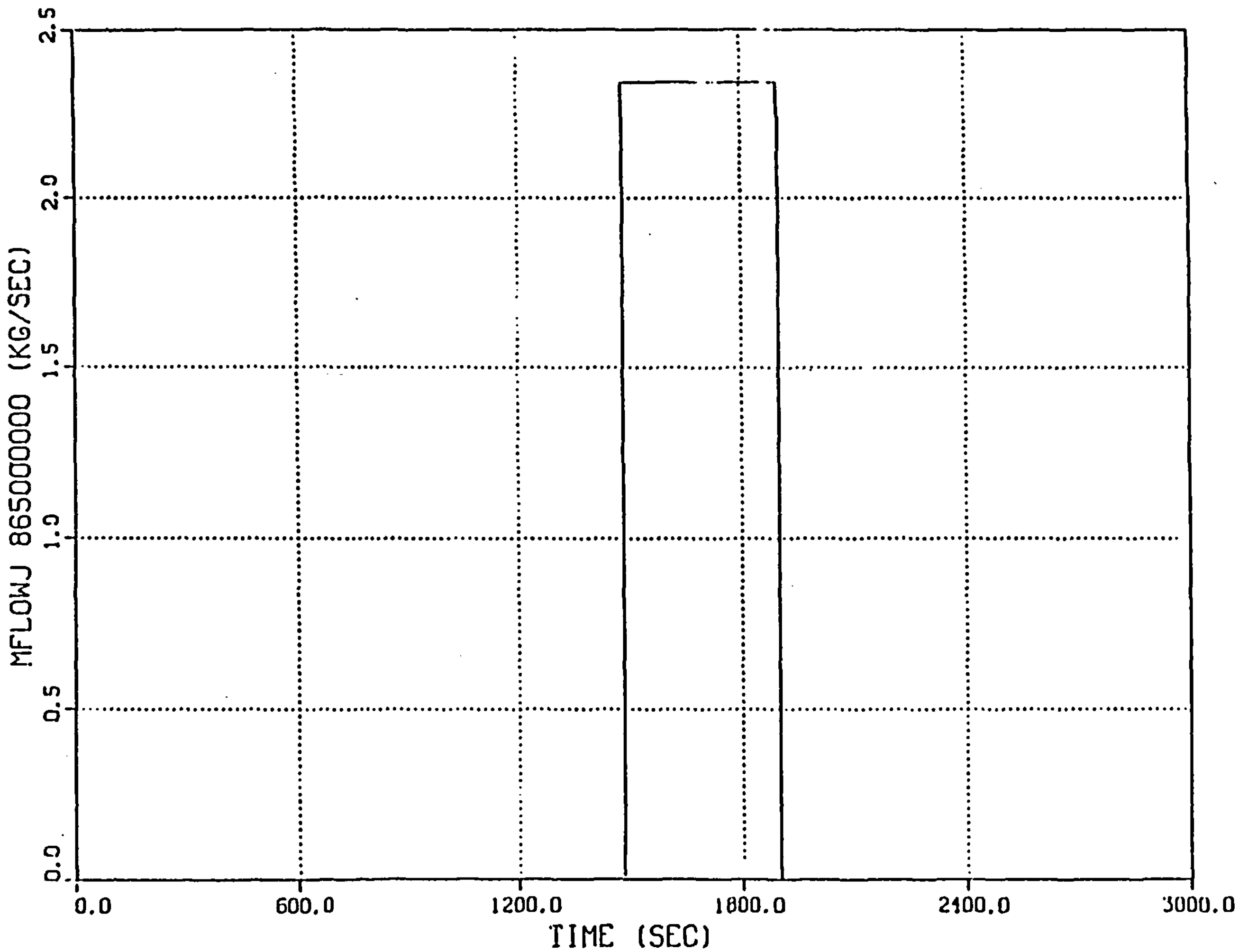


PLOT 0 04.34.23 SAT 28 SEP, 1985 JOB-A3GRDYT , CYBL .I NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

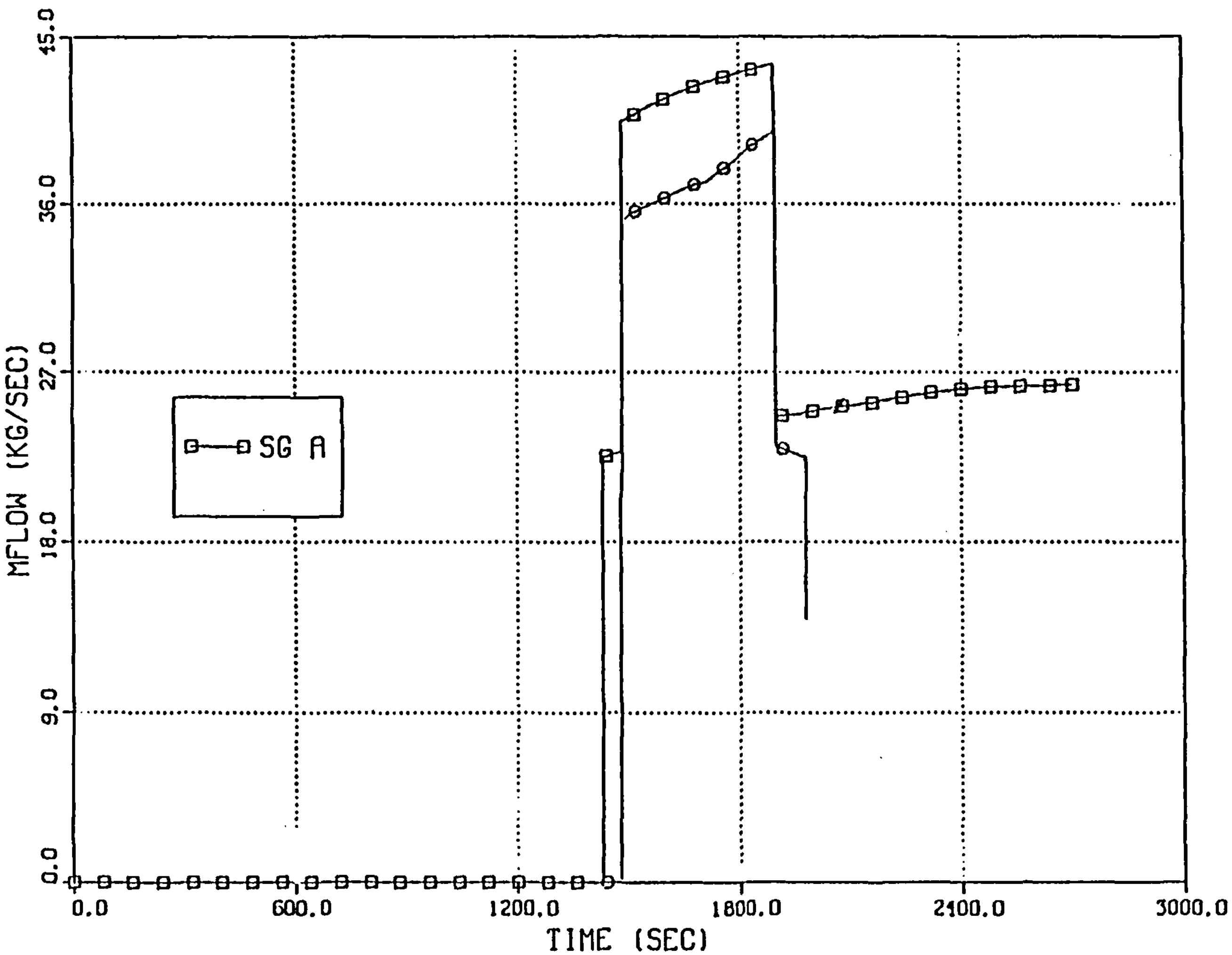
5. FIG 14.7 STEAM MASS FLOW RATE FROM SGB TO TURBOPUMP



RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 14.8 FW AND AFW TO STEAM GENERATOR



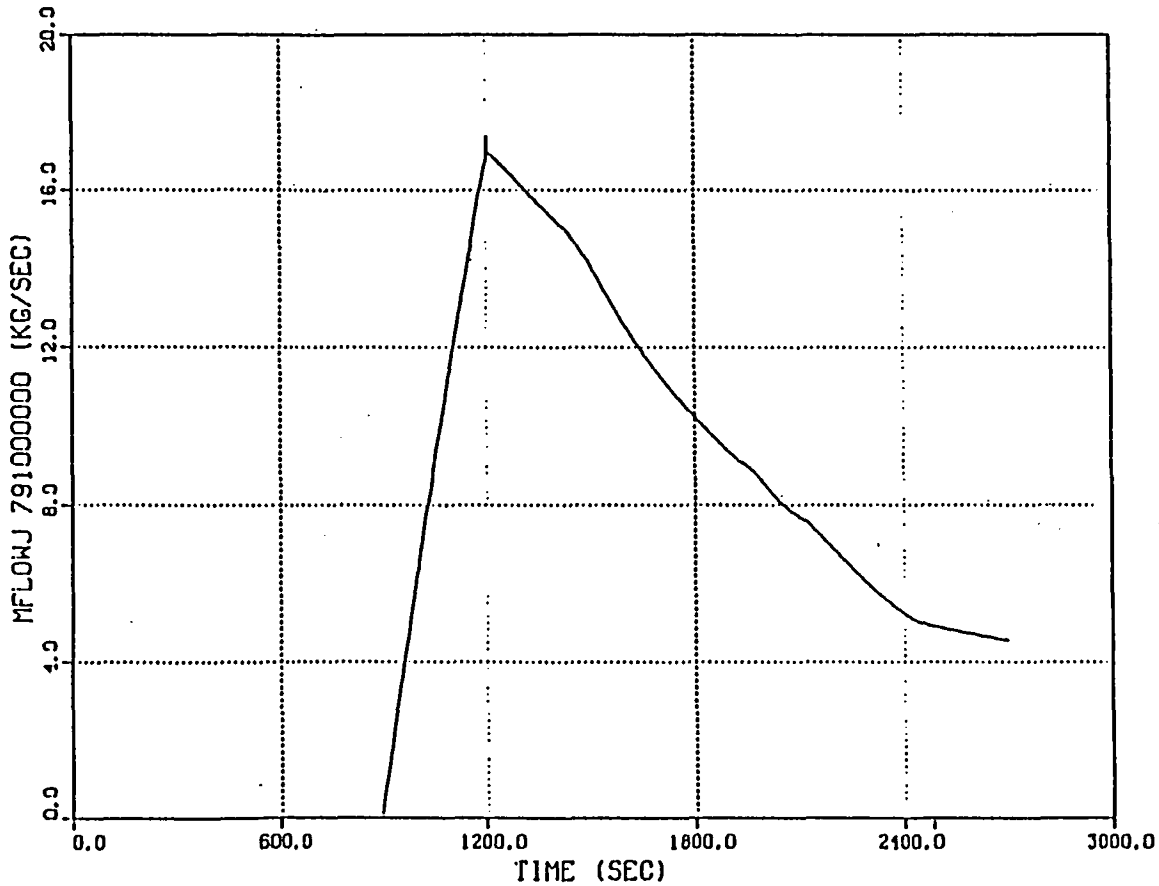
122

PLOT 0 01.35.16 SAT 28 SEP, 1985 JOB-A3CRDYT , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 14.9 SG A RELIEF VALVE MASS FLOW RATE

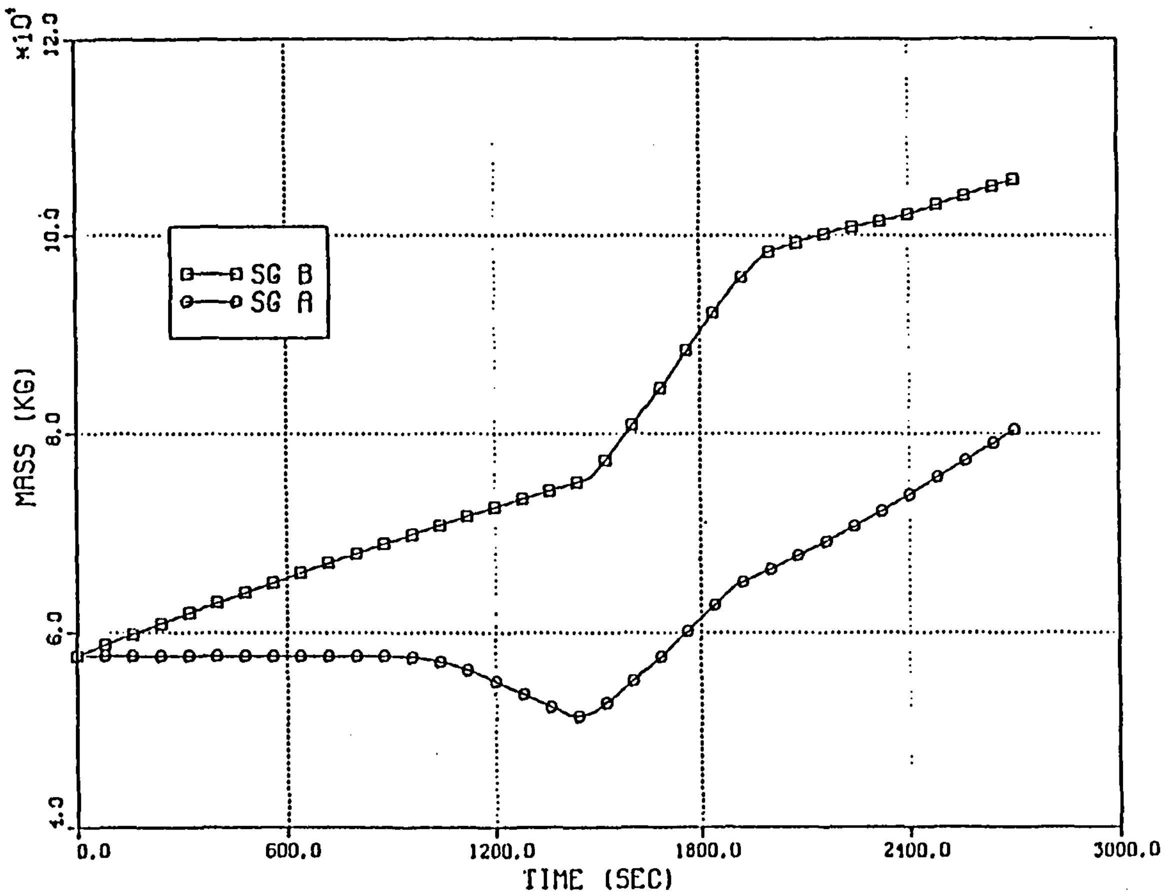


PLOT 0   01.35.13   SAT 28 SEP, 1985   JOB-A3CADYT   CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 15.1 STEAM GENERATORS MASS EVOLUTION

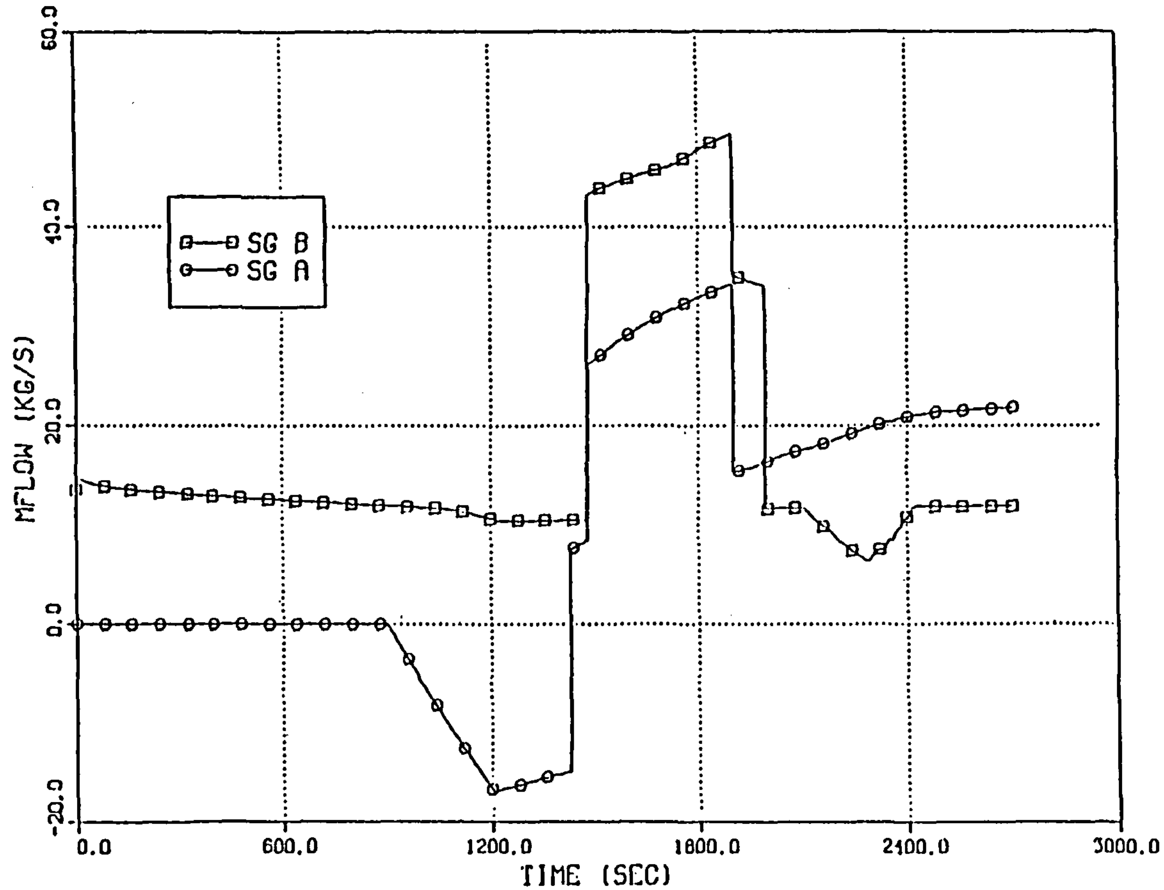


PLOT 0 04.36.10 SAT 28 SEP, 1985 JOB-A3GROYT , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

5. FIG 15.2 SG'S MASS ADDITION AND DEPLETION RATES



6. DISCUSSION OF THE BASE CASE RESULTS

From the comparison between available plant data and calculated data one can state that the code yields in general agreeable results as far as the trends are concerned.
A quantitative code assessment however reveals some serious code deficiencies which will be discussed separately.

6.1. Water level discrepancy in intact S.G. at start of cooldown

Fig. 5.11.8 manifests a level discrepancy at the time the intact S.G. steam relief valve is actuated to initiate a cooldown.

There exists indeed a large uncertainty in the time of the cooldown initation and the opening rate of the relief valve.
A sensitivity study performed earlier, (and discussed in chapter 7.1) by which the valve was opened instantaneously showed a very large level swell which clearly deviated from measured data. Based on this evidence it was decided to program a linear opening rate of the relief valve between 900 and 1200 seconds for this study.
Fig. 5.11.8. shows that the measured water level manifested a shortlived level spike which could be indicative of an actual level swell phenomenon. The irregularities observed could also be due to unknown operator interventions. Debugging the major edit at 1000 and 1200 s, manifests following phenomena:

- the flowregime in the SGA riser is of the BBY or SLUG type;
- the liquid in the riser is entrained by the vapour flow, such that the liquid velocity varies between 1/3 and 1/2 the vapour velocity (around 0.5 m/s), indicative of a high interface friction.
- the FIJ increases from bottom (720) of riser to top (722) from about 3000 to 14000, and is suddenly falling to low values at the separator outlet junction.
  This produces a liquid fall back into the separator volume where water accumulates, hence leading to a large ΔP level

as the smallband level taps are located just above and below the separator.

Even if the precision in the recorded levels is not known, the calculated trend diverges from the measured trend most probably due to excessive level swell in the riser region combined with liquid fallback in the separator region. This would be indicative of too high an interphase friction in the S.G. riser section for the prevailing flow regime (SLUG).

Since the water level measurement in a power plant is used for plant control and also for plant protection, it follows that numerical discrepancies for predicting SG water level could have a large impact on the predicted behaviour of a power plant, and in the timing of the actuation of emergency safeguard features (e.g. auxiliary feedwater).

6.2. Excessive cooldown between 1500 and 2400 seconds

From the comparison between measured and calculated temperatures in the primary loops (fig. 5.5.4., 5.5.5., 5.5.6. and 5.5.7.), the calculated cooldown rate starts diverging from the measured cooldown rate around 1500 sec, which corresponds with the start of the turbine driven auxiliary feedwater pump, whereby steam is derived from the affected S.G. to drive the turbine driven auxiliary feedwater pump, and extra feedwater is fed to both steam generators.

Due to uncertainties in the turbine driven auxiliary feedwater pump caracteristics (steam flow, auxiliary feedwater flow), it is not warranted to look for code model deficiencies which may explain this discrepancy.

During the period wherein the turbine driven auxiliary feedwater pump is operational, the affected S.G. acts as a heat source (fig. 5.12.2), whereby about 7.7 MW of heat is extracted from the S.G. riser volumes, via the SG U tube bundle into the primary system. Notice that due to the availability of only 1 primary coolant pump in the intact loop, a reversed flow exists in the affected loop and cold SI water injected downstream of the stopped coolant pump enters directly into the affected SG, leading to an enhanced cooldown of the riser.

Also the location of the break in the top of the riser provides a cooldown by injecting colder water from the primary. Both effects lead to a strong gravity head in the riser.

On the downcomer side, one observes a strong heat transfer by conduction between volumes 622 and 612/613 (about 3 MW) and a large structural heat input in the injection volumes 612/613 which tends to heat up the cold AF water.

The net result is a reversed buoyancy effect which tends to drive a reversed circulation in the affected SG (K_R = 3 X 1000).

When the turbine driven auxiliary feedwater pump is switched off, the steam flow, taken from the affected SG, is halted and this stops the strong depressurization in this SG. Also the temperature drop is stopped whereby the structural heat (the driving force for the reverse circulation) is strongly reduced.

Between 1900 and 1992, cold auxiliary feedwater is still injected in the affected SG by the motordriven pump.
Both effects lead to a reversal in the natural circulation from initially - 11 kg/s at 1900 s, to over 800 kg/s at 1940 s and dropping down to 160 kg/s at 2000 s.

At 1900, the fluid temperature in the volumes surrounding the feedwaterline (vols 611, 612, 613) is about 20° below the bundle fluid temperature. When the circulation sets in, in the normal direction, this large inventory of cooler fluid, combined with a continuous injection of cold AFW from the motor driven pump (flowrate = 23 kg/s) produces a strong cooldown in the riser and constitutes an abnormal large heat sink for the RCS (see fig. 5.7.3) of max. 50 MW.

The strong reversal in the temperature at bottom of the SG is illustrated in fig. 5.12.4, showing the effect of an overcooling by more than 20°C when the natural circulation sets in.

From the discussion of a parametric study (chapter 7.2.) it is believed that this anomaly is caused principally by a wrong choice of the forward and reverse form losses in the S.G. downcomer.

In this study, very large reverse form losses and low forward form losses may act as a leaky diode where during periods of reversed boyancy colder water leaks slowly in the reverse direction without mixing with hotter fluid on top of the downcomer. When the boyancy changes over to the normal circulation, excessive natural circulation flowrates are observed leading to the observed phenomena.
Since it is known that RELAP-5 tends to exagerate the natural circulation flows, it may be recommended to select suitable form loss factors both for direct and reversed circulation (e.g. $K_F = K_R = 200$ in downcomer junction) in order to allow a larger reversed flow, and hence better mixing, and a reduction of the forward flow which should lead to smoother temperature transitions.
The choice of the form loss factors should however be consistent with plant values in order to lead to the known recirculation ratio at various power levels.

The effect of this apparent anomaly propagates back into the RCS where it aggravates the temperature discrepancy in the cold legs of the primary loops.

When this colder water is used as spray in the pressuriser at 2100 seconds, the excessive spray subcooling must produce an excessive depressurization as shown in fig. 5.4.1. (discrepancy about 9 bar between calculated and measured pressure peak), which in turn increases the cold HPSI flowrate (fig. 5.6.7.) and yields a positive feedback to the overcooling.

This example shows how a code anomaly can propagate back from one S.G. to the primary and lead to a large discrepancy which maintains itself through the existence of a positive feedback (e.g. pressure - SI flow).

6.3. Vapour condensation anomaly in affected S.G.

When the affected SG is completely bottled-up after tripping the AFW turbo and motordriven pump at 1992 s, a large fluid temperature stratification exists in this SG (fig. 5.12.4) and the difference between fluid temperature and vapour temperature (fig. 5.12.1) in the SG dome levels out at about 7°C.

From the pressure history (fig. 7.10.1) one observes a sudden increase in pressure when the turbine driven auxiliary feedwater pump steam valve is closed at 1900 s, but levels off at a pressure of about 36 bar around 2000 s, and has a tendency to decrease afterwards while the recorded pressure keeps rising.

In order to explain this anomaly, one should evaluate the vapour generation/condensation phenomena under such high temperature disequilibrium, for which fig. 6.1 is a good illustration of the phenomena occurring the SG dome.
This figure illustrates a vapour generation rate increasing sharply at 1830 s, when the water level crosses the lower boundary of the upper dome volume. Since a forced steam flow of 2.34 kg/s (fig. 5.14.7) is derived to the turbine driven auxiliary feedwater pump (requiring a vapour generation rate of 0.089 $kg/m^3,s$) the actual vapour generation rate is much lower (fig. 6.1) leading to a net vapour mass depletion and a resulting accelerated pressure drop (see fig 5.10.1).

When the steamline to the turbine driven auxiliary feedwater pump is closed at 1900 s, the vapour generation continues for a while leading to a sharp pressure increase, until the vapour generation reverses to a non negligible vapour condensation at 1960 sec. of 0.009 kg/m^3,s (or about 0.237 kg/s).
This condensation of vapour combined with a net mass addition to the affected SG from the break, leads to a stagnation in the pressure (or even a slight pressure decrease) in contrast to the recorded pressure increase.

This anomaly is likely due to an excessive vapour condensation rate in the dome volume of superheated vapour (523°K) on subcooled fluid (507°K) for a saturation temperature of 517°K (at 2200 s).

From an energy balance in volume 630 at 2200 s, one obtains a vapour-water condensation flux of 436 kW resulting in a vapour-water condensation heat transfer coefficient of about 2 100 W/m^2,°C. Such excessive heat transfert coefficient is calculated for a prevailing flow regime "SLUG", while the volume liquid velocity is negligible (= 6 10^{-4} m/s) and the volume vapour velocity also is negligible (= 3 10^{-4} m/s).
For such velocities a "STRATIFIED" regime should exist which would probably have resulted in much lower vapour condensation rates.

Hence, the pressure anomaly can be traced via a condensation anomaly for a wrong flow regime for this volume.

Finally it should be emphasized that an underestimation of the pressure in the affected S.G. could have an impact on the postulated timing of automatic systems and operator interventions:

a higher S.G. pressure will lead to an earlier isolation of the break flow from primary to secondary and an earlier switch-over to post-SGTR cooldown procedures.

a higher SG pressure may lead to actuation of the SG safety valves, with the danger of failing to close when water should be released.

CONCLUSION :

Two important shortcomings of the code are evident from this analysis :

a. Excessive interphase drag in the S.G. riser is observed under certain conditions.
b. Excessive heat and mass transfer for direct contact condensation and evaporation for various flow regimes. Such "TOO EQUILIBRIUM" conditions have also been observed in RELAP-5/MOD-1 (Ref. 2). Further research on direct contact condensation at higher pressures may be needed to refine these physical models.

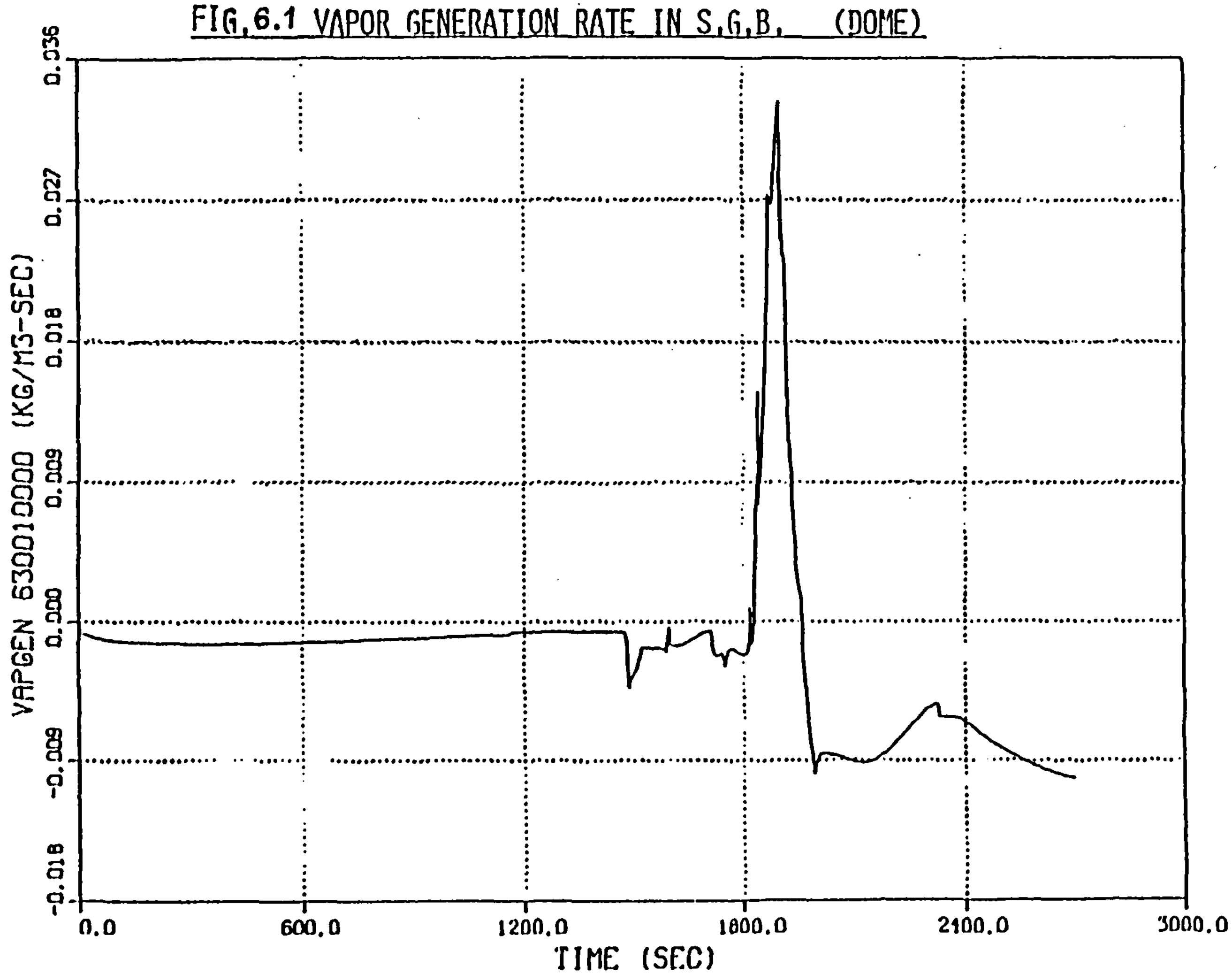
As for the cooldown discrepancy, an optimisation of the form loss factors in the recirculation loops in the steam generators may lead to better code results.

PLOT 8 09.37.30 SAT 28 SEP, 1985 JOB-MICROTI , CYD! 1 NOS 1.0 DISSPLA VER 9.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

FIG.6.1 VAPOR GENERATION RATE IN S.G.B. (DOME)



7. DISCUSSION OF THE RESULTS OF A SENSITIVITY STUDY

Table 7.1. (from Ref. 3) gives a summary of the main input-data modification between 3 simulation studies of the SGTR event. While preceding chapters were concentrated only on the results of case 3, this chapter will discuss those results of case 2 which may help to explain the observed anomalies explained in chapter 6.

7.1. Water level discrepancy in intact S.G. at start of cooldown

For case 2, the cooldown was initiated suddenly at 900 s, by instantaneous opening of the atmospheric steam dump valve of the intact S.G. (rather than a gradual opening during 300 seconds for the base case).

Fig. 7.1. illustrates a comparison between calculated and recorded water level in the intact S.G. for the 3 cases.

The sudden depressurisation produces a much larger level swell resulting in a level overshoot of 20 % (compared to about 8 % for the base case).

Fig. 7.1. also illustrates that the level swell phenomena occurred only for the cases 2 and 3 (RELAP-5 MOD-2) and not for case 1 (RELAP-5 MOD-1). A change in flow regime map between MOD-1 and MOD-2 could explain the basic difference.

Conclusion :

Too strong momentum coupling between the vapour and liquid phase leads to a wrong mass redistribution in the S.G., during a sudden depressurization.

7.2. Discussion of sensitivity study concerning the cooldown period

Fig. 7.2. illustrates the comparison between the heat transfer between primary and S.G.'s.

The basic differences between the nodalisation for case 3 (base case) and case 2 are related to the form loss coefficients introduced in the downcomer of the steam generators, and a slightly simpler nodalisation of the separator region as shown in fig. 7.3.
In the three downcomer junctions, the forward form loss factor was set at 200 (case 2) and zero (case 3 - base case), while the reverse form loss factor was set at 1000 for both cases 2 and 3.
A higher forward form loss factor for case 2 leads to a strong reduction in the natural circulation flowrate (factor 7) in the intact S.G. (at t = 1600 s) resulting in a lower cooling capacity as can be seen in fig. 7.2.
When the AF to the affected S.G. is stopped at t = 1632 s (tripped prematuraly on high water level in intact S.G.), the reversed natural circulation in this S.G. is maintained and has a tendancy to increase, in strong contrast to the base case when AF trips (at 1900 s).
It follows then that the cooldown rate of the RCS temperature is closer to the recorded value (fig. 7.4), and the depressurisation peak at the end of the spray period is also closer to the measured value (fig. 7.5.) for case 2.

Conclusion :
The natural circulation in the S.G. depends strongly on a proper choice of the form loss factors in the junctions along the natural circulation path, and has a very important impact on the primary RCS especially for asymmetric plant behaviour.

7.3. Vapour condensation phenomena in highly stratified conditions

In chapter 6.3., a vapour condensation anomaly was detected in the dome of the affected S.G. under following conditions :

- very high temperature stratification
- zero steam-and feed flow (bottled-up)
- very high water level in the S.G.

Fig. 7.6. illustrates the S.G. pressure evolution in both S.G.'s for case 2 (parametric study). Concerning the affected S.G., the premature pressure rise at 1634 s, is caused by a trip of the turbine driven auxiliary feedwater pump at high S.G. water level in S.G A (Table 7.1), which also closes the steam flow to the turbine, and produces a repressurisation of the affected S.G.

Comparing the measured and the calculated pressure trend beyond 2400 s, one observes an acceptable pressurization rate, in contrast to the results of the base case (fig. 5.10.1) and discussed in chapter 6.3.

Table 7.2 below compares the main S.G. dome parameters for the base case and the sensitivity study (case 2) from a major edit at 2200 s.
The interpretation of the results should account for a different nodalisation between base case (fig. 4.1.) and parametric study (fig. 7.3.).

From this table several observation can be made.

1. For same the flow regime in the dome volume, (ie SLUG), the heat transfer regimes are very different.

2. The structural heat flux repartition between vapour phase and fluid phase is reversed between both cases. While for case 2, heat is exchanged between gas phase and outer structures, for case 3 (base case), heat is exchanged only between water phase and outer structure.

3. For case 2, heat losses from the vapour phase to the structures produces the vapour condensation on the walls and run - off in the water phase which corresponds to the vapour condensation flux calculated.

4. For case 3, the large vapour condensation results only from a direct contact condensation between the vapour and the

water phase, since no heat is extracted from the vapour phase by the colder structures.

Conclusion :

a/ The absence of the large direct contact condensation in the sensitivity study results in a heat balance which yields an acceptable pressure trend.

b/ The selection criteria for the heat transfer regime for condensation in RELAP should be reviewed in the light of above observation.

TABLE 7.1

TABLE 1 : SUMMARY OF SGTR - ACCIDENT SIMULATION NODALISATION AND RESULTS

CASES	1	2	3
date of execution	27 june 83	19 april 85	28 september 85
code : RELAP-5	MOD 1 CYCLE 014	MOD 2 CYCLE 36	MOD 2 CYCLE 36.01
separator model	MOD 1	MOD 2 VOVER = 0.1 VUNDER = 0.1	MOD 2 VOVER = 0.1 VUNDER = 0.1
SG plenum + bypass	-	no	yes
break area (cm^2) (VCAHS)	1.815 (0000)	1.724 (00003)	1.724 (00003)
Forward loss coefficient in SG downcomer	3 X 200	3 x 200	-
letdown closure, back-up heaters off	t = 211 s	$L_{PR} \leq 20\%$	$L_{PR} \leq 20\%$
AFW (turbopump) off	t = 1900 s	LSG $\geq$ 45%	t = 1900 s
spray nozzle location	TOP (TDJ) (EXTERNAL)	TOP (TDV + TDJ)	AS BUILT (TDJ)
SGA cooldown initiated	t = 1000 s	t = 1000 s	$900 \leq t \leq 1200$
structural heat losses to containment	NO	NO	YES
Number of volumes	136	144	154
Number of junctions	140	150	150
Number of heat slabs (mesh points)	157 (463)	161 (553)	164 (563)
TIME - STEP LIMITATION (PRINCIPAL)	MASS ERROR	TRANSIT TIME (HOT LEG)	TRANSIT TIME (U LEG)
ACCUMULATED MASS ERROR RATIO	$- 79.10^{-4}$	$\sim 1.14\ 10^{-4}$	$1.08\ 10^{-6}$
AVERAGE TIME STEP (s)	0.09	0.124	0.124
CPU - TIME / TRANSIENT-TIME	22.6	18.0	19.4

TABLE 7.2.

COMPARISON TABLE OF S.G. DOME VOLUME DATA AT 2200 S

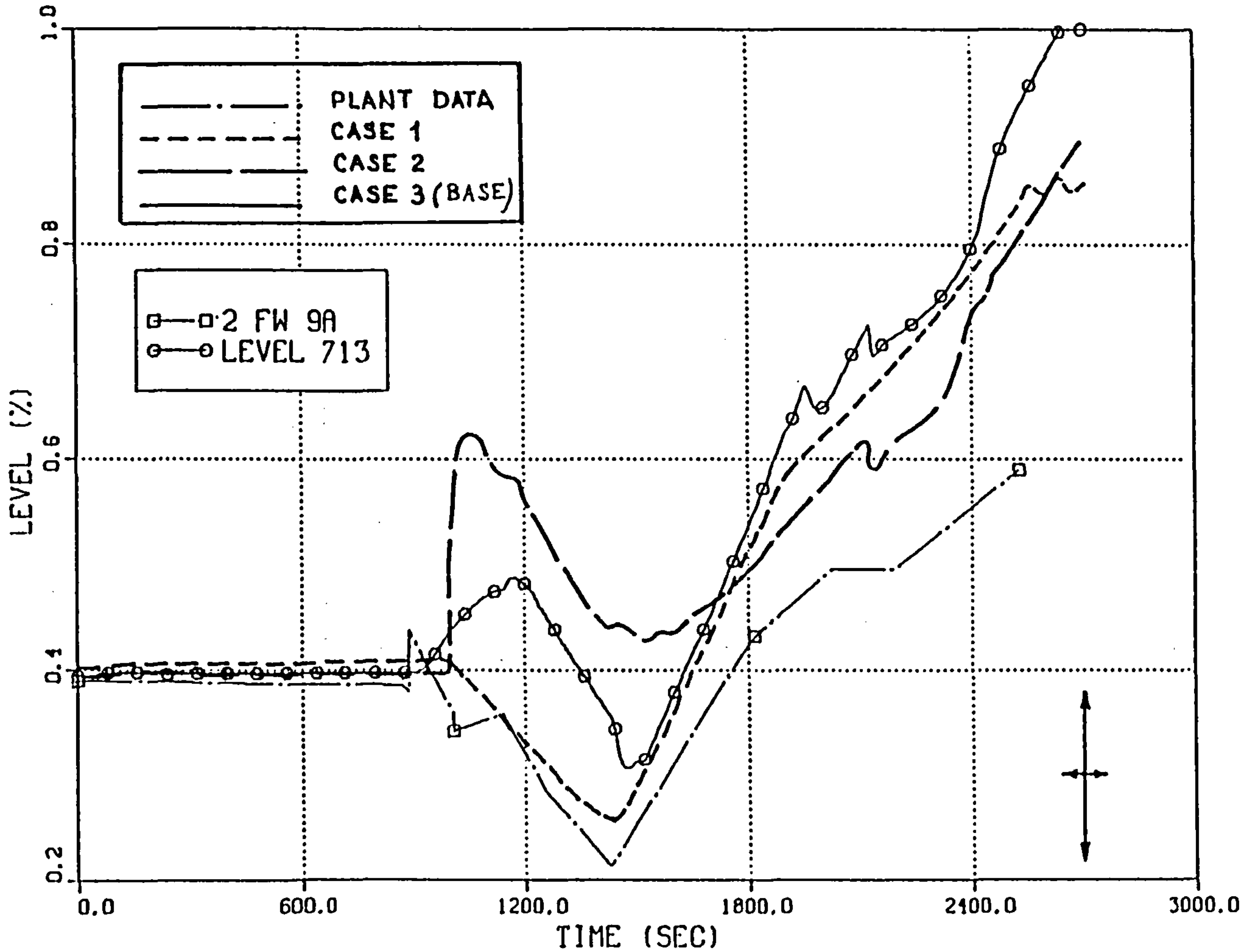
PARAMETER	UNITS	SENSITIVITY STUDY	BASE CASE	
Case	-	2	3	
Height of dome component	m	3.093	2.093	
Volume of dome component	m^3	38.85	26.29	
Dome void	fraction	0.652	0.704	
Dome flow regime	-	SLUG	SLUG	
Dome saturation temperature	°K	540	517	
Dome gas temperature	°K	552	523	
Dome fluid temperature	°K	515	507	
Dome outer heat slab surface temperature	°K	540	517	
Heat transfer regime	-	condensation (11)	Subcooled nucleate boiling (3)	
Heat fluxes				
a. Internal struct. to gas	watt	644	29 903	
b. External struct. to gas	watt	- 76 320	0	
c. External struct. to fluid	watt	0	163 442	
c. Total flux to volume	watt	- 75 676	193 346	
d. Tot. flux to gas	watt	- 78 502	- 406 216	
Vapour generation rate	kg/m^3, s	- 0.00124	- 0.00824	

PLOT 0 01.31.11 SAT 28 SEP, 1985 JOB-ASCROYT , CY6. .T NOS 1.0 DISSPLA VER 9.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

FIG. 7.1 MEASURED WATER LEVEL IN STEAM GENERATOR A



PLOT 7300 04.23.15 SAT 28 SEP, 1985 JOB-A3CRDYT , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

FIG 7.2 HEAT TRANSFER RATE FROM PRIMARY TO SG

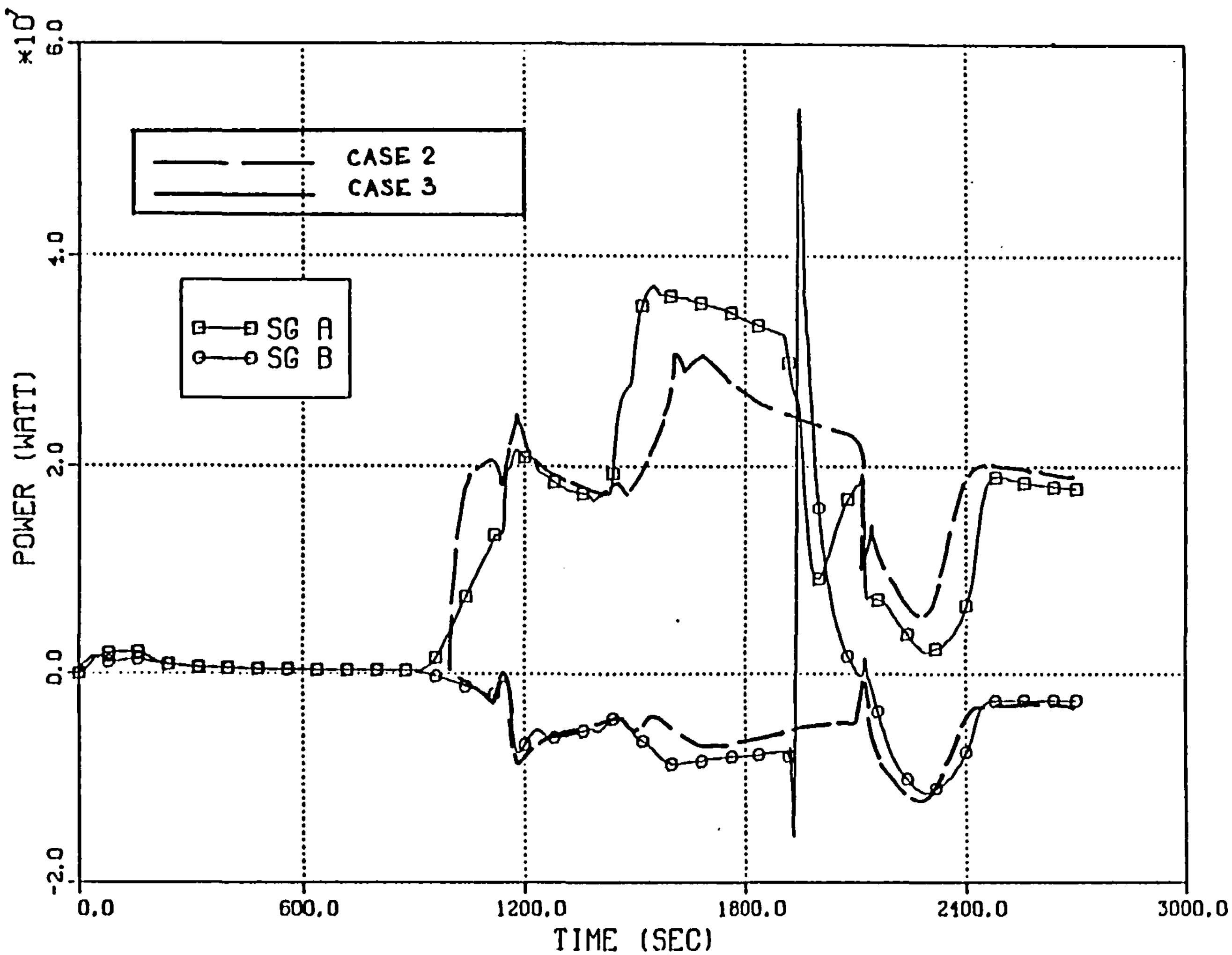
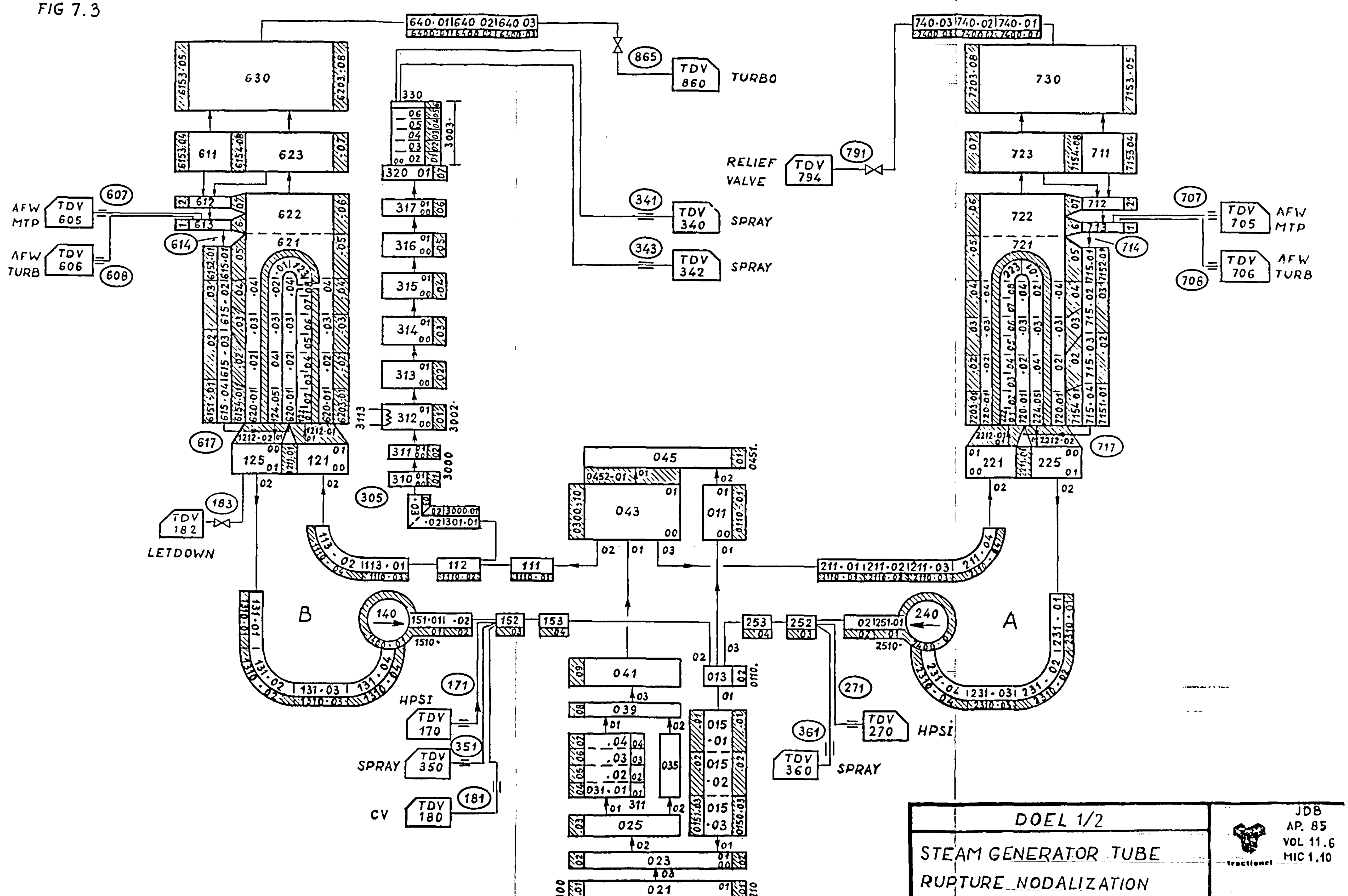


FIG 7.3



DOEL 1/2

STEAM GENERATOR TUBE RUPTURE NODALIZATION

JDB
AP. 85
VOL 11.6
MIC 1.10

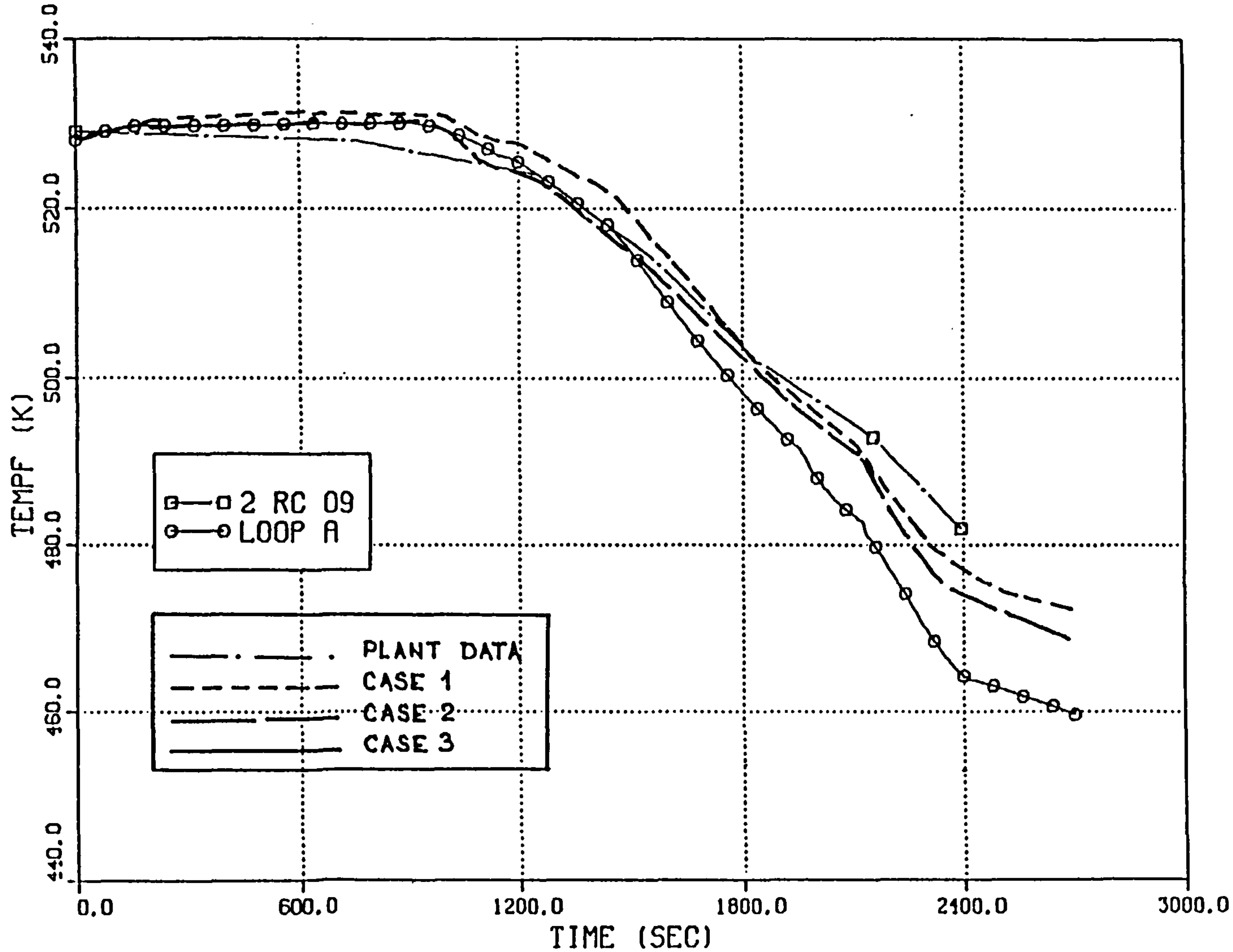
tractionel

PLOT 5600 04.17.05 SAT 28 SEP, 1985 -A3CRDYT , CYBERM. NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

FIG.7.4 TEMPERATURE EVOLUTION IN COLD LEG A

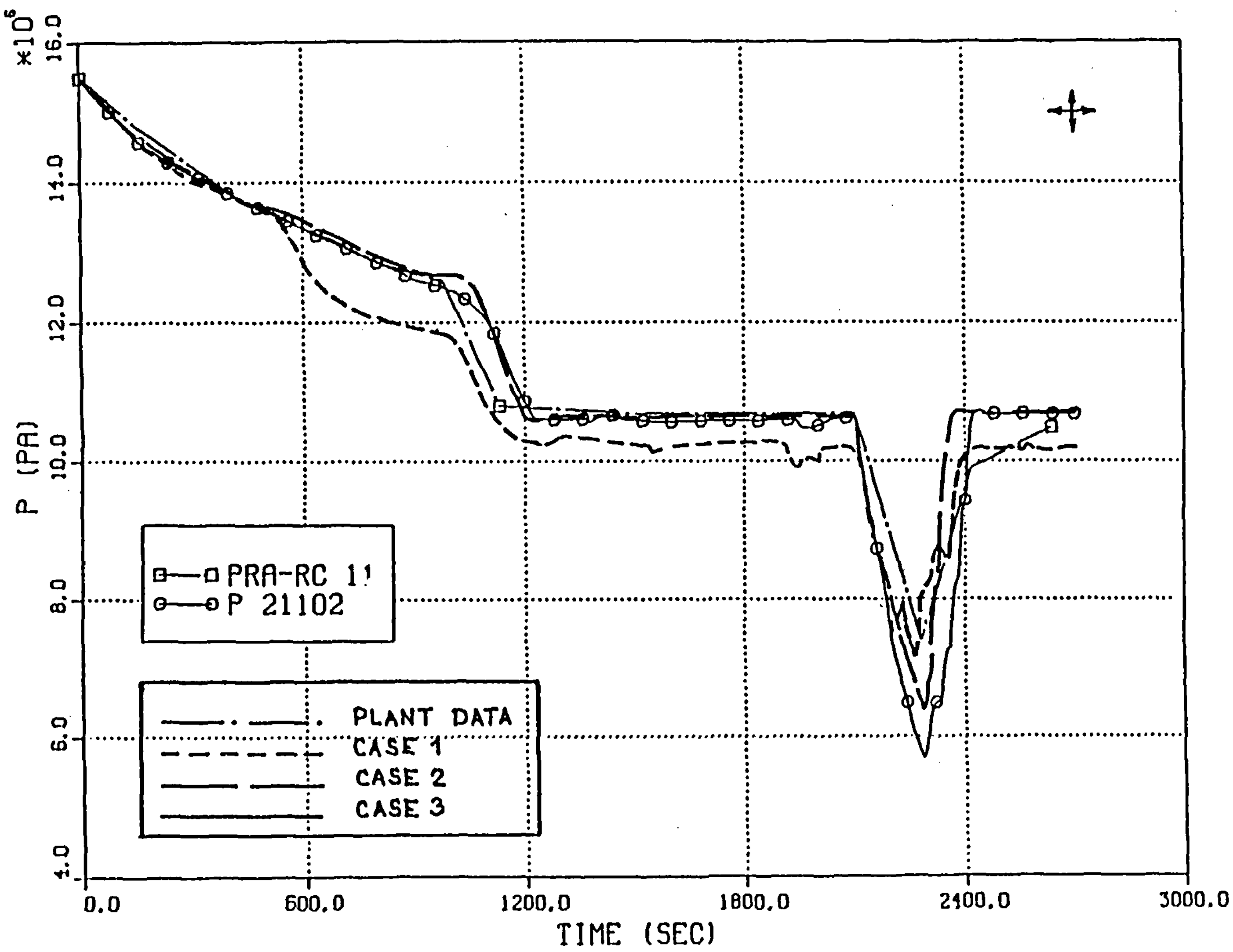


PLOT 4100 04.15.19 SAT 28 SEP, 1985 JOB-A3GROYT , CYBERNET NOS 1.0 DISSPLA VER 8.2

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

FIG 7.5 PRESSURE EVOLUTION IN HOT LEG A

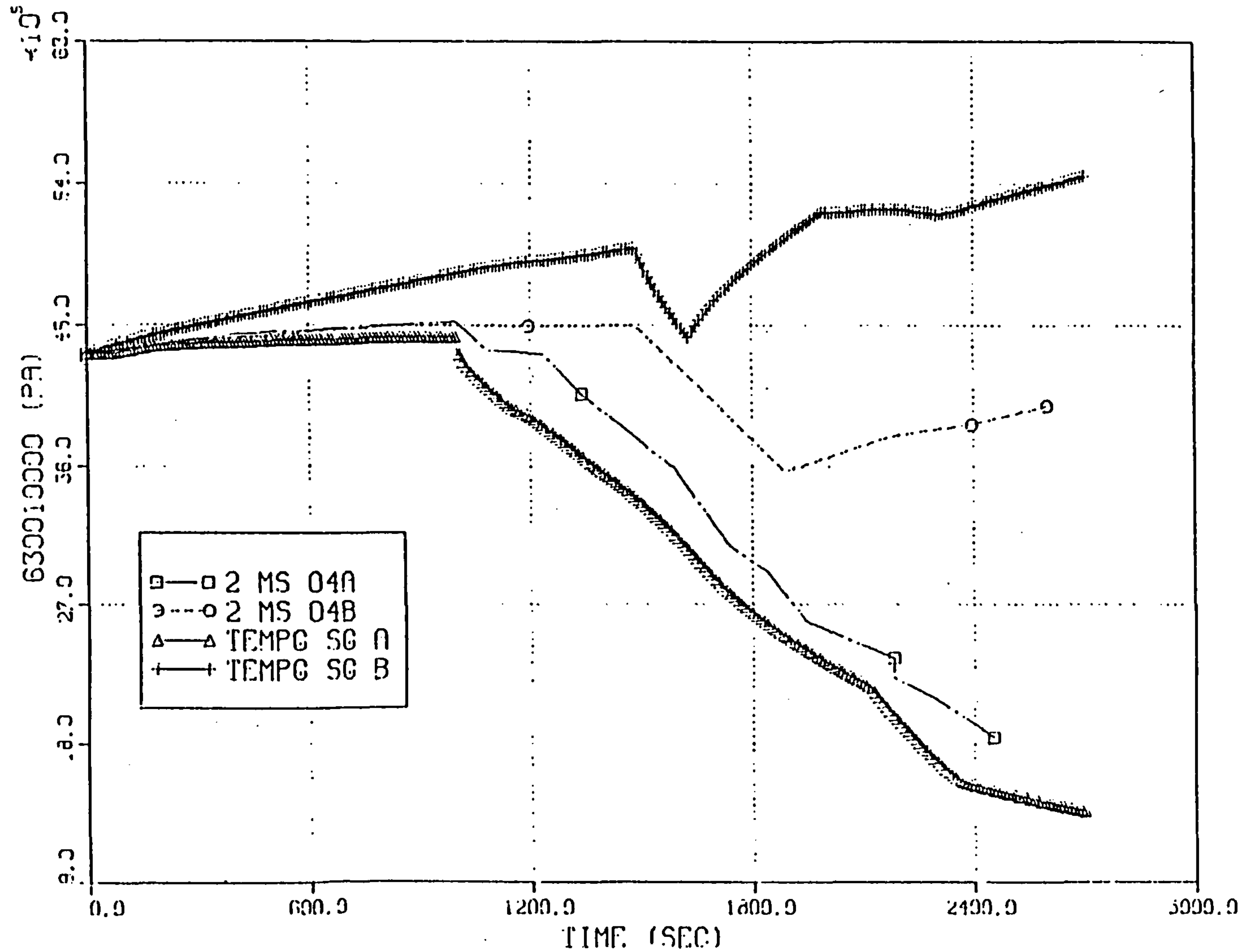


PLOT 0   18.21.52 FRI 19 APR. 1985   JOB=03ERPOF , I   NCI NOS 1.0 DISSPLA VER 8.2

RELAP5/MOD2/036 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

SGTR BENCHMARK 85/04/19.

FIG 7.6 PRESSURE EVOLUTION IN STEAM GENERATORS



8. RUN STATISTICS

In order to compare run times it should be mentionned that the CPU time for the CYBER 176 machine of the CDC CYBERNET system does not correspond with a clock time. For billing purposes, the CPU time has been manipulated such that for all machines of the service center, the same equivalent CPU is applicable. Hence, it turns out that for the CYBER 176 machine the clock time is about 11 times smaller than the printed CPU time.

In further discussions, clock time will be used (as distinct from CPU-time) in order to arrive at run statistics comparable with statistics of other ICAP reports.
Fig. 8.1. illustrates the CPU-time evolution versus transient time.
The requested time step was constant at 0.25 s.
The average time step varies between 0.122 and 0.125 s.
The time step limitation was "minimum Courant" for most of the time steps. The limitation occurred systematically in volume 13302 (vertical pump suction segment of intermediate leg) and 25102 (segment in cold leg between pump and SI injection):

volume	length	max. velocity	max. Courant	possible gain
(-)	(m)	(m/s)	s	%
13302	1.43	9.861	0.145	14
25101	1.968	14.	0.14	12

Table 8.1. illustrates various run statistics at various transient times.
From this table one observes that the maximum mass error goes from + 10.5 kg to - 10.0 kg or a max. fraction of ± 3.5 10^{-6}

Fig 8.1 shows that the CPU TIME versus transient time is very constant and averages out to 19.3 CPU-s/transient-s or 1.76 clock-s/transient-s.

The performance number

$$P.R. = \frac{1\,000 \times \text{clock-s}}{\text{vol} \times DT} = \frac{1\,000 \times \frac{52\,249 - 122}{11}}{154 \times 21\,883} = 1.406$$

Conclusion :

In contrast to previous calculations by means of the Code RELAP-5 MOD-1, the accumulated mass error remains low, and the running time is very stable, with a performance ratio of about 1.8 (execution/transient time)

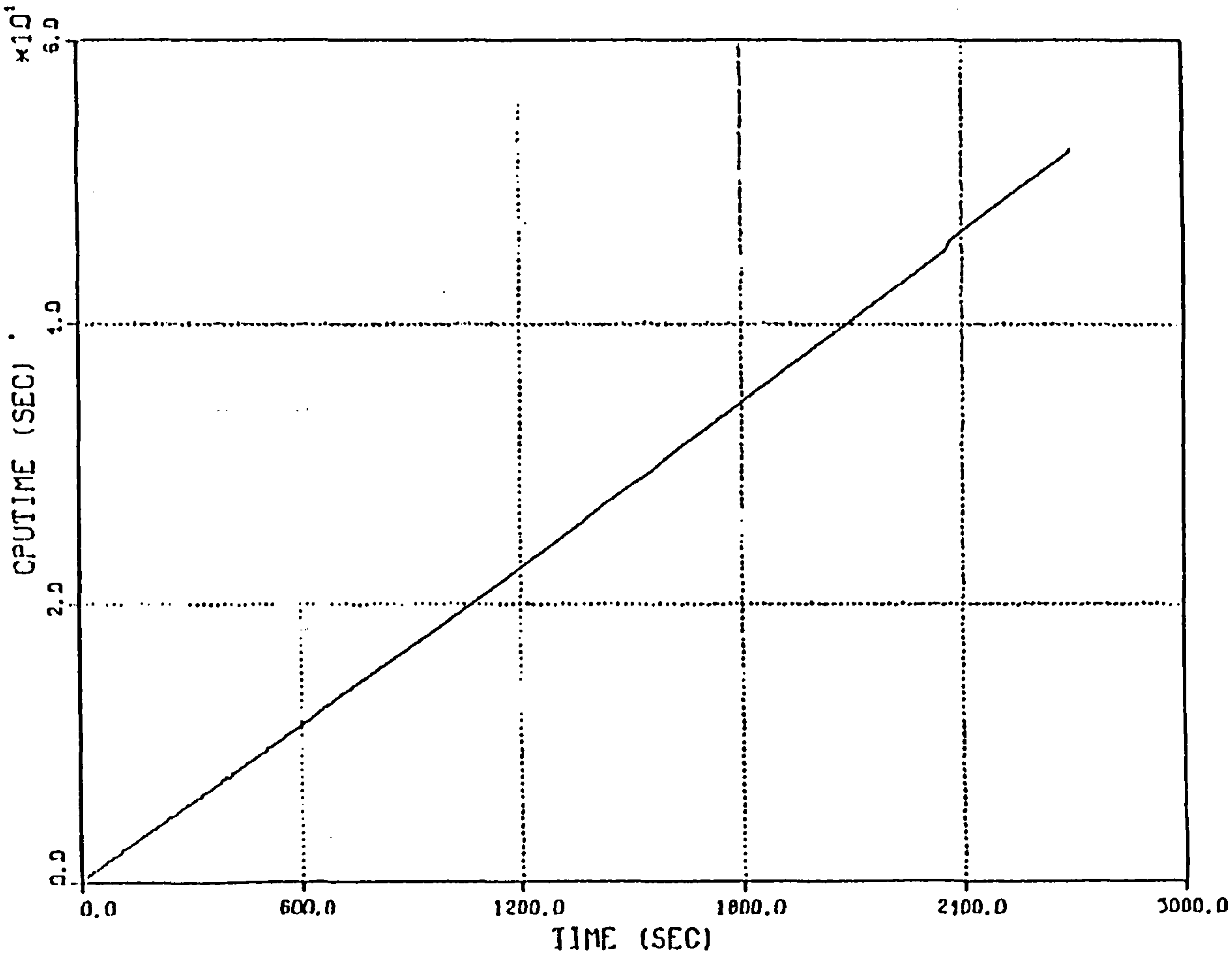
TABLE 8.1 - RUN STATISTICS TABLE

TRANSIANT TIME	CPU-TIME	CLOCK TIME	TOTAL MASS KG	MASS ERROR FRACTION	AVERAGE ΔT	NUMBER OF CYCLES	REPEATED ADV
0	122	11.1	0	0.		0	
200	3855	350	4.46	1.5 E-6	0.1249	1602	-1
400	7546	686	6.53	2.15 E-6	0.125	3202	-1
600	11250	1023	8.37	2.75 E-6	0.125	4802	-1
800	14930	1357	9.66	3.17 E-6	0.125	6402	-1
1000	18666	1697	6.92	2.27 E-6	0.125	8002	-1
1200	22565	2051	1.63	0.54 E-6	0.125	9602	-1
1400	26550	2414	10.503	3.45 E-6	0.124	11232	-12
1600	30564	2779	3.06	2.80 E-6	0.122	12891	-40
1800	34413	3128	7.11	2.31 E-6	0.125	14491	-40
2000	38363	3488	-0.025	0.008 E-6	0.124	16110	-48
2200	42210	3837	-10.09	-3.25 E-6	0.1244	17723	-54
2400	46561	4233	-3.649	-1.17 E-6	0.115	19479	-72
2600	50347	4577	1.663	0.531 E-6	0.1248	21083	-74
2700	52249	4750	3.39	1.08 E-6	0.125	21883	-74

RELAP5/2/36.01 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

DOEL2 SGTR INCIDENT 25 JUNE 1979 85/09/28.

FIG 8.1 CPUTIME VERSUS TRANSIENT TIME



9. CONCLUSIONS

An assessment study for the code RELAP-5 MOD-2 CYCLE 36.01 was presented in this report based on a real plant transient (DOEL-2 SGTR event).

Although the quality and quantity of the plant data in terms of plant diagnostics and recordings may be considered poor with respect the known thermal-hydraulic facilities, it was shown that comparison of parameter trends can lead to an opinion on the strength and weaknesses of the code to simulate the observed phenomena.
Such as :

1. The code is capable to simulate the observed phenomena reasonably well and can be used to predict similar transients. However, lack of precise boundary conditions does not allow one to quantify the error margin from this analysis.

2. The code performance is acceptable. The time step is constant and Courant limited for 99 % of the transient, and the execution time on a CYBER-176 is about 1.8 times the transient time. The mass error ratio remains negligible.

3. Impressive improvements over RELAP-5 MOD-1 CYCLE 19 have been observed in the steady break flow rate, and the water-vapour flow slip (CCFL) in the pressuriser, when pressuriser spray is actuated.

4. Excessive water level swell observed in the intact S.G. during cooldown may be attributed to excessive interphase momentum transfer in the S.G. riser region when bulk boiling is initiated.

5. Excessive interphase mass and heat transfer for condensation and evaporation in quasi stagnant flow conditions was observed in the vapour space of the isolated affected steam generator.

6. Erratic natural circulation in the affected steam generator leads to an anomalous cooldown capacity of the steam generator. This behaviour can be suppressed by inserting high form loss factors in the natural circulation flow path.

7. While some anomalies may be reduced by a judicious choice of the nodalisation and/or code options, this study suggests that further improvements in the constitutive equation package, in function of the various flow regimes is needed, to take full benefit of the potential of a 6 equation code.

10. REFERENCES

1. Analysis of Steam Generator Tube Rupture Events at Oconnee and Ginna. INPO - 82-030 November 1982.

2. Analysis and simulation of the DOEL-2 SGTR event. E.J. STUBBE et al.
ANS PROCEEDINGS : Anticipated and Abnormal plant transients in LWR's, Vol 1 pp 183-192, September 1983.

3. Application of RELAP-5 to the analysis of the Doel-2 SGTR accident, and studies of the Doel 1-2 loss of feedwater and feedwaterline break accidents.
E.J. STUBBE, L. VANHOENACKER
Presented at the 13th Water Reactor Safety Research information meeting, GAITHERSPURG Oct. 22-25 1985.

4. RELAP-5/MOD2 CODE MANUAL
V.H. RANSOM et al, NUREG/CR-4312, EGG-2396, August 1985

ANNEXE 1

PD/VEF

Revision A

25/10/79

REPORT ON THE INCIDENT AT DOEL 2 NUCLEAR POWER PLANT

SEVERE LEAKAGE IN STEAM GENERATOR B ON JUNE 25, 1979

1. Status of the power plant at the moment of the incident

The primary system was being heated up after repair works at the actuation system of the main steam valve.
At the moment of the incident, temperature in the primary system was $\pm$ 255°C (point A on Fig. 1 & 2) and pressure had reached its rated value of 157 kg/cm^2 (point A on Fig. 3 & 4).
The reactor was subcritical with all rods in.
Secondary pressure in the steam generators was $\pm$ 45 kg/cm^2, the saturation pressure corresponding to 255°C (point A on Fig. 6 & 7).
For some time, A-loop steam generator had shown a low
A/ activity value along the secondary side.

2. Sequence of the events (refer also to various computer data given in attachment)

2.1. Initiating phase

A/ About 7:20 PM, a quick level decrease (Fig. 5) and a pressure decrease (about 2 kg/cm^2 per minute : see Fig. 4) are recorded in the pressurizer. The level decrease results in an acceleration of the operating charging pump. A second

A/ charging pump is started manually. It is confirmed that the relief valves are closed, and their isolation valves are preventively closed. The level in the pressurizer continues to decrease, and as a result the letdown station of the CV system closes. The electrical heaters are disconnected, which is confirmed manually.
The steam bubble expands into the primary loop.
At the same time, a quick level increase is recorded in B-loop steam generator (point B on Fig. 7).
A/ The importance of the leak has been later evaluated at 40 t/hr. The activity measurement channels of the blowdown system record a maximum value.
The combination of all those signals indicates a severe leak in B-loop steam generator. The faulted steam generator is then immediately completely isolated along the steam side,
A/ but the line to the turbo-pump is omitted.
The discharge valve to the atmosphere is set at maximum
A/ pressure (80 kg/cm^2).
Meanwhile, the third charging pump is started (was set apart to be maintained), but three charging pumps are not sufficient to compensate the loss of fluid in the steam generator.
Indeed, the CV tank is readily empty, and the charging pumps are automatically supplied from the pool fill tank.
A/ Cooling of the primary system starts through a discharge to the atmosphere of A-loop steam generator, in which pressure and temperature quickly decrease (point A on Fig. 6).
Primary pump B is stopped.

2.2. Actuation of the safety injection

About 20' after the incident started, the threshold pressure (118.5 kg/cm^2) to actuate the safety injection is reached. The emergency diesels start within the required time lapse but are not necessary. Phase A isolation and ventilation isolation of the reactor building are achieved. The vital components not yet in operation are started.
When reaching the 108 kg/cm^2 value, all HP SI-pumps discharge into the primary system, and the pressure decrease is stopped (point C on Fig. 3).

A/ As the low level threshold is exceeded in A-loop steam generator, the auxiliary feed pump starts. The discharge through this turbo-pump results in a quick pressure decrease in B-loop steam generator (point C on Fig. 7) for about 8 minutes, time during which $\pm$ 1 ton steam could be discharged (until a level of about 45% in the two steam generators).
To decrease primary pressure and thus also the leak rate, spray is maximum in the pressurizer. Primary pump B is started, and both spray lines are used (point D on Fig. 3).
During this phase, the steam bubble in the pressurizer completely disappears, and it fills up with primary water at $\pm$ 230°C. Spray is stopped at $\pm$ 75 kg/cm^2, and pressure stabilizes at a value corresponding to the head of the four SI-pumps taking into account the leak flow.

The auxiliary feed pump of the faulted steam generator is stopped locally and isolated (point D on Fig. 7). This cannot be performed from the control room since the SI signal still prevails. The auxiliary feedwater supply tank is filled up from Doel 1.

2.3. Cancelling of SI-signal

Pressure decrease was now mandatory :

(a) to avoid the preset opening of safety valves of the faulted steam generator

(b) to start, as soon as possible, the shutdown cooling system (low pressure circuit !) to stop the letdown of slightly contaminated steam through the A-loop steam generator.

First, the safety injection signal had to be cancelled. This had to be performed more than once (each time requiring A/ 5 minutes interval) because the relay did not start within the required time lapse. Finally, the concerned bistables had to be flicked over.

After definitively cancelling the SI-signal, two HP SI-pumps are stopped and soon thereafter a third one. While considering the subcooling margin, the last HP SI-pump is stopped, and pressure successively decreases to reach $\pm$ 65 kg/cm^2 (point H on Fig. 3).

A/ At that moment, the three charging pumps are running. It is then tried to initiate the CV-discharge line, but valves do not open. Some time goes by before the reason therefore is determined. Due to phase A isolation, there is no longer a compressed-air supply in the reactor building. After re-opening the compressed-air supply line, the discharge line is opened (point I on Fig. 3).

A/ A charging pump is stopped, pressure decreases, first quickly, then slower.

The loss of compressed-air supply has also resulted in the A/ closure of the CC-valves to the thermal shield of the primary pumps. This lasts for about 10 minutes, but no damage was recorded.

2.4. Initiation of the residual heat removal system

As the CV-system permitted only a slow pressure decrease, the interlock, which maintains the isolation of the RHRS up to a pressure of 28 kg/cm^2, has been bypassed at 31 kg/cm^2. There was indeed a sufficient margin compared to the design pressure of the system (42 kg/cm^2). Thanks to this operation, the letdown through A-loop steam generator could be stopped earlier and the discharge of slightly contaminated steam could be reduced (point J on Fig. 3).

A/ The signal ordering the automatic isolation of the system is again operational. However, shortly thereafter isolation starts again (pressure peak at 37 bar) due to a misregulation of pressure. Isolation is again bypassed to allow starting the RHRS.

2.5. Further sequences

Primary pressure decreases to become lower than the secondary pressure in B-loop steam generator. Secondary level decreases, which may create a dilution risk. The boric acid concentration is controlled every half hour (stabilized at ± 1500 ppm).
Thanks to cooling down, pressure decreases slowly in B-loop steam generator and reaches a value lower than the primary pressure. From this moment on, attention is paid to always maintain primary pressure above that in the steam generator. Despite the cold water so discharged in the steam generator, pressure decreases only slowly (due to the presence of a warm water film at the water surface).
As the level of water in the steam generator approaches the

upper limit of the broad level measurement, pressure is sufficiently low ($\pm$ 12 kg/cm^2) to allow nitrogen injection. The secondary drain line is coupled with system B for liquid waste, and the steam generator discharges into it through the nitrogen pressure.
As the nitrogen is only slightly contaminated, it is possible to discharge it to the atmosphere via the annulus between primary and secondary containments.

A/ 2.6. <u>Comments and conclusion</u>

1) The incident has been mastered as prescribed and has affected neither the environment nor the installation.

2) The procedure has to be reviewed with regard to the cancellation of phase A isolat on to restore compressed air supply to the reactor building.

3) It has to be checked if some changes are not required in the IA system within the reactor building.

4) The further analysis of the incident has been hard to perform due to the poor quality of the computer data.

ATTACHMENT 1 - COMPUTER DATA

1. Initiating phase

19 21'06" : pressurizer pressure below reference pressure

19 22'51" : demand for accelerating charging pump

19 23'31" : pressurizer heaters disconnected due to low level

19 23'32" : CV letdown station valves closed

19 25'42" : isolation valves of relief and spray valves closed

19 26'14" : low pressure ~~in~~ primary system

19 30'30" : very low pressure in pressurizer

19 30'30" : high level in B-loop steam generator

19 38'32" : B primary pump disconnected

2. Safety injection phase

19 40'18" : low pressure in pressurizer

19 40'19" : safety injection due to pressurizer low pressure

19 40'19" : diesels started

19 40'19" : isolation of reactor building ventilation

19 40'20" : phase A isolation of reactor building

19 40'24" : actuation signal of HP SI-pumps

19 40'33" : HP SI-valves opened

19 43'48" : very large auxiliary feedwater flow to A SG

A/ 19 43'54" : low level in A SG

19 44'39" : very large auxiliary feedwater flow to B SG

A/ 19 44'42" : valve from B SG to turbo-pump opened

A/ 19 44'51" : valve from A SG to turbo-pump opened

19 53'12" : auxiliary feed pump B disconnected

19 56'37" : very low level in auxiliary feedwater tank

19 57'11" : pressurizer level back to normal

19 57'29" : pressurizer heaters re-started

19 58'48" : high level in pressurizer

3. SI-signal cancelling phase

20 00'15" : diesel automatic starting signal cancelled and SI-pumps actuation signal cancelled

20 00'21" : back to SI

20 03'24" : LP compressed air in the reactor building

20 05'59" : safety injection cancelled

20 06'05" : safety injection

20 10'59" : reactor building ventilation isolation cancelled

20 21'15" : HP SI-pump B disconnected

A/ 20 22'36" : accumulator A valve closed

20 25'22" : HP SI-pump A disconnected

20 38'33" : valve CC-096 closed

20 40'25" : valve CC-099 closed

20 48'54" : compressed air supply to reactor building restored

20 49'00" : primary pumps CC valves re-opened

4. Actuation of RHRS

22 35'54" : valves RC-003 opened

Temperature hot leg

TEMPERATUUR WARM BEEN FIGUUR 1

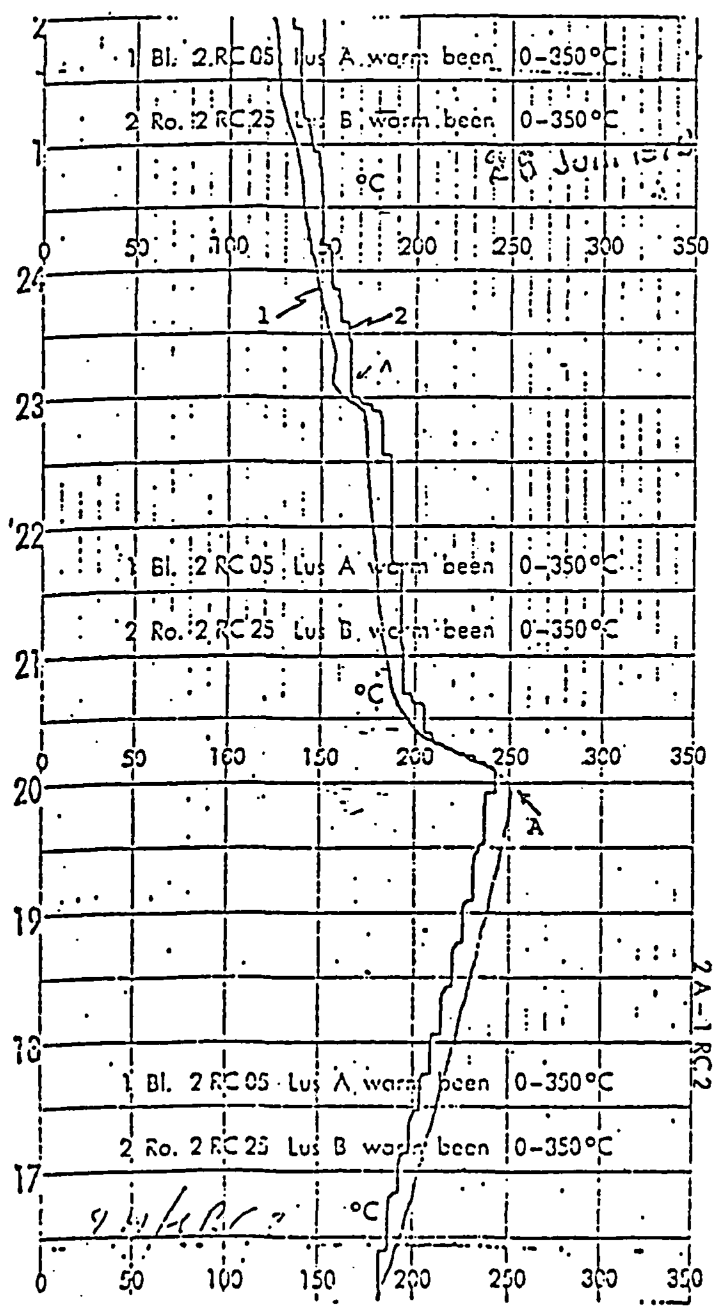
Schrijver : 2 A - 1 RC 2

loop A - hot leg

1. Bl. RC 05 lus A warm been 0 - 350°C

loop B hot leg

2. Ro. RC 25 lus B warm been 0 - 350°C



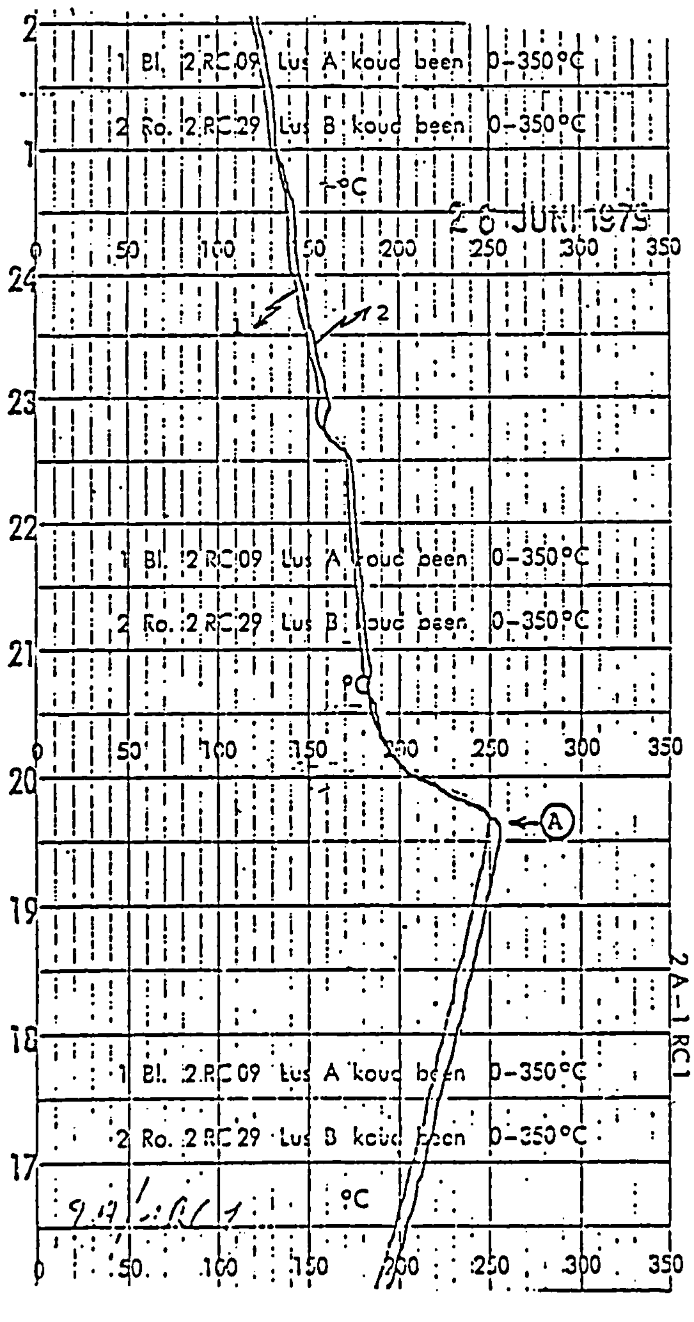
Temperature cold leg

TEMPERATUUR KOUD BEEN   FIGUUR 2

Schrijver : 2. A - 1 RC 1

loop A cold leg
1. Bl. RC 09 lus A koud been   0 - 350°C

loop B cold leg
2. Ro. RC 29 lus B koud been   0 - 350°C

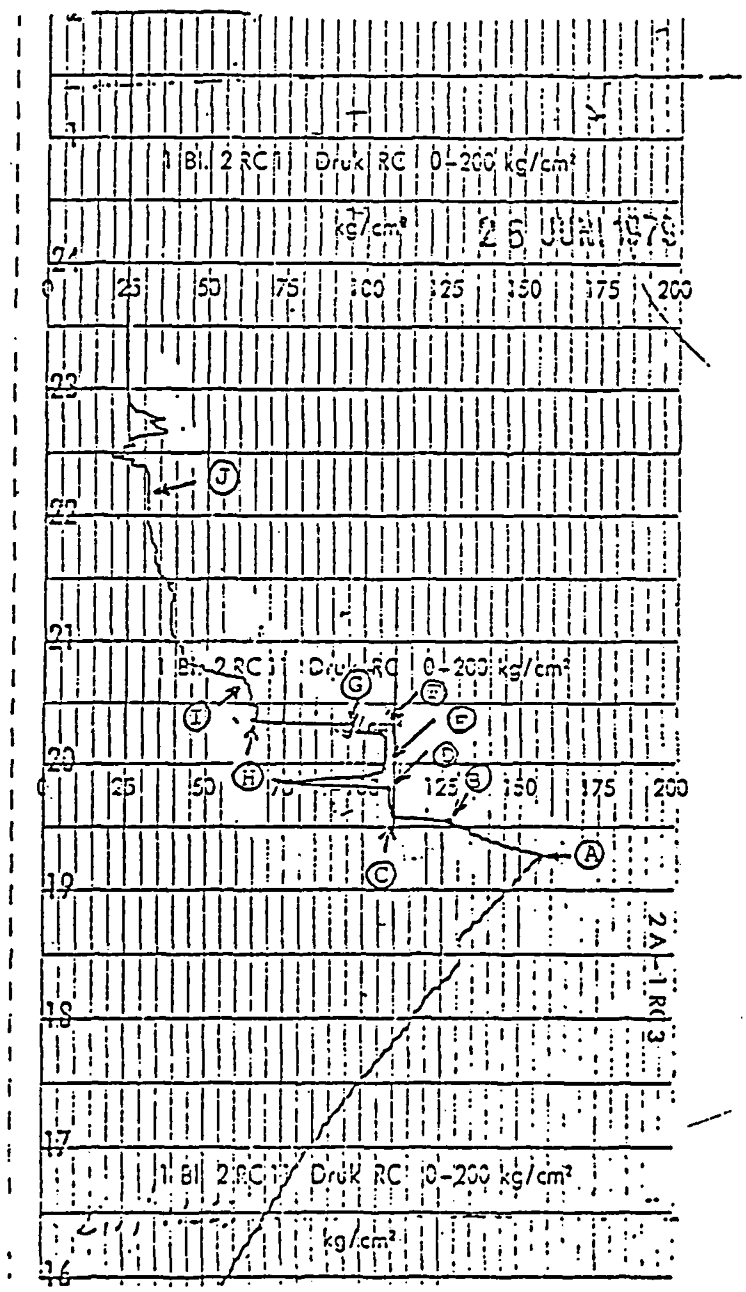


Pressure RC

DRUK RC FIGUUR 3

Schrijver : 2 A - 1 RC 3

1. Bl. RC 11 druk RC pressure RC 0 - 200 kg/cm2

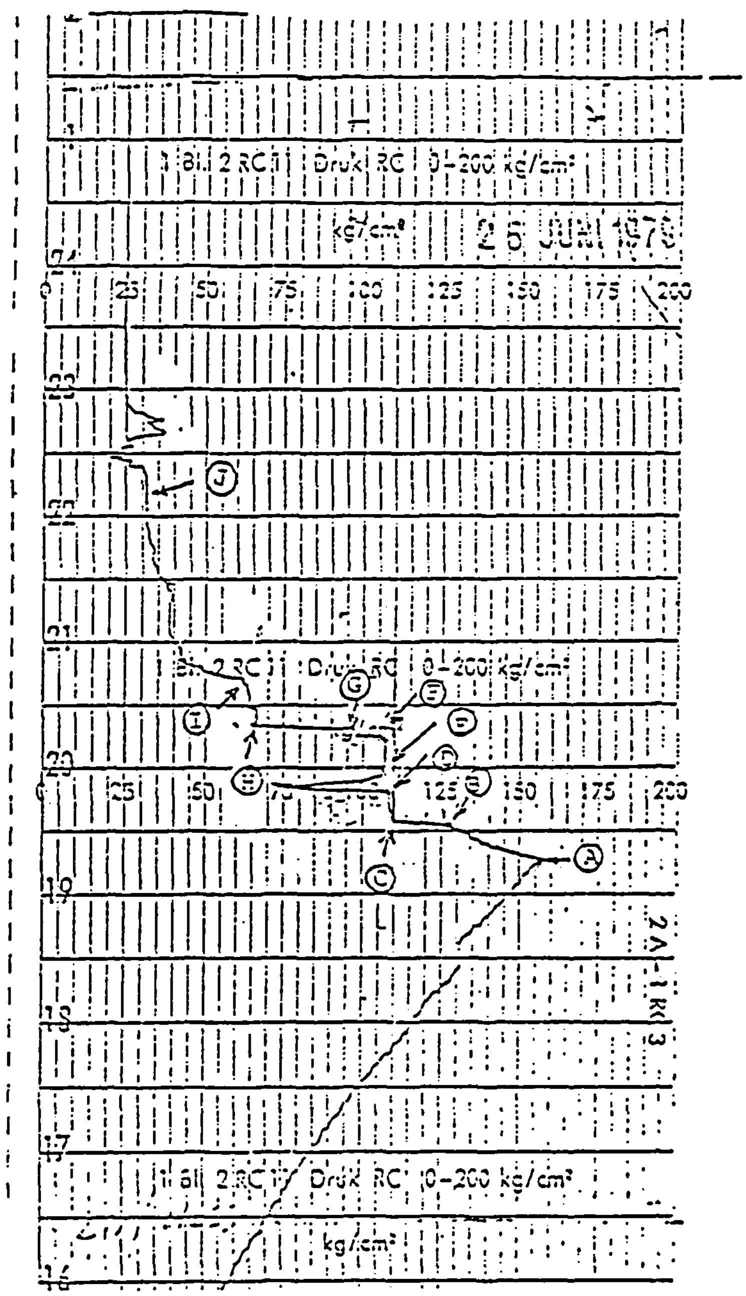


Pressure RC

DRUK RC FIGUUR 3

Schrijver : 2 A - 1 RC 3

1. Bl. RC 11 druk RC pressure RC 0 - 200 kg/cm2



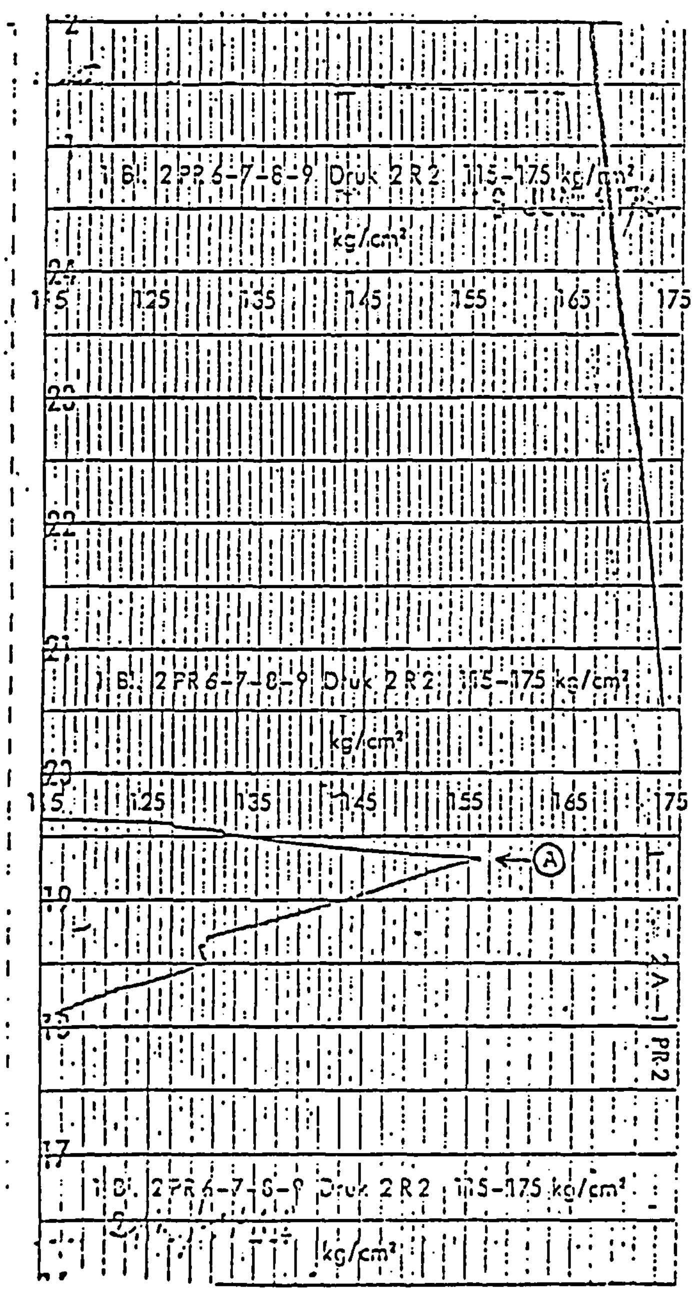
Pressuriger Pressure

DRUK R 2 FIGUUR 4

Schrijver : 2. A - 1 PR 2

1. Bl. PR 6 - 7 - 8 - 9 Druk R2 Pressuriger pressure 115 - 175 kg/cm2

Meting in dienst spoor 1 :



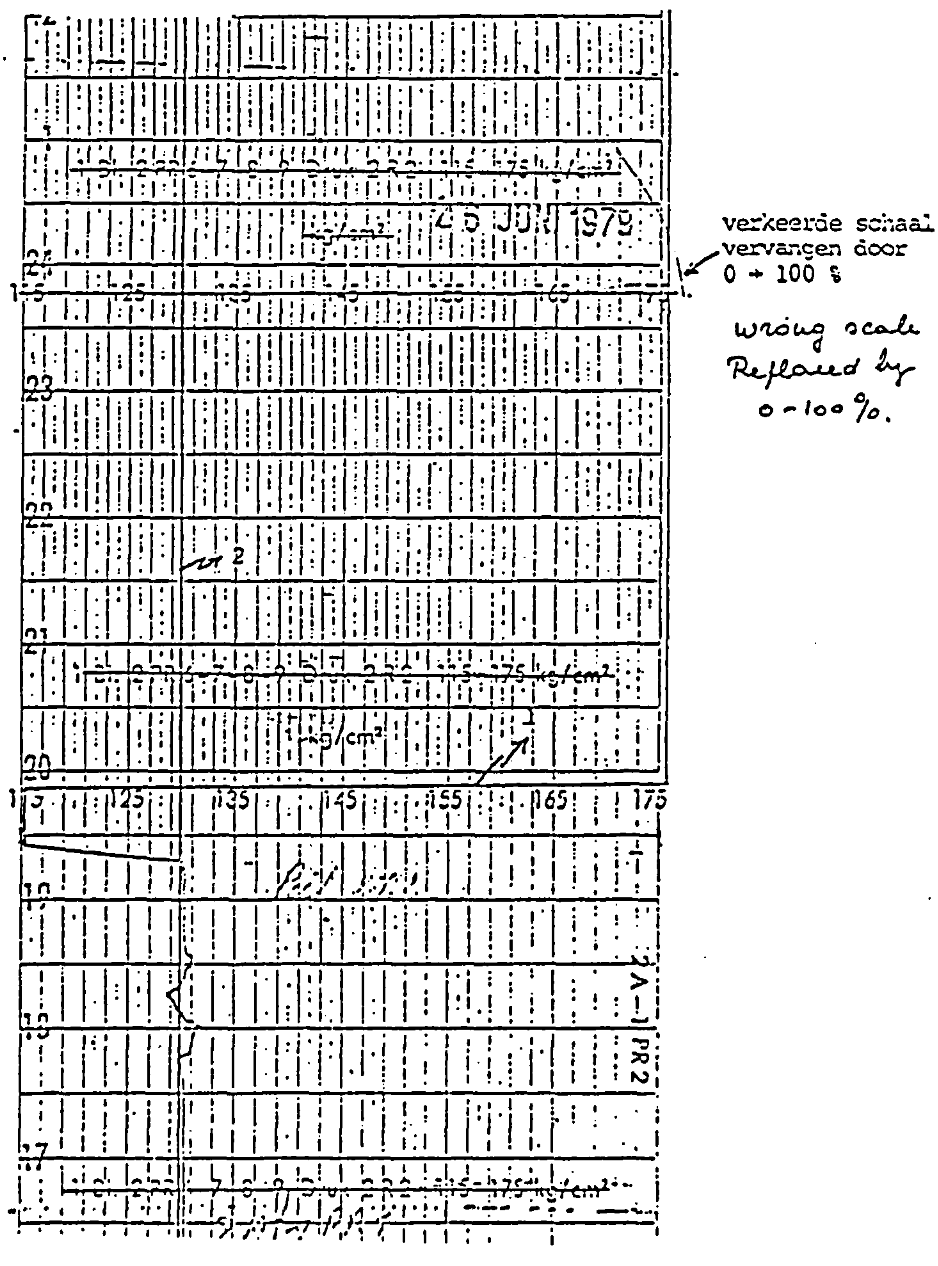
Pressurizer level

PEIL R 2 FIGUUR 5

Schrijver : 2 A - 1 PR 1

1. Bl. L. PR 11 - 12 - 13	Peil R 2 (*Pressurizer level*)		0 - 100 %
2. Ro. L. Ref.	Ref. Peil R 2 (*Reference level*)		0 - 100 %

Meting in dienst spoor 1 :



SG A - level and Pressure

SG. A PEIL - DRUK FIGUUR 6

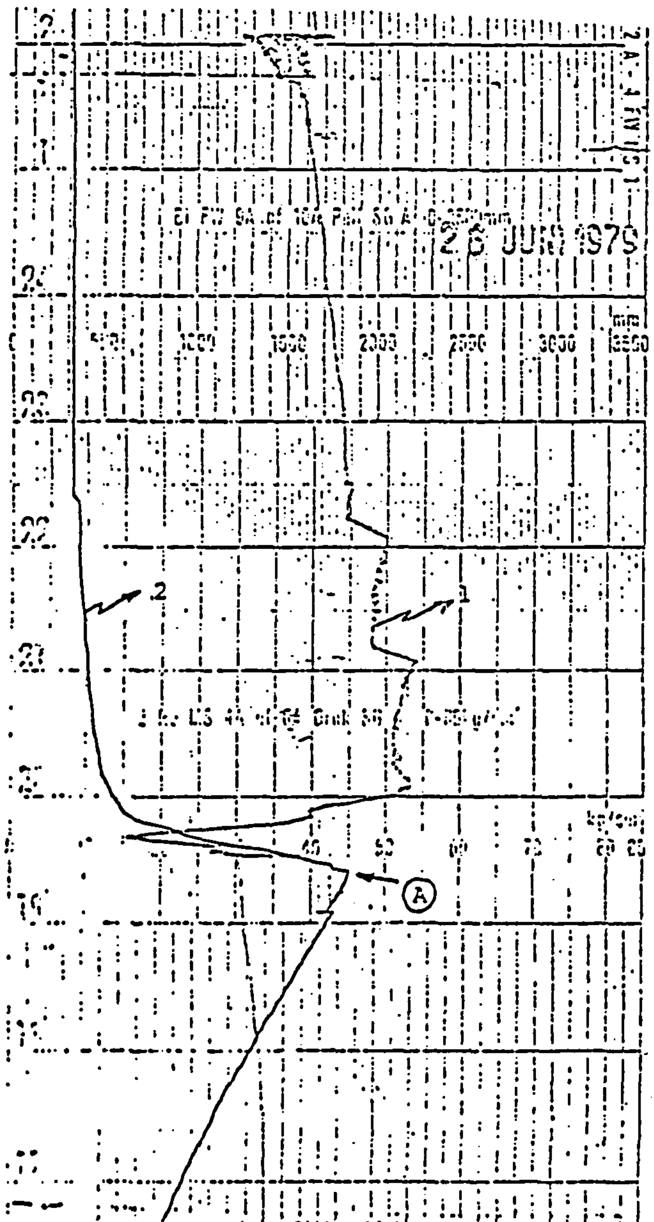
Schrijver : 2 A - 4 FW MS. 1

1. Bl. L. FW 9 A - 10 A Peil SGA *(SG A level)* 0 - 3500 mm

2. Ro. P. MS 4 A - 6 A Druk SGA *(SG A pressure)* 0 - 85 kg/cm2

Meting in dienst spoor 1 :

spoor 2 :



SG B - level and pressure

SG. B PEIL - DRUK   FIGUUR 7

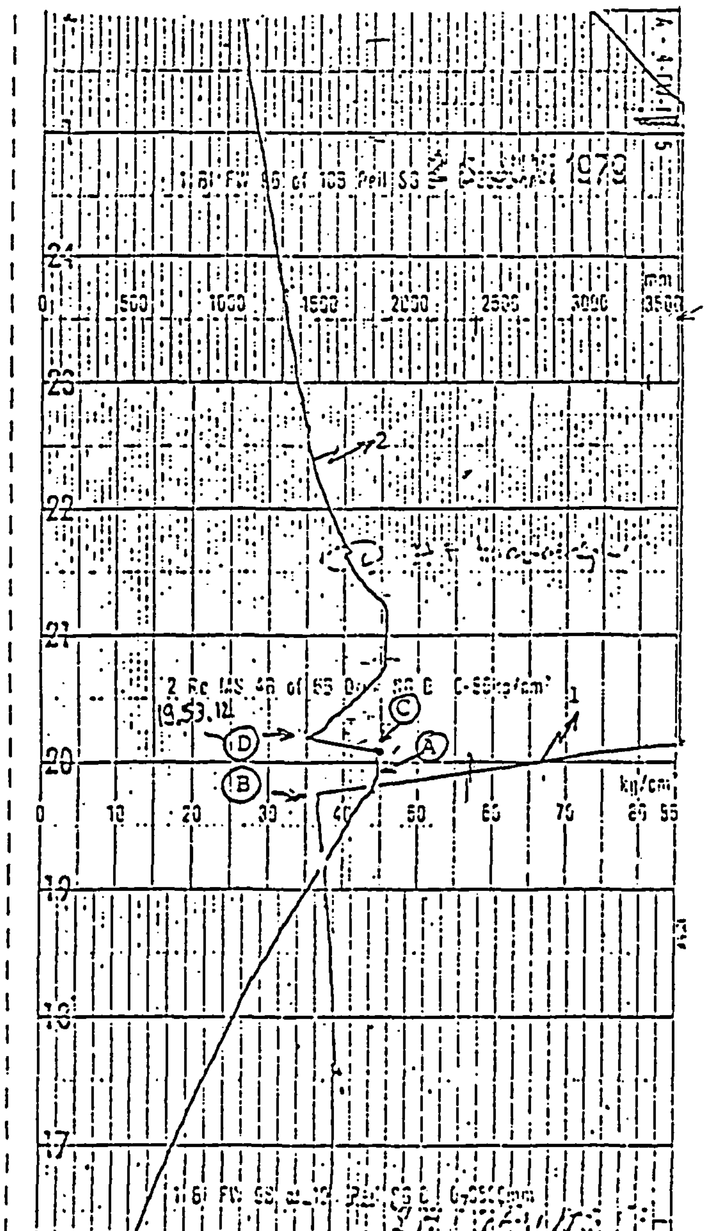
Schrijver : 2. A - 4 FW MS 5

1. Bl. L. FW 9 B - 10 B Peil SG B (SG B level)   0 - 3500 mm

2. Ro. P. MS 4 B - 6 B Druk SG B (SG B pressure)   0 - 85 kg/cm2

Meting in dienst spoor 1 :

. spoor 2 :



```
 ***********************
 *  A N N E X E    2  *
 ***********************
```

```
=DOEL2 SGTR INCIDENT  25 JUNE 1979
*
*
*
*
*
100  NEW TRANSNT
101  RUN
201 2700.  1.E-6  0.25   3  8  800 2000
*
*****************************************************************************
* MINOR EDIT                                                                *
*****************************************************************************
*
*
301   P              330010000          * PRESSURISER
302   CNTRLVAR             031          * CORE POWER
303   CNTRLVAR             305          * HEATERS POWER
304   CNTRLVAR             901          * PRESSU LEVEL
305   MFLOWJ         183000000          * LETDOWN
306   MFLOWJ         181000000          * CV
307   P              123010000          * PRESSURE AT BREAK
308   P              621010000          *
309   VOIDG          045010000          * UPPER HEAD
310   CNTRLVAR             007          *
311   CNTRLVAR             600          *
312   CNTRLVAR             700          *
315   CNTRLVAR             078          * HPSI
318   CNTRLVAR             969          * FW + AFW
319   CNTRLVAR             979          *
320   MFLOWJ         865000000          * STEAM TURBOPUMP
322   P              630010000          * SG  PRESSURE
323   P              730010000          *
324   MFLOWJ         617000000
325   MFLOWJ         717000000          *
328   CNTRLVAR             610          * HEAT TRANSFER RATE
329   CNTRLVAR             710          *
330   CNTRLVAR             009          * ENERGY BALANCE
331   MFLOWJ         112030000          * SURGELINE MASS FLOWRATE
332   MFLOWJ         618000000          *
333   CNTRLVAR             002          * MASS BALANCE
334   CNTRLVAR             612          * SG B  RISER LEVEL
335   CNTRLVAR             712          * SG A
336   MFLOWJ         043010000          * PRIMARY MASS FLOW RATES
337   MFLOWJ         043020000
338   MFLOWJ         043030000
339   CNTRLVAR             045          * PRESSURISER MASS
```

```
*
340   MFLOWJ      618000000        * BREAK
341   CNTRLVAR          012        *
342   VOIDGJ      618000000        *
343   TEMPF       015030000        * VESSEL TEMPERATURE
344   TEMPF       041010000        *
345   TEMPF       045010000        *
346   TEMPG       330010000        * PRESSU TEMPERATURE
347   CNTRLVAR          991        * PRESSU HEAT LOSSES
348   CNTRLVAR          113        * AVG TEMPERATURE
349   CNTRLVAR          114        * SUBCOOLING
*                            * SGB VOIDG
351   VOIDG       620010000
352   VOIDG       620020000
353   VOIDG       620030000
354   VOIDG       620040000
355   VOIDG       621010000
356   VOIDG       623010000
357   VOIDG       611010000
358   VOIDG       613010000
359   VOIDG       612010000
*
360   CNTRLVAR          600     * SG B MASS INVENTORY
361   VOIDG       720010000     * SG A VOIDG
362   VOIDG       720020000
363   VOIDG       720030000
364   VOIDG       720040000
365   VOIDG       721010000
366   VOIDG       723010000
367   VOIDG       711010000
368   VOIDG       713010000
369   VOIDG       712010000
*
370   MFLOWJ      623030000        * SG B SEPARATOR MASS FLOW RATESY
371   MFLOWJ      623020000        *
372   MFLOWJ      623030000        *
373   MFLOWJ      611010000        * SG B BY PASS MASS FLOW RATES
374   MFLOWJ      611020000        *
375   MFLOWJ      617000000        * SG B DOWNCOMER MASS FLOW RATE
376   CNTRLVAR          611        * SG B COLLAPSED WATER LEVEL
377   CNTRLVAR          613        * SG B MEASURED WATER LEVEL
378   VAPGEN      613010000
379   VAPGEN      622010000
*
380   MFLOWJ      723030000        * SG A SEPARATOR MASS FLOW RATES
381   MFLOWJ      723020000        *
382   MFLOWJ      723030000        *
383   MFLOWJ      711010000        * SG A BYPASS MASS FLOW RATES
384   MFLOWJ      711020000        *
385   MFLOWJ      717000000        * SG A DOWNCOMER MASS FLOW RATE
386   CNTRLVAR          711        * SG A COLLAPSED WATER LEVEL
387   CNTRLVAR          713        * SG A MEASURED WATER LEVEL
388   VAPGEN      713010000
389   VAPGEN      722010000
*
```

```
391   VOIDG          630010000
392   VOIDG          625010000
393   VOIDG          627010000
394   CNTRLVAR             993
395   TEMPF          251020000
396   TEMPF          211030000
397   TEMPF          151020000
398   TEMPF          113010000
399   CPUTIME                0
*
*
*
******************************************************************************
* TRIP
******************************************************************************
*
*
*
550  TIME             O GT  NULL  O       900        N     * OPEN RELIEF VALVE
*
561  TIME             O LT  NULL  O      1900.       N     * TURBOPUMP ON
 *
 *
 503  TIME        O       GT      NULL     O      1112.     N     * PUMP B  STOP
 504  TIME        O       LT      NULL     O      2105.     N     * PUMP B  STOP
 529  TIME        O       GT      NULL     O      2106.     N     * SPRAY
 530  TIME        O       LT      NULL     O      2287.     N     * SPRAY
 542  TIME        O       GT      NULL     O      2248.     N     * HEATER  ON
 560  TIME        O       GT      NULL     O      1482.     N     * TURBOPUMP
 571  P  330010000        LT      NULL     O      117.E5    L     * SI
 580  CNTRLVAR 901        LT      NULL     O      0.2       L     * LPR 20%
 574  TIME        O       GT      NULL     O      1428.     N     * MOTOPUMP "A" ON
 575  TIME        O       GT      NULL     O      1479.     N     * MOTOPUMP "B"
 576  TIME        O       LT      NULL     O      1992.     N     *            "B"
 591  TIME        O       GT      NULL     O      1000.     N     * SGA DISCHARGE
  *
 601   503   AND   504    N
 602  -503   OR   -504    N
 630   529   AND   530    N   * SPRAY ON
 641  -591   AND  -580    N   *
 642   641   OR    542    N   * HEATER ON
 661   560   AND   561    N   * TURBOPUMP   ON
 676   575   AND   576    N   * MOTOPUMP B   ON
 *
*
598  TIME             O LE  NULL   O     10000.      L     * BIDON
599  TIME             O GE  NULL   O     10000.      L     * BIDON
*
*
*
******************************************************************************
* VESSEL                                                                     *
******************************************************************************
*
*
```

173

```
*DOWNCOMER
0110000  VDCOMER  BRANCH
0110001  2  1
0110101  2.169  1.584  0.  0.   90.  1.584  4.E-5  0.467  00
0111101  013000000  011000000  0.  0.  0.  0000
0112101  011010000  045000000  0.00256  2.7  2.7  0000
*
0130000  INOZZLE  BRANCH
0130001  3  1
0130101  2.0874  0.872  0.  0.  -90.  -0.872  4.E-5  0.467  00
0131101  013010000  015000000  0.  0.  0.  0000
0132101  153010000  013000000  0.383  0.6075  0.6075  0000
0133101  253010000  013000000  0.383  0.6075  0.6075  0000
*
*
*
*
* DOWNCOMER ANNULUS
*
0150000  DOWNCOM  ANNULUS
0150001  3
0150101  1.41  3
0150301  1.361  2
0150302  1.362  3
0150601  -90.  3
0150801  4.E-5  0.11  3
0150901  0.10835   0.10835    2
0151001  00  3
0151101  0000  2
0151300  1
*
* VESSEL BOTTOM
*
0210000  VESBOT  SNGLVOL
0210101  0.  0.638  2.679  0.  90.  0.638  4.E-5  0.  00
*
* LOWER MIXING  PLENUM
*
0230000  LMIXPL  BRANCH
0230001  3  1
0230101  0.  0.638  5.359  0.  90.  0.638  4.E-5  0.  00
0231101  015010000  023010000  0.  1.  1.  0000
0232101  023010000  025000000  1.  1.  1.  0000
0233101  023000000  021010000  0.  0.  0.  0000
*
* CORE INLET PLENUM
*
0250000  CORINPL  BRANCH
0250001  2  1
0250101  0.  1.013  3.574  0.  90.  1.013  4.E-5  0.  00
0251101  025010000  031000000  2.5  3.93  3.93  0000
0252101  025010000  035000000  0.1  6.32  6.32  0000
*
* CORE
*
```

```
0310000  CORE  PIPE
0310001  4
0310101  2.5  4
0310301  0.6095  4
0310601  90. 4
0310801  4.E-5  0.0155  4
0310901  2.5     2.5     3
0311001  00  4
0311101  0000  3
0311300  1
*
* CORE EXIT
*
* CORE BYPASS
*
0350000  CORBYPS  SNGLVOL
0350101  0.  2.438  1.9706  0.  90.  2.438  4.E-5  0.0  00
*
0390000  COREX  BRANCH
0390001  3  1
0390101  0.  0.6085  2.3252  0.  90.  0.6085  4.E-5  0.  00
0391101  031010000  039000000  2.5   1.8    1.8    0000
0392101  035010000  039000000  0.1   6.32   6.32   0000
0393101  039010000  041000000  1.    0.262  0.262  0000
*
* CORE PLENUM
*
0410000  CORPLEN  SNGLVOL
0410101  0.  0.8965  5.103   0.  90.  0.8965  4.E-5  0.2  00
*
* UPPER PLENUM
*
0430000  UPPLEN  BRANCH
0430001  3  1
0430101  0   1.584  9.349  0.   90.  1.584  4.E-5  0.2  00
0431101  041010000  043000000  0.  0.  0.  0000
0432101  043000000  111000000  0.383  0.1737  0.1737  0000
0433101  043000000  211000000  0.383  0.1737  0.1737  0000
*
* VESSL DOME
*
0450000  DOME  BRANCH
0450001  1  1
0450101  0.  1.496  8.833  0.  90.  1.496  4.E-5  0.  00
0451101  043010000  045000000  0.00256  2.7  2.7  0000
*
* HEAT STRUCTURES
*
* CORE HEAT STRUCTURES
*
10311000  4  5  2  1  0.
10311100  0  1
10311101  2  0.004647  1  0.0047425  1  0.005395
10311201  1  1  1  2  -4  3  -2  4
10311301  1.  1  1.  2  0.  3  0.  4
```

```
10311400 -1
10311401 1158.3 1061.4 812.12 606. 583.
10311402 1158.3 1061.4 812.12 606. 583.
10311403 1158.3 1061.4 812.12 606. 583.
10311404 1158.3 1061.4 812.12 606. 583.
10311501    0     0     0     0     0.  4
10311601  031010000  10000  1  0  441.0  4
10311701  100  0.16667  0.  0.  1
10311702  100  0.33333  0.  0.  2
10311703  100  0.33333  0.  0.  3
10311704  100  0.16667  0.  0.  4
10311901  0  0.  0.0136  0.0136  4
*
*
***************************************************************************************
* FIRST PRIMARY LOOP
***************************************************************************************
*
* HOT LEG
*
1110000  HTLG11 SNGLVOL
1110101  0.383 2.476 0. 0. 0. 0. 4.E-5  0.698  00
*
1120000  HTLG12  BRANCH
1120001  3 1
1120101  0.383 2.476 0. 0. 0. 0. 4.E-5  0.698  00
1121101   111010000 112000000 0. 0. 0.  0000
1122101   112010000 113000000 0. 0. 0.  0000
1123101  301000000   112000000 0.   10.   10. 0000  *! KF TO BE CHECKED
*
*
*
1130000  HTLG13  SNGLVOL
1130101  0.383   2.476  0.   0.   30.8  0.95  4.E-5  0.698  00
*
*
* STEAM  GENERATOR B
*
*
* INLET BOX
*
1210000  INBOX  BRANCH
1210001  2  1
1210101  0. 1.685 4.392 0.  90.  1.685 4.E-5 1.822      00
1212101  121010000  122000000   0.99 0.5    1.0   0000
1211101  113010000  121000000  0.435  0.4145  0.5  0000
*
1220000  UUTUBE  PIPE
1220001   8
1220101  0.99   8
1220301  0.908  8
1220601  90.  8
1220801  1.6E-6  0.01966   8
1221001  00   8
1221101  0000  7
```

176

```
 1221300  1
 *
 *
 1230000 UJUN BRANCH
 1230001 2  1
 1230101 0.99       1.816     0.  0.  45.0  1.284  1.6E-6  0.01966  00
 1231101 122010000 123000000  00.00  0.  0.  0000
 1232101 123010000 124000000  00.00  0.  0.  0000
 *
*
*
*
1240000  DUTUB1 PIPE
1240001  5
1240101  0.99    5
1240301  1.816   5
1240601  -45.    1
1240602  -90.    5
1240801  1.E-7  0.01966  5
1241001  00      5
1241101  0000    4
1241300  1
*
* OUBOX  BRANCH
*
1250000  OUBOX  BRANCH
1250001  2  1
1250101  0.  1.685  4.392  0.  -90.  -1.685  4.E-5  1.822    00
1251101  124010000  125000000  0.99  1.  0.5  0000
1252101  125010000  131000000  0.487  0.040  1.000  0000
*
*
* STEAM GENERATOR SECONDARY SIDE
*
*
*
6110000  BYPASSB  BRANCH
6110001  2 0
6110101  8.048 2.424  0.  0.  90. 2.424   5.E-5  0.  00
6112101  611010000  627000000   0.00   00.0   00.0    00000
6111101  611000000  612000000 0.     200. 1000.   00000
*
6120000 B612 BRANCH
6120001 1  0
6120101 8.048      .735       0.  0. -90. -.735 5.E-5  0.  00
6121101 612010000 613000000  00.00  0. 200. 0000
*
6130000   FEEDMIX  SNGLVOL
6130101   0.  0.697  5.596   0.  -90.  -0.697  5.E-5  0.  00
*
6140000  FEEDDWC  SNGLJUN
6140101  613010000  615000000 8.0398  0. 1000.  0000
*
6150000  SGLDCOME1 ANNULUS
6150001  4
```

```
6150101  2.589  1
6150102  0.4845  4
6150301  1.938  1
6150302  2.55   4
6150601  -90.   4
6150801  5.E-5  0.  1
6150802  5.E-5   0.1015 4
6150901  0.  1000.  3
6151001  00     4
6151101  0000   3
6151300  0
*
6170000  SGDCPJ1 SNGLJUN
6170101  615010000 620000000   .000     3.3     1000.     0000
*
*
*
*
6200000  SGPIPE  PIPE
6200001   4
6200101  4.432  4
6200301  1.816    4
6200601  90.      4
6200801  1.E-4  0.03543   4
6201001  00   4
6201101  0000   3
6201300  0
*
*
6210000 BREAK BRANCH
6210001 2  0
6210101 4.432     2.324     0.  0.  90.0  2.324  1.E-4  0.03543  00
6211101 620010000 621000000  00.00  0.  0.  0000
6212101 621010000 622000000  00.00  0.  0.  0000
*
*
*
6220000 TOPRI1 BRANCH
6220001 0  0
6220101 4.     1.432    0.     0.     90.0    1.432    0.00005    0.    00
*
6230000 TOPRI2 SEPARATR
6230001  3  0
6230101  4.     2.424     0.     0.    90.0     2.424    0.00005    0.    00
6231101    623010000    625000000 2.75 20.4  20.4 01000  0.1
6232101    623000000    612000000 0.00 1.0 1000. 01000  0.1
6233101    622010000    623000000 0.00 1.81  1.81 01000
 *
*---------------------------------------------*
*      B R E A K   J U N C T I O N            *
*---------------------------------------------*
6180000  BREAK SNGLJUN
6180101  122010000  621000000   1.724E-4  2.6  2.6  00003 0.  0.
6180201  1    14.987    0.   0.
*
```

```
*
*
6300000  SGDOME1  BRANCH
6300001  1  1
6300101 12.5600  2.093  0.  0.  90.  2.093  5.E-5  0.  00
6301101  630010000  640000000 .13 .2269 .4969  0000
*
*
6250000  DRYER  BRANCH
6250001  1  1
6250101 4.00  1.  0.  0.  90.  1.  5.E-5  0.  00
6251101  625010000  630000000 .00 .0000 .0000  00000
*
6270000  PLENUMB  BRANCH
6270001  1  1
6270101 8.5600  1.  0.  0.  90.  1.  5.E-5  0.  00
6271101  627010000  625000000 .00 .0000 .0000  00003
*
*
6400000  SGL1  PIPE                                 * STEAM LINES
6400001  3
6400101  0.288  3
6400301  22.7171  3
6400601  00.0  3
6400801  4.E-5  00.000  3
6401001  00  3
6401101  0000  2
6401300  1
*
*
*
*
8600000  TV860 TMDPVOL
8600101  10.  1.  0.  0   0.  0.  0.  0.  00
8600200  2
8600201  0.  1.E5   1.
*
*
8650000  TJ865  TMDPJUN                          * TURBOPUMP (STEAM)
8650101  640010000  860000000  0.
8650200   1 661        CNTRLVAR 883
8650201  -1.       0.       0.      0.0
8650202   0.       0.       0.      0.0
8650203  10.       0.       10.     0.0
*
*          AUXILIARY  FEED  WATER  (1MTPUMP)
*
6050000  POOL1 TMDPVOL
6050101  1.  1.  0.  0.  0.  0.  0.  0.  00
6050200  3
6050201  0.  1.E5  308.15
*
6060000  POOL2 TMDPVOL
6060101  1.  1.  0.  0.  0.  0.  0.  0.  00
6060200  3
```

```
6060201  O.  1.E5  308.15
*
6070000  MTPOM    TMDPJUN
6070101  605000000  613000000   0.068              *IDELIVERY CURVE OF 1
6070200  1  676  P  630010000                      * MOTOPUMP FEEDING 1SG
6070201  -1.  O.  O.  O.                           *
6070202   1.E5     27.71    O.   O.
6070203   5.E5     27.17    O.   O.
6070204  10.E5     26.46    O.   O.
6070205  15.E5     25.74    O.   O.
6070206  20.E5     24.99    O.   O.
6070207  25.E5     24.22    O.   O.
6070208  30.E5     23.42    O.   O.
6070209  35.E5     22.58    O.   O.
6070210  40.E5     21.72    O.   O.
6070211  45.E5     20.81    O.   O.
6070212  50.E5     19.86    O.   O.
6070213  55.E5     18.85    O.   O.
6070214  60.E5     17.78    O.   O.
6070215  65.E5     16.63    O.   O.
6070216  70.E5     15.39    O.   O.
6070217  75.E5     14.02    O.   O.
6070218  80.E5     12.46    O.   O.
6070219  85.E5     10.64    O.   O.
*
*
* STEAM GENERATOR HEAT STRUCTURE
*
*
16202000 15 2 2 1 0.00983
16202100 O  1
16202101 1 0.0111
16202201 6  1
16202301 O. 1
16202501    122010000    10000    1    O    164.04455     8
16202502    123010000        O    1    O    164.04455    10
16202503    124010000    10000    1    O    328.08909    15
16202601    620010000     0000    1    O    185.2385      2
16202602    620020000     0000    1    O    185.2385      4
16202603    620030000     0000    1    O    185.2385      6
16202604    620040000     0000    1    O    185.2385      8
16202605    621010000     0000    1    O    185.2385     10
16202607    621010000     0000    1    O    370.477      11
16202608    620040000   -10000    1    O    370.477      15
16202701  O  O.  O.  O.  15
16202801  O.  0.01966  O.          .908   10
16202802  O.  0.01966  O.         1.816   15
16202901  O.  0.03543  0.02223     .908   10
16202902  O.  0.03543  0.02223    1.816   15
*
*
* PUMP SUCTION LEG
*
*
1310000 B131 BRANCH
```

```
1310001 1  1
1310101 0.487      1.806      O.  O. -90. -1.806 4.E-5 .787 00
1311101 131010000 132000000  .487  O. O. 0000
*
1320000 B132 BRANCH
1320001 1  1
1320101 0.487      1.806      O.  O. -90. -1.806 4.E-5 .787 00
1321101 132010000 133000000  .487 0.11 0.11 0000
*
1330000  PSUC1  PIPE
1330001  2
1330101  0.487   2
1330301  1.633   1
1330302  1.43    2
1330601    O.    1
1330602   90.    2
1330801  4.E-5  0.787  2
1330902  0.11  0.11  1
1331001  00      2
1331101  0000    1
1331300  1
*
*
*
* PUMP
*
1400000  PUMP1 PUMP
1400101  O. 1.232 7.757 O. 90. 1.232   00
1400108  133010000 0.487 0.4385 0.4385      0000
1400109  151000000 0.383 0.2712 0.2712      0000
1400301  -2  -1  -2  -1   0    0   1
1400302  103.67 1. 4.826 58. 19998. 3458.75 755. 23536.
1400303 -862.87     4064.6     114.6     204.3
1406100 0
1406101 O.   103.67
1406102 1112.   103.67
1406103 1117.    77.75
1406104 1122.    69.46
1406105 1127.    45.1
1406106 1132.    35.25
1406107 1142.    20.73
1406108 1152.    8.81
1406109 1172.    O.
1406110 2106.  O.
1406111 2124.  69.46
1406112 2133.  103.67
1406113 9999.  103.67
*
*
*
* COLD LEG
*
1510000  CLDLG11  PIPE
1510001  2
1510101  0.383  2
```

```
1510301  1.968 2
1510601  0.      2
1510801  4.E-5  0.698  2
1511001  00      2
1511101  0000    1
1511300  1
*
1520000  CLDLG12  BRANCH
1520001  2 1
1520101  0.383 1.968 0. 0. 0. 0. 4.E-5  0.698  00
1521101  151010000 152000000 0.383   0. 0.     0000
1522101  152010000 153000000 0.383   0. 0.     0000
*
1530000  CLDLG13  SNGLVOL
1530101  0.383 1.968 0. 0. 0. 0. 4.E-5  0.698  00
*
*
* ECCS    CLDLG  B
*
1700000  SIPOOL  TMDPVOL
1700101  100.  10.  0.  0.  0.  0.  0.  0.  11
1700200  3
1700201  0.  1.E5  288.15
*
*
 *
 *
 *  ECCS-4PP    (50%)
 *
 *
 1710000  ECCSJUN  TMDPJUN
 1710101  170000000  152000000  0.1
 1710200  1 571 CNTRLVAR 070                    * DELIVERY CURVE OF 4 PUMPS
 1710222  107.91E5         0.00      0.  0.
 1710221  105.00E5        10.65      0.  0.
 1710220  100.00E5        17.00      0.  0.
 1710219   95.00E5        21.40      0.  0.
 1710218   90.00E5        24.80      0.  0.
 1710217   85.00E5        28.00      0.  0.
 1710216   80.00E5        30.90      0.  0.
 1710215   75.00E5        33.60      0.  0.
 1710214   70.00E5        36.25      0.  0.
 1710213   65.00E5        38.90      0.  0.
 1710212   60.00E5        41.30      0.  0.
 1710211   55.00E5        43.65      0.  0.
 1710210   50.00E5        46.00      0.  0.
 1710209   45.00E5        48.25      0.  0.
 1710208   40.00E5        50.40      0.  0.
 1710207   35.00E5        52.40      0.  0.
 1710206   30.00E5        54.40      0.  0.
 1710205   25.00E5        56.30      0.  0.
 1710204   20.00E5        58.00      0.  0.
 1710203   15.00E5        60.00      0.  0.
 1710202   13.12E5        61.00      0.  0.
 1710201   -1.           0.        0.  0.
```

```
*
*
*
*
*
1800000  CVV TMDPVOL                                   ***
1800101  10. 1.  0.  0    0.  0.   0.  0.  00
1800200  3    580
1800201  -1.     155.E5    523.
1800202  0.     155.E5    293.15
*
*
*
1810000  CVJ   TMDPJUN                          * CHARGING FLOW
1810101  180000000  152000000   1.E-1
1810200  1
1810201   0.0      3.2      0.0     0.0
1810202 170.0     4.08      0.0     0.0
1810203  171.    8.16   0.   0.
1810204  900.    8.16   0.   0.
1810205  901.   12.25   0.   0.
1810206 9999.   12.25   0.   0.
*
*
*
1820000  LDV TMDPVOL
1820101  10. 1.  0.  0    0.  0.   0.  0.  00
1820200  3
1820201  0.      1.E5     293.
*
*
*
1830000  LDJ   TMDPJUN                          * LETDOWN
1830101  132010000  182000000   1.E-1
1830200  1   580
1830201  -1.   6.8  0. 0.
1830202  0.    0. 0. 0.
*
*
*
*
**********************************************************************************
* SECOND PRIMARY LOOP                                                            *
**********************************************************************************
*
* HOT LEG
*
2110000  HTLG20   PIPE
2110001  3
2110101  0.383           3
2110301  2.476           3
2110601   0.             2
2110602  30.8            3
2110701  0.              2
2110702  0.95            3
```

```
2110801   4.E-5  0.698    3
2111001   00              3
2111101   0000            2
2111300   1
*
*
* INLET BOX
*
2210000   INBOX  BRANCH
2210001   2  1
2210101   0. 1.685 4.392 0.  90.  1.685 4.E-5 1.822      00
2212101   221010000  222000000   0.99  0.5    1.0   0000
2211101   211010000  221000000  0.435  0.4145 0.5  0000
*
*
2220000    UTUB1 PIPE
2220001   10
2220101   0.99      10
2220301   0.908   10
2220601    90.      8
2220602    45.      10
2220801 1.E-7  0.01966   10
2221001   00        10
2221101   0000      9
2221300   1
*
2230000   UJUN1 SNGLJUN
2230101   222010000 224000000 0.99 0. 0. 0000 0. 0.
*
2240000   DUTUB1 PIPE
2240001   5
2240101   0.99      5
2240301   1.816     5
2240601   -45.      1
2240602   -90.      5
2240801   1.E-7  0.01966  5
2241001   00        5
2241101   0000      4
2241300   1
*
* OUBOX   BRANCH
*
2250000   OUBOX  BRANCH
2250001   2  1
2250101   0.  1.685  4.392  0.  -90.  -1.685  4.E-5  1.822     00
2251101   224010000  225000000  0.99  1.  0.5  0000
2252101   225010000  231000000  0.487  0.040  1.000  0000
*
* STEAM GENERATOR SECONDARY SIDE
*
7110000   BYPASSB  BRANCH
7110001   2 0
7110101   8.048 2.424  0.  0.  90. 2.424   5.E-5  0.  00
7112101   727000000  711010000   0.00    10.0  100.0    00000
7111101   711000000  712000000 0.      10.  1000.   00000
```

```
*
7120000 B712 BRANCH
7120001 1  0
7120101 8.048      .735       0.  0. -90. -.735 5.E-5  0.  00
7121101 712010000 713000000  00.00  0. 200. 0000
*
7130000   FEEDMIX  SNGLVOL
7130101   0.  0.697  5.596   0.  -90.  -0.697  5.E-5  0.  00
*
7140000  FEEDDWC  SNGLJUN
7140101  713010000  715000000 8.0398  0. 1000.  0000
*
7150000  SGLDCOME1 ANNULUS
7150001  4
7150101  2.589  1
7150102  0.4845  4
7150301  1.938  1
7150302  2.55   4
7150601  -90.   4
7150801  5.E-5  0.  1
7150802  5.E-5   0.1015 4
7150901  0.  1000.  3
7151001  00     4
7151101  0000   3
7151300  0
*
7170000  SGDCPJ1 SNGLJUN
7170101  715010000 720000000   .000     3.3     1000.     0000
*
*
*
*
7200000  SGPIPE  PIPE
7200001   4
7200101  4.432  4
7200301  1.816    4
7200601  90.      4
7200801  1.E-4  0.03543   4
7201001  00   4
7201101  0000   3
7201300  0
*
*
7210000 BREAK BRANCH
7210001 2  0
7210101 4.432      2.324     0.  0.  90.0  2.324  1.E-4  0.03543  00
7211101 720010000 721000000  00.00  0.  0.  0000
7212101 721010000 722000000  00.00  0.  0.  0000
*
*
*
7220000 TOPRI1 BRANCH
7220001 0  1
7220101 4.     1.432     0.     0.    90.0    1.432    0.00005    0.    00
*
```

```
7230000 TOPRI2 SEPARATR
7230001 3  0
7230101 4.     2.424     0.    0.    90.0    2.424    0.00005    0.    00
7231101   723010000   725000000 2.75 20.4  20.4 01000  0.1
7232101   723000000   712000000 0.00 1.0 1000. 01000  0.1
7233101   722010000   723000000 0.00 1.81  1.81 01000
*
*
*
*
7300000  SGDOME1  BRANCH
7300001   1  1
7300101 12.5600  2.093  0.  0.  90.  2.093  5.E-5  0.  00
7301101  730010000  740000000 .13 .2269 .4969  0000
*
7250000  DRYER  BRANCH
7250001   1  1
7250101 4.00  1.  0.  0.  90.  1.  5.E-5  0.  00
7251101  725010000  730000000 .00 .0000 .0000  00000
*
7270000  PLENUMB  BRANCH
7270001   1  1
7270101 8.5600  1.  0.  0.  90.  1.  5.E-5  0.  00
7271101  727010000  725000000 .00 .0000 .0000  00003
*
*
7400000  SGL1  PIPE
7400001  3
7400101  0.288  3
7400301  22.7171  3
7400601  00.0  3
7400801  4.E-5  00.000  3
7401001  00  3
7401101  0000  2
7401300  1
*
*
*
7940000  ATM  TMDPVOL
7940101  10.  10.  0.  0.  0.  0.  0.  0.  00
7940200  2
7940201 0.0   1.0E5 1.
*
*
7910000  RELIEF  VALVE
7910101  740010000  794000000  2.74670E-3  1.  1.  0100  0.  0.
7910201  1  0.  0.  0.
7910300  MTRVLV
7910301  550   599  3.33E-3  0.
*
*
* AUXILIARY  FEED  WATER  (1MTPUMP)
*
7050000  POOLMT TMDPVOL
7050101  1.  1.  0.  0.  0.  0.  0.  0.  00
```

186

```
7050200  3
7050201  0.   1.E5  308.15
*
7060000  TURPOOL   TMDPVOL
7060101  1.  1.  0.  0.  0.  0.  0.  0.  00
7060200  3
7060201  0.   1.E5  308.15              *! DELIVERY CURVE OF 1
*                                    *  MOTOPUMP FEEDING 1SG
7070000  AFWMT TMDPJUN                      *
7070101  705000000  713000000  0.136
7070200  1  574  P  730010000
7070201  -1.  0.  0.  0.
7070202   1.E5      27.71      0.     0.
7070203   5.E5      27.17      0.     0.
7070204  10.E5      26.46      0.     0.
7070205  15.E5      25.74      0.     0.
7070206  20.E5      24.99      0.     0.
7070207  25.E5      24.22      0.     0.
7070208  30.E5      23.42      0.     0.
7070209  35.E5      22.58      0.     0.
7070210  40.E5      21.72      0.     0.
7070211  45.E5      20.81      0.     0.
7070212  50.E5      19.86      0.     0.
7070213  55.E5      18.85      0.     0.
7070214  60.E5      17.78      0.     0.
7070215  65.E5      16.63      0.     0.
7070216  70.E5      15.39      0.     0.
7070217  75.E5      14.02      0.     0.
7070218  80.E5      12.46      0.     0.
7070219  85.E5      10.64      0.     0.
*
*
* STEAM GENERATOR HEAT STRUCTURE
*
*
17202000 15 2 2 1 0.00983
17202100 0 1
17202101 1 0.0111
17202201 6  1
17202301 0. 1
17202501   222010000    10000   1   0   164.04455    10
17202502   224010000    10000   1   0   328.08909    15
17202601   720010000     0000   1   0   185.2385      2
17202602   720020000     0000   1   0   185.2385      4
17202603   720030000     0000   1   0   185.2385      6
17202604   720040000     0000   1   0   185.2385      8
17202605   721010000     0000   1   0   185.2385     10
17202607   721010000     0000   1   0   370.477      11
17202608   720040000   -10000   1   0   370.477      15
17202701  0  0.  0.  0.  15
17202801  0.  0.01966  0.          .908   10
17202802  0.  0.01966  0.         1.816   15
17202901  0.  0.03543  0.02223     .908   10
17202902  0.  0.03543  0.02223    1.816   15
*
```

187

```
*
* PUMP SUCTION LEG
*
2310000  PSUC2  PIPE
2310001  4
2310101  0.487    4
2310301  1.806  2
2310302  1.633  3
2310303  1.430  4
2310602  -90.     2
2310603    0.     3
2310604   90.     4
2310801  4.E-5  0.787  4
2310901  0.     0.     1
2310902  0.11   0.11   3
2311001  00       4
2311101  0000     3
2311300  1
*
* PUMP
*
2400000  PUMP2 PUMP
2400101  0. 1.232 7.757 0. 90. 1.232   00
2400108  231010000 0.487 0.4385  0.4385       0000
2400109  251000000 0.383 0.27120  0.27120       0000
2400301  -2  -1  -2  -1  -1   0   1                        *CHECK
2400302  103.67 1. 4.826 58. 19998. 3458.75 755. 23536.
2400303  -862.87   4064.6    114.6    204.3
*
*
*
*
* COLD LEG
*
2510000  CLDLG21  PIPE
2510001  2
2510101  0.383  2
2510301  1.968 2
2510601  0.      2
2510801  4.E-5  0.698  2
2511001  00      2
2511101  0000    1
2511300  1
*
2520000  CLDLG22  BRANCH
2520001  2 1
2520101  0.383 1.968 0. 0. 0. 0. 4.E-5  0.698  00
2521101  251010000 252000000 0.383   0. 0.     0000
2522101  252010000 253000000 0.383   0. 0.     0000
*
2530000  CLDLG23  SNGLVOL
2530101  0.383 1.968 0. 0. 0. 0. 4.E-5  0.698  00
*
* ECCS    COLD LEG A
*
```

```
2700000  SIPOOL  TMDPVOL
2700101  100.  10.  0.  0.  0.  0.  0.  0.  11
2700200  3
2700201  0.  1.E5  288.15
*
*
 *
 *  ECCS-4PP    (50%)
 *
 *
 2710000  ECCSJUN  TMDPJUN
 2710101  270000000  252000000  0.1
 2710200  1 571 CNTRLVAR 070                   * DELIVERY CURVE OF 4 PUMPS
 2710222  107.91E5         0.00      0.  0.
 2710221  105.00E5        10.65      0.  0.
 2710220  100.00E5        17.00      0.  0.
 2710219   95.00E5        21.40      0.  0.
 2710218   90.00E5        24.80      0.  0.
 2710217   85.00E5        28.00      0.  0.
 2710216   80.00E5        30.90      0.  0.
 2710215   75.00E5        33.60      0.  0.
 2710214   70.00E5        36.25      0.  0.
 2710213   65.00E5        38.90      0.  0.
 2710212   60.00E5        41.30      0.  0.
 2710211   55.00E5        43.65      0.  0.
 2710210   50.00E5        46.00      0.  0.
 2710209   45.00E5        48.25      0.  0.
 2710208   40.00E5        50.40      0.  0.
 2710207   35.00E5        52.40      0.  0.
 2710206   30.00E5        54.40      0.  0.
 2710205   25.00E5        56.30      0.  0.
 2710204   20.00E5        58.00      0.  0.
 2710203   15.00E5        60.00      0.  0.
 2710202   13.12E5        61.00      0.  0.
 2710201   -1.           0.        0.  0.
 *
*
*
*************************************************************************************
* PRESSURIZER                                                                       *
*************************************************************************************
3010000  SURGELN  PIPE
3010001  3
3010101  0.03875  3
3010301  6.3465       2
3010302  4.07         3
3010601   0.         2
3010602  90.         3
3010801  4.E-5 0.    3
3010901  0.294  0.294  2
3011001  00          3
3011101  0000        2
3011300  1
*
3050000  PRESLL  SNGLJUN
```

```
3050101  301010000 310000000 0. 2.  2.  0100 0. 0.
*
3100000  PRES310  BRANCH
3100001  0  1
3100101  1.6964   0.3   0.    0.    90.    0.3    0.    0.    01
3100200  2  155.E5        0.
*
3110000  PRES311  BRANCH
3110001  1  1
3110101  1.6964   0.6   0.    0.    90.    0.6    0.    0.    01
3110200  2  155.E5       0.
3111101  310010000  311000000 0. 0. 0. 0000
3111201  0. 0. 0.
*
3120000  PRES312  BRANCH
3120001  1  1
3120101  2.5164  1.766  0.  0.  90.  1.766  0.  0.  01
3120200  2  155.E5      0.
3121101  311010000  312000000  0.  0.  0.  0000
3121201  0.  0.  0.
*
3130000  PRES313  BRANCH
3130001  1  1
3130101  2.5164  1.766  0.  0.  90.  1.766  0.  0   01
3130200  2  155.E5      0.25751
3131101  312010000  313000000  0.  0.  0.  0000
3131201  0.  0.  0.
*
3140000  PRES314  BRANCH
3140001  1  1
3140101  2.5164  1.539  0.  0.  90.  1.539  0.  0.  01
3140200  2  155.E5     1.
3141101  313010000  314000000  0.  0.  0.  0000
3141201  0.  0.  0.
*
3150000  PRES315  BRANCH
3150001  1  1
3150101  2.5164  1.515  0.  0.  90.  1.515  0.  0.  01
3150200  2  155.E5     1.
3151101  314010000  315000000  0.  0.  0.  0000
3151201  0.  0.  0.
*
3160000  PRES316  BRANCH
3160001  1  1
3160101  2.5164  0.8  0.  0.  90.  0.8  0.  0.  01
3160200  2  155.E5     1.
3161101  315010000  316000000  0.  0.  0.  0000
3161201  0.  0.  0.
*
3170000  PRES317  BRANCH
3170001  2  1
3170101  2.5164  0.6  0.  0.  90.  0.6  0.  0.  01
3170200  2  155.E5      1.
3171101  316010000  317000000  0.  0.  0.  0000
3172101  317010000  320000000  0.  0.  0.  0000
```

```
3171201  O.  O.  O.
3172201  O.  O.  O.
*
3200000  PRES320  PIPE
3200001  6
3200101  2.5164 1  1.6964 6
3200301  0.4 1  0.3 2  0.2 3  0.15 4  0.1 6
3200601  90.  6
3200801  O.  O.  6
3201001  01  6
3201101  0000  5
3201201  2  155.E5     1.  O. O.     O.     6
3201300  1
3201301  O.  O.  O.  5
*
3300000  PRESDOM  BRANCH
3300001  1  1
3300101  1.6964  0.05  O.  O.  90.  0.05  O.  O.  01
3300200  2  155.E5 1.
3301101  320010000  330000000  O.  O.  O.  0000
3301201  O.  O.  O.
*
*
*
*
*
* HEATERS
*
13113000  2  3  2  1  O.
13113100  0  2
13113101  0.005  1  0.00338  2
13113201  5  2
13113301  1.  1 O.  2
13113401  618.  3
13113501  0  0  0  1  62.532  1
13113502  0  0  0  1  93.798  2
13113601  312010000  0  1  1  62.532  1
13113602  312010000  0  1  1  93.798  2
13113701  311  0.4  O.  O.  1
13113702  311  0.6  O.  O.  2
13113901    0  O.  O.  0.772  1
13113902    0  O.  O.  1.158  2
*********************************************************************
*  SPRAY SYSTEM                                                     *
*********************************************************************
*
*
*
3410000 SPRJUN  SNGLJUN
3410101 152010000 343000000  8.171E-3  O.  O.  0000
3410201 0  O.  O.  O.
*
3430000 SPRLINE  PIPE
3430001 4
3430101 8.171E-3 4
```

```
3430301 3.         3
3430302 3.956      4
3430601  90.       4
3430801  4.E-5    O.    4
3431001 00 4
3431101 0000  3
3431201 3 154.88E5  528. O. O. O. 1
3431202 3 154.64E5  528. O. O. O. 2
3431203 3 154.41E5  528. O. O. O. 3
3431204 3 154.13E5  528. O. O. O. 4
3431300 1
3431301 O. O. O. 3
*
3450000  RESPR  TMDPJUN
3450101  343010000  317010000  0.00456
3450200  O  630
3450201 -1.  0.0     O.  O.
3450202  O.  2.741   O.  O.
*
*
3420000 SPRJUN  SNGLJUN
3420101 252010000 344000000  8.171E-3  O.  O.  0000
3420201 O  O.  O.  O.
*
3440000 SPRLINE  PIPE
3440001 4
3440101 8.171E-3 4
3440301 3.         3
3440302 3.956      4
3440601  90.       4
3440801  4.E-5    O.    4
3441001 00 4
3441101 0000  3
3441201 3 154.88E5  528. O. O. O. 1
3441202 3 154.64E5  528. O. O. O. 2
3441203 3 154.41E5  528. O. O. O. 3
3441204 3 154.13E5  528. O. O. O. 4
3441300 1
3441301 O. O. O. 3
*
*
3460000  RESPR  TMDPJUN
3460101  344010000  317010000  0.00456
3460200  O  630
3460201 -1.  0.0     O.  O.
3460202  O.  2.741   O.  O.
*
****************************************************************************************
* CONTAINEMENT
****************************************************************************************
*
*
9500000  V950  SNGLVOL
9500101 10000.  10.33  O.  O. -90.0 -10.33 4.E-5  O.  00
9500200  1   318.   .01
```

```
*
9600000  V960  SNGLVOL
9600101 10000.  16.53  0.  0. -90.0 -16.53 4.E-5  0.  00
9600200  1   318.   .01
*
9700000  V970  SNGLVOL
9700101 10000.  16.53  0.  0. -90.0 -16.53 4.E-5  0.  00
9700200  1   318.   .01
*
*
****************************************************************************
* HEAT STRUCTURES                                                          *
****************************************************************************
*
* PRESSURIZER
*
* SURGE LINE
*
13000000  3  3  2  1  0.10795
13000100  0  2
13000101  0.01  1  0.01858  2
13000201  3  2
13000301  0.  2
13000501  301010000  10000  1  1  6.3465  2
13000502  301030000      0  1  1  4.07    3
13000601          0      0  0  1  6.3465  2
13000602          0      0  0  1  4.07    3
13000701  0  0.  0.  0.  3
13000801  0  0.  0.  0.  2
13000802  0  0.  0.  4.07  3
*
* BOTTOM
*
13001000  2  4  3  1  0.9
13001100  0  2
13001101  0.01  1  0.02  2  0.044  3
13001201  5  3
13001301  0.  3
13001401  617.91  4
13001501  310010000   0     1     1     0.16666  1
13001502  311010000   0     1     1     0.33333  2
13001601  950010000   0  3950     1     0.16666  1
13001602  950010000   0  3950     1     0.33333  2
13001701          0   0.    0.    0.    2
13001801          0   0.    0.    0.3   1
13001802          0   0.    0.    0.6   2
*
* CYLINDRICAL SHELL
*
13002000  7  4  2  1  0.895
13002100  0  2
13002101  0.01  1  0.02  2  0.069  3
13002201  5  3
13002301  0.  3
13002401  617.91  4
```

```
13002501  312010000  1000000         1       1       1.766      2
13002502  314010000        0         1       1       1.539      3
13002503  315010000        0         1       1       1.515      4
13002504  316010000        0         1       1       0.8        5
13002505  317010000        0         1       1       0.6        6
13002506  320010000        0         1       1       0.4        7
13002601  950010000        0      3950       1       1.766      2
13002602  950010000        0      3950       1       1.539      3
13002603  950010000        0      3950       1       1.515      4
13002604  950010000        0      3950       1       0.8        5
13002605  950010000        0      3950       1       0.6        6
13002606  950010000        0      3950       1       0.4        [illegible]
13002701  0  0.  0.  0.  7
13002801  0  0.  0.  1.766  2
13002802  0  0.  0.  1.539  3
13002803  0  0.  0.  1.515  4
13002804  0  0.  0.  0.8    5
13002805  0  0.  0.  0.6    6
13002806  0  0.  0.  0.4    7
*
* UPPER SHELL
*
13003000  6  4  3  1  0.9
13003100  0  2
13003101  0.01  1  0.02  2  0.034  3
13003201  5  3
13003301  0.  3
13003401  617.91  4
13003501  320020000  0  1  1  0.16666  1
13003502  320030000  0  1  1  0.11111  2
13003503  320040000  0  1  1  0.08333  3
13003504  320050000  0  1  1  0.05555  4
13003505  320060000  0  1  1  0.05555  5
13003506  330010000  0  1  1  0.02777  6
13003601  950010000     0   3950   1   0.16666   1
13003602  950010000     0   3950   1   0.11111   2
13003603  950010000     0   3950   1   0.08333   3
13003604  950010000     0   3950   1   0.05555   4
13003605  950010000     0   3950   1   0.05555   5
13003606  950010000     0   3950   1   0.02777   6
13003701  0  0.  0.  0.  6
13003801  0  0.  0.  0.3   1
13003802  0  0.  0.  0.2   2
13003803  0  0.  0.  0.15  3
13003804  0  0.  0.  0.1   4
13003805  0  0.  0.  0.1   5
13003806  0  0.  0.  0.05  6
*
*
*
* STEAM GENERATOR
*
*
* COOLANT CHANNEL
*
```

```
11211000  1  7  1  1  0.
12211000  1  7  1  1  0.
11211100  0  2
12211100  1211
11211101  0.01  1  0.05  2  0.083  4  0.05  5  0.01  6
11211201  5  6
11211301  0.  6
11211501  121010000  0  1  0  7.1  1
11211601  125010000  0  1  0  7.1  1
11211701  0  0.  0.  0.  1
11211801  0  0.  0.  1.503  1
11211901  0  0.  0.  1.503  1
12211501  221010000  0  1  0  7.1  1
12211601  225010000  0  1  0  7.1  1
12211701  0  0.  0.  0.  1
12211801  0  0.  0.  1.503  1
12211901  0  0.  0.  1.503  1
*
* TUBE  PLATE
*
11212000  2  2  1  1  0.
12212000  2  2  1  1  0.
12212100  1212
11212100  0  2
11212101  0.03056 1
11212201  5  1
11212301  0.  1
11212501  121010000  4000000  1  0  61.  2
11212601  620010000  0  1  0  61.  2
11212701  0  0.  0.  0.  2
11212801  0  0.01966  0.01966  .575  2
11212901  0  0.  0.  0.  2
*
12212501  221010000  4000000  1  0  61.  2
12212601  720010000        0  1  0  61.  2
12212701  0  0.  0.  0.  2
12212801  0  0.01966  0.01966  0.575  2
12212901  0  0.  0.  0.  2
*
* LOWER SHELL
*
16151000  3  4  2  1  1.5465
17151000  3  4  2  1  1.5465
16151100  0  2
17151100  6151
16151101  0.01  1  0.02  2  0.04526 3
16151201  5  3
16151301  0.  3
16151501  615040000  -10000  1  1  2.55  3
16151601  960010000     0  3960 1  2.55  3
16151701  0  0.  0.  0.  3
16151801  0  0.  0.  2.55  3
17151501  715040000  -10000  1  1  2.55  3
17151601  970010000     0 3960  1  2.55  3
17151701  0  0.  0.  0.  3
```

195

```
17151801  0  0.   0.   2.55   3
*
* TRANSITION CONE
16152000  1  4  2  1  1.7822
17152000  1  4  2  1  1.7822
16152100  0  2
17152100  6152
16152101  0.01   1  0.03  2  0.055  3
16152201  5  3
16152301  0.  3
16152501  615010000  0  1  1  1.937  1
16152601  960010000          0 3960 1  1.937  1
16152701  0  0.  0.  0.  1
16152801  0  0.  0.  1.937  1
17152501  715010000  0  1  1  1.937  1
17152601  970010000         0 3960  1  1.937  1
17152701  0  0.  0.  0.  1
17152801  0  0.  0.  1.937  1
*
* UPPER SHELL
*
* UPPER SHELL
16153000  5  4  2  1  2.2446
17153000  5  4  2  1  2.2446
16153100  0  2
17153100  6153
16153101  0.01   1  0.03  2  0.051  3
16153201  5  3
16153301  0.  3
16153501  613010000  0  1  1  0.696  1
16153502  612010000  0  1  1  0.735  2
16153503  611010000  0  1  1  2.424  3
16153504  627010000  0  1  1  1.000  4
16153505  630010000  0  1  1  2.093  5
16153601  960010000 0 3960 1  0.696  1
16153602  960010000 0 3960 1  0.735  2
16153603  960010000 0 3960 1  2.424  3
16153604  960010000 0 3960 1  1.000  4
16153605  960010000 0 3960 1  2.093  5
16153701            0  0.  0.  0.  5
16153801            0  0.  0.  0.696  1
16153802            0  0.  0.  0.735  2
16153803            0  0.  0.  2.424  3
16153804            0  0.  0.  1.000  4
16153805            0  0.  0.  2.093  5
17153501  713010000  0  1  1  0.696  1
17153502  712010000  0  1  1  0.735  2
17153503  711010000  0  1  1  2.424  3
17153504  727010000  0  1  1  1.000  4
17153505  730010000  0  1  1  2.093  5
17153601  970010000  0 3960  1  0.696  1
17153602  970010000  0 3960  1  0.735  2
17153603  970010000  0 3960  1  2.424  3
17153604  970010000  0 3960  1  1.000  4
17153605  970010000  0 3960 1  2.093  5
```

```
17153701  0  0.   0.   0.    5
17153801  0  0.   0.   0.696   1
17153802  0  0.   0.   0.735   2
17153803  0  0.   0.   2.424   3
17153804  0  0.   0.   1.000   4
17153805  0  0.   0.   2.093   5
*
* WRAPPER
16154000  8  2  2  1   1.524
17154000  8  2  2  1   1.524
16154100  0  2
17154100  6154
16154101  0.01   1
16154201  5  1
16154301  0.   1
16154501  620010000    10000  1  1  1.461  1
16154502  620020000    10000  1  1  1.816  4
16154503  621010000  0  1  1  2.324  5
16154504  622010000  0  1  1  0.696  6
16154505  622010000  0  1  1  0.735  7
16154506  623010000  0  1  1  2.424  8
16154601  615040000  -10000  1  1  1.461  1
16154602  615030000  -10000  1  1  1.816  4
16154604  615010000  0  1  1  2.324  5
16154605  613010000  0  1  1  0.696  6
16154606  612010000  0  1  1  0.735  7
16154607  611010000  0  1  1  2.424  8
16154701  0  0.   0.   0.   8
16154801  0  0.   0.   1.461   1
16154802  0  0.   0.   1.816   4
16154803  0  0.   0.   2.324   5
16154804  0  0.   0.   0.696   6
16154805  0  0.   0.   0.735   7
16154806  0  0.   0.   2.424   8
16154901  0  0.   0.   1.461   1
16154902  0  0.   0.   1.816   4
16154903  0  0.   0.   2.324   5
16154904  0  0.   0.   0.696   6
16154905  0  0.   0.   0.735   7
16154906  0  0.   0.   2.424   8
17154501  720010000    10000  1  1  1.461  1
17154502  720020000    10000  1  1  1.816  4
17154503  721010000  0  1  1  2.324  5
17154504  722010000  0  1  1  0.696  6
17154505  722010000  0  1  1  0.735  7
17154506  723010000  0  1  1  2.424  8
17154601  715040000  -10000  1  1  1.461  1
17154602  715030000  -10000  1  1  1.816  4
17154604  715010000  0  1  1  2.324  5
17154605  713010000  0  1  1  0.696  6
17154606  712010000  0  1  1  0.735  7
17154607  711010000  0  1  1  2.424  8
17154701  0  0.   0.   0.   8
17154801  0  0.   0.   1.461   1
17154802  0  0.   0.   1.816   4
```

```
17154803  0  0.   0.   2.324  5
17154804  0  0.   0.   0.696  6
17154805  0  0.   0.   0.735  7
17154806  0  0.   0.   2.424  8
17154901  0  0.   0.   1.461  1
17154902  0  0.   0.   1.816  4
17154903  0  0.   0.   2.324  5
17154904  0  0.   0.   0.696  6
17154905  0  0.   0.   0.735  7
17154906  0  0.   0.   2.424  8
*
* INTERNAL STRUCTURES
*
16203000  9  3  2  1  2.214
17203000  9  3  2  1  2.214
16203100  0  2
17203100  6203
16203101  0.015 2
16203201  5  2
16203301  0.  2
16203501  620010000       10000     1     1     1.816     4
16203503  621010000           0     1     1     2.324     5
16203504  622010000           0     1     1     1.432     6
16203506  623010000           0     1     1     2.424     7
16203507  625010000           0     1     1     1.000     8
16203508  630010000           0     1     1     2.093     9
16203601  620010000       10000     1     1     1.816     4
16203603  621010000           0     1     1     2.324     5
16203604  622010000           0     1     1     1.432     6
16203606  623010000           0     1     1     2.424     7
16203607  625010000           0     1     1     1.000     8
16203608  630010000           0     1     1     2.093     9
16203701  0      0.      0.     0.        9
16203801  0      0.      0.     1.816     4
16203802  0      0.      0.     2.324     5
16203803  0      0.      0.     1.432     6
16203804  0      0.      0.     2.424     7
16203805  0      0.      0.     1.000     8
16203806  0      0.      0.     2.093     9
16203901  0      0.      0.     1.816     4
16203902  0      0.      0.     2.324     5
16203903  0      0.      0.     1.432     6
16203904  0      0.      0.     2.424     7
16203905  0      0.      0.     1.000     8
16203906  0      0.      0.     2.093     9
17203501  720010000       10000      1     1     1.816     4
17203503  721010000           0      1     1     2.324     5
17203504  722010000           0      1     1     1.432     6
17203505  723010000           0      1     1     2.424     7
17203506  725010000           0      1     1     1.000     8
17203507  730010000           0      1     1     2.093     9
17203601  720010000       10000      1     1     1.816     4
17203603  721010000           0      1     1     2.324     5
17203604  722010000           0      1     1     1.432     6
17203605  723010000           0      1     1     2.424     7
```

```
17203606  725010000           0       1     1     1.000    8
17203607  730010000           0       1     1     2.093    9
17203701  0    0.   0.   0.       9
17203801  0    0.   0.   1.816    4
17203802  0    0.   0.   2.324    5
17203803  0    0.   0.   1.432    6
17203805  0    0.   0.   2.424    7
17203806  0    0.   0.   1.000    8
17203807  0    0.   0.   2.093    9
17203901  0    0.   0.   1.816    4
17203902  0    0.   0.   2.324    5
17203903  0    0.   0.   1.432    6
17203905  0    0.   0.   2.424    7
17203906  0    0.   0.   1.000    8
17203907  0    0.   0.   2.093    9
*
*
*
* STEAM LINES
*
16400000  3  3  2  1  0.30296
17400000  3  3  2  1  0.30227
16400100  0  2
17400100  0  2
16400101  0.01804   1  0.02  2
17400101  0.02      1  0.02346  2
16400201  3  2
17400201  3  2
16400301  0.  2
17400301  0.  2
16400501  640010000  10000  1  1  22.717  3
17400501  740010000  10000  1  1  16.242  3
16400601          0      0  0  1  22.717  3
17400601          0      0  0  1  16.242  3
16400701  0  0   0.  0.  3
17400701  0  0.  0.  0.  3
16400801  0  0.  0.  0.  3
17400801  0  0   0.  0.  3
*
* VESSEL
*
* CUVER
*
10451000  1  6  3  1  1.705
10451100  0  2
10451101  0.005  1  0.005 2  0.01  3  0.100  4   0.216   5
10451201  3  1
10451202  5  5
10451301  0
10451501  045010000 0  1  1  0.5  1
10451601        0  0  0  1  0.5  1
10451701  0  0.  0   0.  1
10451801  0  0.  0.  1.496  1
*
*WALL  045-043
```

```
*
10452000  1  5  1  0  0.
10452100  0  2
10452101  0.01  1  0.04  3  0.01  4
10452201  3  4
10452301  0.  4
10452501  045010000 0  1  0  20.51  1
10452601  043010000  0  1  0  20.51  1
10452701  0  0.  0.  0.  1
10452801  0  0.  0.  0.  1
10452901  0  0.  0.  0.  1
*
* BOTTOM
*
10210000  2  5  3  1  1.695
10210100  0  2
10210101  0.005  1  0.025  2  0.03  3  0.055  4
10210201  3  1
10210202  5  4
10210301  0.  4
10210501  021010000  2000000  1  1  0.25  2
10210601          0          0  0  1  0.25  2
10210701  0  0.  0.  0.  2
10210801  0  0.  0.  0.638  2
*
* DOWNCOMER WALL
*
10150000  3  20  2  1  1.6635
10150100  0  2
10150101  1.25E-3 5 2.00E-3 6 3.00E-3 7 4.00E-3 8 5.0E-3 9 6.00E-3 10
10150102  8.00E-3 11 10.E-3 12 12.E-3 13 15.E-3 14 20.E-3 16
10150103  23.916E-3  19
10150201  3  4
10150202  5  19
10150301 0.   19
10150501  015010000  10000  1  1  1.361  2
10150502  015030000  1000   1  1  1.362  3
10150601          0        0  0  1  1.361  2
10150602          0        0  0  1  1.362  3
10150701  0  0.  0.  0.  3
10150801  0  0.  0.  1.361  2
10150802  0  0.  0.  1.362  3
*
* UPPER PLENUM
*
10110000  2  7  2  1  1.6635
10110100  0  2
10110101  0.005 2  0.03  3  0.06  4  0.10  5  0.137  6
10110201  3  1
10110202  5  6
10110301  0.  6
10110501  011010000  0  1  1  1.584  1
10110502  013010000  0  1  1  0.872  2
10110601          0  0  0  1  1.584  1
10110602          0  0  0  1  0.872  2
```

200

```
10110701  0  0.  0.  0.  2
10110801  0  0.  0.  1.584  1
10110802  0  0.  0.  0.872  2
*
* THERMAL  SHIELD
*
10151000  3  3  2  1  1.4635
10151100  0  2
10151101  0.04525  2
10151201  3  2
10151301  0.  2
10151501  015010000  10000  1  1  1.136  3
10151601  015010000  10000  1  1  1.136  3
10151701  0  0.  0.  0.  3
10151801  0  0.  0.  1.136  3
10151901  0  0.  0.  1.136  3
*
* INTERNAL STRUCTURES
*
10300000  10  3  2  1  6.255
10300100  0  2
10300101  0.01  2
10300201  3  2
10300301  0.  2
10300501  021010000  2000000  1  1  0.638   2
10300502  025010000        0  1  1  1.013   3
10300503  031010000    10000  1  1  0.6095  7
10300504  039010000        0  1  1  0.6095  8
10300505  041010000        0  1  1  0.8965  9
10300506  043010000        0  1  1  1.584  10
10300601  021010000  2000000  1  1  0.638   2
10300602  025010000        0  1  1  1.013   3
10300603  031010000    10000  1  1  0.6095  7
10300604  039010000        0  1  1  0.6095  8
10300605  041010000        0  1  1  0.8965  9
10300606  043010000        0  1  1  1.584  10
10300701  0  0.  0.  0.  10
10300801  0  0.  0.  0.638  2
10300802  0  0.  0.  1.013  3
10300803  0  0.  0.  0.6095  8
10300804  0  0.  0.  1.  9
10300805  0  0.  0.  1.584  10
10300901  0  0.  0.  0.638  2
10300902  0  0.  0.  1.013  3
10300903  0  0.  0.  0.6095  8
10300904  0  0.  0.  0.8965  9
10300905  0  0.  0.  1.584  10
*
* PRIMARY LEGS
*
* HOT-COLD  LEGS
11110000  3  3  2  1  0.34925
11510000  4  3  2  1  0.34925
12110000  3  3  2  1  0.34925
12510000  4  3  2  1  0.34925
```

```
11110100  0  2
11510100  1110
12110100  1110
12510100  1110
11110101  0.031375  2
11110201  3  2
11110301  0.  2
11110501  111010000  1000000     1    1    2.476    2
11110502  113010000        0     1    1    2.476    3
12110503  211010000    10000     1    1    2.476    3
11510504  151010000    10000     1    1    1.968    2
11510505  152010000  1000000     1    1    1.968    4
12510506  251010000    10000     1    1    1.968    2
12510507  252010000  1000000     1    1    1.968    4
11110601          0        0     0    1    2.476    3
11510602          0        0     0    1    1.968    4
11110701  0  0.  0.  0.  3
11510701  0  0.  0.  0.  4
11110801  0  0.  0.  0.6985  3
11510801  0  0.  0.  0.6985  4
12110601  0  0  0  1  2.476  3
12510601  0  0  0  1  1.968  4
12110701  0  0.  0.  0.  3
12510701  0  0.  0.  0.  4
12110801  0  0.  0.  0.6985  3
12510801  0  0.  0.  0.6985  4
*
* PUMP  SUCTION  LEG
*
11310000  4  3  2  1  0.3937
11310100  0  2
12310000  4  3  2  1  0.3937
12310100  1310
11310101  0.035125  2
11310201  3  2
11310301  0.  2
11310501  131010000  10000  1  1  1.806  1
11310502  132010000  10000  1  1  1.806  2
12310502  231010000  10000  1  1  1.806  2
11310503  133010000  0  1  1  1.633  3
11310504  133020000  0  1  1  1.43  4
11310601  0  0  0  1  1.806  2
11310602  0  0  0  1  1.633  3
11310603  0  0  0  1  1.43  4
11310701  0  0.  0.  0.  4
11310801  0  0.  0.  1.806  2
11310802  0  0.  0.  0.7874  3
11310803  0.  0.  0.  1.43  4
12310503  231030000  0  1  1  1.633  3
12310504  231040000  0  1  1  1.430  4
12310601  0  0  0  1  1.806  2
12310602  0  0  0  1  1.633  3
12310603  0  0  0  1  1.430  4
12310701  0  0.  0.  0.  4
12310801  0  0.  0.  1.806  2
```

```
12310802  0  0.   0.   0.7874  3
12310803  0  0.   0.   1.43  4
*
* PUMP
*
11400000  1  5  3  1  1.228
11400100  0  2
12400000  1  5  3  1  1.228
12400100  1400
11400101  0.01  1  0.03  2  0.08  3  0.162  4
11400201  5  4
11400301  0.  4
11400501  140010000  0  1  1  1.  1
11400601          0          0  0  1  1.  1
11400701  0  0.  0.  0.  1
11400801  0  0.  0.  1.232  1
12400501  240010000  0  1  1  1.  1
12400601  0  0  0  1  1.  1
12400701  0  0.  0.  0.  1
12400801  0  0.  0.  1.232  1
*
******************************************************************************
* INITIAL CONDITIONS                                                         *
******************************************************************************
*
* MASS FLOW RATE
*
0111201      16.900     0.      0.
0112201      16.900     0.      0.
0131201   7239.1        0.      0.
0132201   3628.         0.      0.
0133201   3628.         0.      0.
0151301   7239.1        0.      0.      2
0231201   7239.1        0.      0.
0232201   7239.1        0.      0.
0233201      0.         0.      0.
0251201   6911.8        0.      0.
0252201    327.33       0.      0.
0311301   6912.         0.      0.      3
0391201   6912.         0.      0.
0392201    327.35       0.      0.
0393201   7239.1        0.      0.
0431201   7239.1        0.      0.
0432201   3628.         0.      0.
0433201   3628.         0.      0.
0451201    -16.894      0.      0.
1121201   3628.         0.      0.
1122201   3628.         0.      0.
1123201      0.         0.      0.
1211201   3628.         0.      0.
1212201   3628.         0.      0.
1221301   3628.         0.      0.      9
1231201   3628.         0.      0.
1232201   3628.         0.      0.
1241301   3628.         0.      0.      4
```

```
1251201   3628.        0.      0.
1252201   3628.        0.      0.
1311201   3628.        0.      0.
1321201   3628.        0.      0.
1331301   3628.        0.      0.     1
1400201  1  3628.      0.      0.
1400202  1  3628.      0.      0.
1511301   3628.        0.      0.     1
1521201   3628.        0.      0.
1522201   3628.        0.      0.
2111301   3628.        0.      0.     2
2211201   3628.        0.      0.
2212201   3628.        0.      0.
2221301   3628.        0.      0.     9
2230201  1  3628.      0.      0.
2241301   3628.        0.      0.     4
2251201   3628.        0.      0.
2252201   3628.        0.      0.
2311301   3628.        0.      0.     3
2400201  1  3628.      0.      0.
2400202  1  3628.      0.      0.
2511301  3628.         0.      0.     1
2521201  3628.         0.      0.
2522201  3628.         0.      0.
3011301  0.            0.      0.     2
3050201  1             0.      0.     0.
 *
 *
 6111201  0.  0. 0.
 6112201  0.  0.  0.
 6121201 0.      0.        0.
 6301201 0.00    0.   0.
 6140201 0    .0           .0      .0
 6151301     0.           0.       .0       1
 6151302     0.           0.       .0       2
 6151303     0.           0.       .0       3
 6170201 0   0.           0.       .0
 6201301     .0           0.      0.        3
 6211201   0.    0.   0.
 6231201 0. 0. 0.
 6232201 0. 0. 0.
 6233201 0. 0. 0.
 6212201   0.    0.   0.
 6401301 0.   0.  0.  2
 7111201  0.  0.  0.
 7112201  0.  0. 0.
 7121201 0.      0.        0.
 7301201 0.00    0.   0.
 7140201 0    .0          .0  .0
 7151301     0.           0.  .0  1
 7151302     0.           0. .0   2
 7151303     0.           0. .0   3
 7170201 0   0.           0. .0
 7201301     .0           0.       0. 1
 7201302     .0           0.       0. 2
```

```
7201303     .0          0.       0. 3
7211201     .0          0.       0.
7212201     .0          0.       0.
7231201    0.           0.       0.
7232201    0.           0.       0.
7233201    0.           0.       0.
7401301 0. 0.     0.  2
3011301  0.  0.  0.  2
3050201  1  0.  0.  0.
*
* HEAT STRUCTURES TEMPERATURES
*
10110401  528.     7
10150401  528.    20
10151401  528.     3
10210401  528.     5
10300400  0
10300401  528.     3
10451401  528.     6
10452401  528.     5
11110401  528.     3
11510401  528.     3
11211401  528.     7
11212401  528.     2
12212401  528.     2
11310401  528.     3
11400401  528.     5
13000401  528.     3
16151401  528.     4
16152401  528.     4
16153401  528.     4
16154401  528.     2
16203401  528.     3
16202401  528.     2
16400401  528.     3
17400401  528.     3
17202401  528.     2
12110401  528.     3
12510401  528.     3
12211401  528.     7
12310401  528.     3
12400401  528.     5
17151401  528.     4
17152401  528.     4
17153401  528.     4
17154401  528.     2
17203401  528.     3
*
*   PRESSURE,INTERNAL ENERGY,QUALITY
0110200  3  155.E5      528.
0130200  3  155.E5      528.
0151201  3  155.E5      528.      0.      0.  0.   3
0210200  3  155.E5      528.
0230200  3  155.E5      528.
0250200  3  155.E5      528.
```

```
0311201  3  155.E5        528.     0.      0.      0. 4
0350200  3  155.E5        528.
0390200  3  155.E5        528.
0410200  3  155.E5        528.
0430200  3  155.E5        528.
0450200  3  155.E5        528.
1110200  3  155.E5        528.
1120200  3  155.E5        528.
1131202  3  155.E5        528.     0.      0.      0.  2
1210200  3  155.E5        528.
1221201  3  155.E5        528.     0.      0.      0. 8
1230200  3  155.E5  528.
1241201  3  155.E5        528.     0.      0.      0.  5
1250200  3  155.E5        528.
1311201  3  155.E5        528.     0.      0.      0. 4
1400200  3  155.E5        528.
1511201  3  155.E5        528.     0.      0.      0.   2
1520200  3  155.E5        528.
1530200  3  155.E5        528.
2111201  3  155.E5        528.     0.      0.      0.  4
2210200  3  155.E5        528.
2221201  3  155.E5        528.     0.      0.      0. 10
2241201  3  155.E5        528.     0.      0.      0.  5
2250200  3  155.E5        528.
2311201  3  155.E5        528.     0.      0.      0.  4
2400200  3  155.E5        528.
2511201  3  155.E5        528.     0.      0.      0.    2
2520200  3  155.E5        528.
2530200  3  155.E5        528.
3011201  2  155.E5        0.       0.      0.      0.  3
6110200  1  528.        0.2277
6120200  1  528.        0.
6130200  1  528.        0.
6151201  1  528.        0.         0.      0.       0. 4
6201201  1  528.        0.         0.      0.      0. 4
6210200  1  528.        0.
6220200  1  528.        0.
6300200  1  528.        1.
6230200  1  528.      .2277
6401201  1  528.      1.         0.      0.      0. 3
7110200  1  528.        0.2277
7120200  1  528.        0.
7130200  1  528.        0.
7151201  1  528.        0.         0.      0.      0. 4
7201201  1  528.        0.         0.      0.      0. 4
7210200  1  528.        0.
7220200  1  528.  0.
7230200  1  528.  0.2277
7300200  1  528.        1.0000
7401201  1  528.        1.         0.      0.      0. 3
*
*
*
****************************************************************************
*     THERMAL PROPERTIES                                                   *
```

```
*                                                                           *
*     N 1   U02                                                             *
*       2   ZR                                                              *
*       3   S-STEEL                                                         *
*       4   GAP                                                             *
*       5   C-STEEL                                                         *
*       6   INCONEL-600                                                     *
*****************************************************************************
*
20100100   TBL/FCTN  1   1   * U02
20100101   293.   8.37
20100102   366.   6.577
20100103   533.   5.78
20100104   616.   4.623
20100105   700.   4.633
20100106   783.   4.221
20100107   866.   3.88
20100108   950.   3.596
20100109  1033.   3.357
20100110  1200.   2.984
20100111  1977.   2.29
20100112  3088.   2.99
*
20100151   273.   2.31E6
20100152   323.   2.57E6
20100153   373.   2.75E6
20100154   473.   2.92E6
20100155   673.   3.13E6
20100156  1373.   3.44E6
20100157  4700.   6.80E6
*
*
20100200  TBL/FCTN  1  1  * ZR
20100201   273.15      7.
20100202   473.15      1.200438E1
20100203   673.15      1.400510E1
20100204   873.15      1.700793E1
20100205  1073.15      1.900866E1
20100206  1273.15      2.200975E1
20100207  1473.15      2.501085E1
20100208  1673.15      3.001267E1
20100209  1873.15      3.601486E1
20100210  2073.15      4.401777E1
20100211  2273.15      5.502352E1
20100212  2473.15      6.802826E1
*
20100251   255.3722   1.904141E6
20100252  1077.594    2.312171E6
20100253  1185.928    5.712422E6
20100254  1248.428    2.311769E6
20100255  2199.817    2.312171E6
*
20100300  TBL/FCTN  1  1  *S-STEEL
20100301   273.       13.
20100302  1190.       25.
```

```
*
20100351   225.        3.5E6
20100352   580.        4.34E6
20100353  1300.        5.29E6
*
*
20100400  TBL/FCTN  1  1  *GAP
20100401     0.56         *REF.:STABILIZATION VESSEL.
20100451     5.4          *RHO-CD   EGG-LOFT-5480
*
*
20100500 TBL/FCTN 1 1 *C-STEEL
20100501 46.05
20100551 3.8775E6
*
*
20100600 TBL/FCTN 1 1 *INCONNEL-600
20100601 294.15   14.86
20100602 366.15   15.76
20100603 477.15   17.45
20100604 589.15   19.18
20100605 700.15   20.91
*
20100651 294.15    3.88E6
20100652 366.15    3.88E6
20100653 477.15    4.227E6
20100654 589.15    4.227E6
20100655 700.15    4.580E6
*
*
*****************************************************************************
*CONTROL SYSTEM
*****************************************************************************
*
*                                                      **************************
*                                                      * SATURATION TEMPERATURE *
*                                                      **************************
*
9990000   TV999 TMDPVOL
9990101   10.  1.  0.  0   0.  0.  0.  0.  00
9990200   2  0  P 113010000
9990201 -1.  155.E5  0.
9990202   1.E5   1.E5  0.
9990203   200.E5  200.E5  0.
*
20500100 BREAK INTEGRAL 1. 0. 0
20500101 MFLOWJ 618000000
*                                                             ****************
20500200 MASSBIL  SUM 1.  0. 0                                * MASS BALANCE *
20500201 0.   -1.  CNTRLVAR 001  *BREAK                       ****************
20500202       1.  CNTRLVAR 079  *SI
20500203       1.  CNTRLVAR 180  *CV
20500206      -1.  CNTRLVAR 004  *LETDOWN
*
20500400 LETDO INTEGRAL 1. 0. 0
```

208

```
20500401 CNTRLVAR 188                                                          **********
*                                                                              * ENERGY *
20500500 LETENERG  MULT 1. O. 1                                                **********
20500501 CNTRLVAR 188   CNTRLVAR 093
*
*
20500600 CVENERGY  MULT 1. O. 1
20500601 MFLOWJ 181000000  CNTRLVAR 083
*
20500700 BREAKENER  MULT 1. O. 1
20500701  CNTRLVAR 012      CNTRLVAR 081
*
*                                                                       *****************
20500900 ENERGY SUM 1. O. 1                                             * ENERGY BALANCE*
20500901 O.      1.  CNTRLVAR 031      * CORE POWER                     *****************
20500902        -1.  CNTRLVAR 610      * SGB TRANSFER
20500903        -1.  CNTRLVAR 710      * SGA TRANSFER
20500904    73190.  CNTRLVAR 078       * SI
20500905         1.  CNTRLVAR 006      * CV
20500906       -1.  CNTRLVAR 007       * BREAK
20500907         1.  CNTRLVAR 993      * METAL
20500909        -1.  CNTRLVAR 005      * LETD
20500911         1.  CNTRLVAR 140      * PUMP B
20500912         1.  CNTRLVAR 240      * PUMP A
*                                                                       *****************
20501000 SUMW   SUM  1. O. 1                                            * ADDITION RATE *
20501001  O.    1. CNTRLVAR 078        *  SI                            *****************
20501002        1. MFLOWJ 181000000    *  CV
20501003       -1. MFLOWJ 618000000    *  BREAK
20501006       -1. CNTRLVAR 188        *  LETDOWN
*
20501200 BRKDIFF DIFFREND  1.   O.O  O
20501201  CNTRLVAR 001
*
*
20501300 CVLET SUM 1.0 O. O
20501301 O.  1. CNTRLVAR 006
20501302    -1. CNTRLVAR 005
*
*
*                                                                       ****************
20503100  COREPOW  SUM  1.        6.E6  O                               ** CORE  POWER *
20503101  O.   1.  Q  031010000                                         ****************
20503102       1.  Q  031020000
20503103       1.  Q  031030000
20503104       1   Q  031040000
*
*
*
20503300  LEVELCORE  SUM  1.   O.    1                          *****************************
20503301  O    0.638   VOIDF 021010000                          *** CORE  COLLAPSED LEVEL **
20503302       0.638   VOIDF 023010000                          *****************************
20503303       1.013   VOIDF 025010000
20503304       0.6095  VOIDF 031010000
20503305       0.6095  VOIDF 031020000
```

209

```
20503306        0.6095 VOIDF 031030000
20503307        0.6095 VOIDF 031040000
20503308        0.6095 VOIDF 039010000
20503309        0.8965 VOIDF 041010000
*
20503400  HEADLEV  SUM   1.   0.   1        ********************************
20503401 O.    1.584  VOIDF 043010000       ** UPPER HEAD COLLAPSED LEVEL *
20503402       1.496  VOIDF 045010000       ********************************
*
*
20503500  DOWNLEV  SUM   1.   O.   1      **********************************
20503501 O.    0.638  VOIDF 021010000     **  DOWNCOMER COLLAPSED LEVEL   **
20503502       0.638  VOIDF 023010000     **********************************
20503503       1.362  VOIDF 015030000
20503504       1.361  VOIDF 015020000
20503505       1.361  VOIDF 015010000
20503506       0.872  VOIDF 013010000
*
*
*                                                 ***************************
20504000 VESSMASS  SUM   1.  O. 1                 ** VESSEL MASS INVENTORY *
20504001   O.    3.4357    RHO  011010000         ***************************
20504002         1.8202    RHO  013010000
20504003         1.9190    RHO  015010000
20504004         1.9190    RHO  015020000
20504005         1.9190    RHO  015030000
20504006         2.6790    RHO  021010000
20504007         5.3590    RHO  023010000
20504008         3.5740    RHO  025010000
20504009         1.5238    RHO  031010000
20504010         1.5238    RHO  031020000
20504011         1.5238    RHO  031030000
20504012         1.5238    RHO  031040000
20504013         1.9706    RHO  035010000
20504014         2.3252    RHO  039010000
20504015         5.1030    RHO  041010000
20504016         9.3490    RHO  043010000
20504017         8.8330    RHO  045010000
*
*
*                                                 ***************************
20504100  LOOPB   SUM   1. O. 1                   ** LOOP B MASS INVENTORY *
20504101   O.     .9483    RHO  111010000         ***************************
20504102          .9483    RHO  112010000
20504103          .9483    RHO  113010000
20504104          .87952   RHO  131010000
20504105          .87952   RHO  132010000
20504106          .79527   RHO  133010000
20504107          .69641   RHO  133020000
20504108          .75374   RHO  151010000
20504109          .75374   RHO  152010000
20504110          .75374   RHO  153010000
20504113          .75374   RHO  151020000
20504111         7.7570    RHO  140010000
*
```

```
*
*                                                   ***************************
20504200  LOOPA   SUM   1. O. 1                     ** LOOP A MASS INVENTORY *
20504201   O.    .9483   RHO  211010000             ***************************
20504202         .9483   RHO  211020000
20504203         .9483   RHO  211030000
20504204         .87952  RHO  231010000
20504205         .87952  RHO  231020000
20504206         .79527  RHO  231030000
20504207         .69641  RHO  231040000
20504208         .75374  RHO  251010000
20504213         .75374  RHO  251020000
20504209         .75374  RHO  252010000
20504210         .75374  RHO  253010000
20504211         7.7570  RHO  240010000
*
*                                                   ******************************
20504300  SGB   SUM 1.  O. 1                        ** UTUBE SGA MASS INVENTORY *
20504301  O.    .89892  RHO  122010000              ******************************
20504302        .89892  RHO  122020000
20504303        .89892  RHO  122030000
20504304        .89892  RHO  122040000
20504305        .89892  RHO  122050000
20504306        .89892  RHO  122060000
20504307        .89892  RHO  122070000
20504308        .89892  RHO  122080000
20504310        1.7978  RHO  123010000
20504311        1.7978  RHO  124010000
20504312        1.7978  RHO  124020000
20504313        1.7978  RHO  124030000
20504314        1.7978  RHO  124040000
20504315        1.7978  RHO  124050000
20504316        4.3920  RHO  121010000
20504317        4.3920  RHO  125010000
*                                                   ******************************
20504400  SGA   SUM 1.  O. 1                        ** UTUBE SGA MASS INVENTORY *
20504401  O.    .89892  RHO  222010000              ******************************
20504402        .89892  RHO  222020000
20504403        .89892  RHO  222030000
20504404        .89892  RHO  222040000
20504405        .89892  RHO  222050000
20504406        .89892  RHO  222060000
20504407        .89892  RHO  222070000
20504408        .89892  RHO  222080000
20504409        .89892  RHO  222090000
20504410        .89892  RHO  222100000
20504411        1.7978  RHO  224010000
20504412        1.7978  RHO  224020000
20504413        1.7978  RHO  224030000
20504414        1.7978  RHO  224040000
20504415        1.7978  RHO  224050000
20504416        4.3920  RHO  221010000
20504417        4.3920  RHO  225010000
*
*                                                   **************************
```

```
20504500  PRES   SUM   1.   O.  1                                ** PRESU MASS INVENTORY *
20504501  O.     .24593     RHO 301010000                        **************************
20504502         .24593     RHO 301020000
20504503         .15771     RHO 301030000
20504504         .50892     RHO 310010000
20504505        1.0178      RHO 311010000
20504506        4.4440      RHO 312010000
20504507        4.4440      RHO 313010000
20504508        3.8727      RHO 314010000
20504509        3.8123      RHO 315010000
20504510        2.0131      RHO 316010000
20504511        1.5098      RHO 317010000
20504512        1.0066      RHO 320010000
20504513         .50892     RHO 320020000
20504514         .33928     RHO 320030000
20504515         .25446     RHO 320040000
20504516         .16964     RHO 320050000
20504517         .16964     RHO 320060000
20504518        8.482E-2    RHO 330010000
*
*                                                                          ****************
20505000  PRIMASS   SUM   8.5982E-6   O.    1                              * PRIMARY MASS *
20505001  O.          1.    CNTRLVAR  045                                  ****************
20505002              1.    CNTRLVAR  044
20505003              1.    CNTRLVAR  043
20505004              1.    CNTRLVAR  042
20505005              1.    CNTRLVAR  041
20505006              1.    CNTRLVAR  040
*
*
*                                                                            **************
20507000  PO11   SUM   1.   107.910E5   O                                    ** SI SYSTEM *
20507001  O.   O.1   P   043010000                                           **************
20507002       O.9   CNTRLVAR  070
*
20507100 SISUM   SUM   1. O. O
20507101  O.   1. MFLOWJ 171000000
20507102       1. MFLOWJ 271000000
*
20507800 SISUM   SUM   1. O. 1
20507802  O.   1. CNTRLVAR 071
*
20507900 SIBILAN   INTEGRAL 1. O. O
20507901  CNTRLVAR 078
*
20508000  P/RHO122   DIV    1.   O.   1
20508001    RHOF   122080000     P 122080000
*
20508100  ENTHA122    SUM   1.   O.   1
20508101  O.   1.    UF 122080000
20508102       1.    CNTRLVAR 080
*
20508200  P/RHO180   DIV    1.   O.   1
20508201    RHOF   180010000     P 180010000
*
```

```
20508300  ENTHA180   SUM  1   O.   1
20508301  O.   1.   UF 180010000
20508302       1.   CNTRLVAR 082
*
*20508400  P/RHOG     DIV   1.   O.   1
*20508401   RHOG  ???010000     P ???010000
*
*20508500  P/RHOF     DIV   1.   O.   1
*20508501   RHOF  ???010000     P ???010000
*
*20508600  ENTHAF??   SUM  1.  O.   1
*20508601  O.   1.   UF ???010000
*20508602       1.   CNTRLVAR 085
*
*
*20508700  ENTHAG??   SUM  1.  O.   1
*20508701  O.   1.   UG ???010000
*20508702       1.   CNTRLVAR 084
*
*20508800 XENTHAG??   MULT 1.  O.   1
*20508801  CNTRLVAR 087      QUALE  ???010000
*
*20508900 XENTHAL??   MULT 1.  O.   1
*20508901  CNTRLVAR 086      QUALE  ???010000
*
*20509000  ENTHA???   SUM  1.  O.   1
*20509001  O.   1.   CNTRLVAR 086
*20509002       1.   CNTRLVAR 088
*20509003      -1.   CNTRLVAR 089
*
20509200  P/RHO131  DIV   1   C.   1
20509201   RHOF  131010000    P 131010000
*
20509300  ENTHA131   SUM  1.  O.   1
20509301  O.  1.   UF 131010000
20509302       1.   CNTRLVAR 092
*
*
*                                                   ************************
20511300 TAVG  SUM 0.25 575.33 1                    **AVERAGED TEMPERATURE*
20511301 O.  1. TEMPF 113010000                     ************************
20511302     1. TEMPF 151010000
20511303     1. TEMPF 251020000
20511304     1. TEMPF 211030000
*
20511400 SUBCOOLING  SUM   1.   O.   1
20511401    O.      1.    TEMPF 999010000
20511402           -1.    TEMPF 113010000
*
*                                                      ********************
*                                                      * SGB U TUBE LEVEL *
*                                                      ********************
20512200   LEVCSGB   SUM   O.908   O.   1
20512201   O.     1.          VOIDF  122010000
20512202          1.          VOIDF  122020000
```

213

```
20512203          1.          VOIDF   122030000
20512204          1.          VOIDF   122040000
20512205          1.          VOIDF   122050000
20512206          1.          VOIDF   122060000
20512207          1.          VOIDF   122070000
20512208          1.          VOIDF   122080000
20512209          1.414       VOIDF   123010000
*
20512400   LEVHSGB   SUM    1.816      O.    1
20512401   O.     0.707       VOIDF   124010000
20512402          1.          VOIDF   124020000
20512403          1.          VOIDF   124030000
20512404          1.          VOIDF   124040000
20512405          1.          VOIDF   124050000
*
*
*                                                   **********************************
*                                                   ** LOOP SEAL B COLLAPSED LEVEL *
*                                                   **********************************
20513100   SEALB      SUM    1.         O.    1
20513101   O.     1.806       VOIDF   131010000
20513102          1.806       VOIDF   132010000
*
20513200   SEALB      SUM    1.         O.    1
20513201   O.     1.43        VOIDF   133020000
*
*
*
20514000 PUMPB TRIPUNIT 2.44E6 2.44E6 O
20514001 602
*
*
*
*                                                              ********************
20518000 INTCV INTEGRAL 1. O. O                                ** CHARGING SYSTEM *
20518001 MFLOWJ 181000000                                      ********************
*
20518800 LETDOWN  SUM  1. O. O
20518801 O.  1.  MFLOWJ 183000000
*
*
*                                                              ********************
*                                                              * SGA U TUBE LEVEL *
*                                                              ********************
20522200   LEVCSGA   SUM    0.908      O.    1
20522201   O.     1.          VOIDF   222010000
20522202          1.          VOIDF   222020000
20522203          1.          VOIDF   222030000
20522204          1.          VOIDF   222040000
20522205          1.          VOIDF   222050000
20522206          1.          VOIDF   222060000
20522207          1.          VOIDF   222070000
20522208          1.          VOIDF   222080000
20522209          0.707       VOIDF   222090000
20522210          0.707       VOIDF   222100000
```

```
*
20522400   LEVHSGA   SUM    1.816    O.    1
20522401   O.     0.707        VOIDF  224010000
20522402           1.          VOIDF  224020000
20522403           1.          VOIDF  224030000
20522404           1.          VOIDF  224040000
20522405           1.          VOIDF  224050000
*
*
*
*                                                ********************************
*                                                ** LOOP SEAL A COLLAPSED LEVEL **
*                                                ********************************
20523100   SEALA     SUM    1.       O.    1
20523101   O.     1.806        VOIDF  231010000
20523102          1.806        VOIDF  231020000
*
20523200   SEALA     SUM    1.       O.    1
20523201   O.     1.43         VOIDF  231040000
*
*
*
20524000 PUMPA TRIPUNIT 2.44E6 2.44E6 0
20524001 598
*
*
*
20542000    FRBL    SUM   9.81  O.   1                  **************************
20542001    O.    0.908   RHO 122010000                 ** DRIVING  FORCE IN LOOP B
20542002          0.908   RHO 122020000                 **************************
20542003          0.908   RHO 122030000
20542004          0.908   RHO 122040000
20542005          0.908   RHO 122050000
20542006          0.908   RHO 122060000
20542007          0.908   RHO 122070000
20542008          0.908   RHO 122080000
20542009          1.284   RHO 123010000
20542011          1.685   RHO 121010000
20542012          0.950   RHO 113010000
20542013          1.430   RHO 133020000
20542014          1.232   RHO 140010000
*
20542100    FMBL    SUM   9.81  O.   1
20542101    O.    1.284   RHO 124010000
20542102          1.816   RHO 124020000
20542103          1.816   RHO 124030000
20542104          1.816   RHO 124040000
20542105          1.816   RHO 124050000
20542106          1.685   RHO 125010000
20542107          1.806   RHO 131010000
20542108          1.806   RHO 132010000
*
20542200  FMFRBL    SUM  1.0   O.   1
20542201    O.    1.    CNTRLVAR 421
20542202         -1.    CNTRLVAR 420
```

```
*
20542300  FMFRTOBL  SUM  1.0  O.  1
20542301   O.   1.   CNTRLVAR 422
20542302        1.   CNTRLVAR 400
*
*
20541000   FRAL    SUM  9.81  O.  1          ****************************
20541001   O.   0.908   RHO 222010000        ** DRIVING FORCE IN LOOP A *
20541002        0.908   RHO 222020000        ****************************
20541003        0.908   RHO 222030000
20541004        0.908   RHO 222040000
20541005        0.908   RHO 222050000
20541006        0.908   RHO 222060000
20541007        0.908   RHO 222070000
20541008        0.908   RHO 222080000
20541009        0.642   RHO 222090000
20541010        0.642   RHO 222100000
20541011        1.685   RHO 221010000
20541012        0.950   RHO 211030000
20541013        1.430   RHO 231040000
20541014        1.232   RHO 240010000
*
20541100   FMAL    SUM  9.81  O.  1
20541101   O.   1.284   RHO 224010000
20541102        1.816   RHO 224020000
20541103        1.816   RHO 224030000
20541104        1.816   RHO 224040000
20541105        1.816   RHO 224050000
20541106        1.685   RHO 225010000
20541107        1.806   RHO 231010000
20541108        1.806   RHO 231020000
*
20541200  FMFRAL    SUM  1.0  O.  1
20541201   O.   1.   CNTRLVAR 411
20541202       -1.   CNTRLVAR 410
*
*
20541300  FMFRTOAL  SUM  1.0  O.  1
20541301   O.   1.   CNTRLVAR 412
20541302        1.   CNTRLVAR 400
*
20540000  FMFRCORE  SUM  9.81  O.  1         ****************************
20540001   O.   0.872   RHO 013010000        ** DRIVING FORCE IN VESSEL *
*                                            ****************************
20540003        1.361   RHO 015010000
20540004        1.361   RHO 015020000
20540005        1.362   RHO 015030000
20540006       -1.013   RHO 025010000
20540007       -0.6095  RHO 031010000
20540008       -0.6095  RHO 031020000
20540009       -0.6095  RHO 031030000
20540010       -0.6095  RHO 031040000
20540011       -0.6095  RHO 039010000
20540012       -0.8965  RHO 041010000
*
```

```
*
*                                                   ************************
20560000 SGBMASS  SUM   1.  O. 1                    ** SG B MASS INVENTORY *
20560001  O.   19.508    RHO 611010000              ************************
20560002        5.596    RHO 613010000
20560003        5.015    RHO 615010000
20560004        1.2355   RHO 615020000
20560005        1.2355   RHO 615030000
20560006        1.2355   RHO 615040000
20560007        8.049    RHO 620010000
20560008        8.049    RHO 620020000
20560009        8.049    RHO 620030000
20560010        8.049    RHO 620040000
20560011       10.3      RHO 621010000
20560014        5.728    RHO 622010000
20560015        9.696    RHO 623010000
20560016       26.288    RHO 630010000
20560017        4.000    RHO 625010000
20560018        8.560    RHO 627010000
20560012        5.90940  RHO 612010000
*
*
*                                                   **********************
*                                                   * SGB ADDITION RATES *
20560300  G600  SUM  1.  O.  1                      **********************
20560301  O.  1.  MFLOWJ  618000000
20560302      1.  MFLOWJ  607000000
20560303      1.  MFLOWJ  608000000
20560309     -1.  MFLOWJ  865000000
*
20560400  BILSGB  INTEGRAL 1.  O.  1
20560401  CNTRLVAR 603
*
*                                                   ****************************
20560900  SGBPOWPR  SUM  1.  5.96E8  O              ** SGB  HEAT TRANSFER RATE *
20560901  O.  1.  Q  121010000                      ****************************
20560902      1.  Q  122010000
20560903      1.  Q  122020000
20560904      1.  Q  122030000
20560905      1.  Q  122040000
20560906      1.  Q  122050000
20560907      1.  Q  122060000
20560908      1.  Q  122070000
20560909      1.  Q  122080000
20560910      1.  Q  123010000
20560911      1.  Q  124010000
20560912      1.  Q  124020000
20560913      1.  Q  124030000
20560914      1.  Q  124040000
20560915      1.  Q  124050000
20560916      1.  Q  125010000
*
*
20561000  SGBPOW  SUM  1.  5.96E8  O
20561001  O.  1.  Q  620010000
```

```
20561002      1.  Q  620020000
20561003      1.  Q  620030000
20561004      1.  Q  620040000
20561005      1.  Q  621010000
*
*
*                                                          ***************************
20561100  LSGB     SUM  1.   11.662  1                     ** LEVEL  SGB  DOWNCOMER  *
20561101  O.  2.424  VOIDF  611010000                      ***************************
20561102      0.696  VOIDF  613010000
20561103      1.937  VOIDF  615010000
20561104      2.55   VOIDF  615020000
20561105      2.55   VOIDF  615030000
20561106      2.55   VOIDF  615040000
20561107      0.735  VOIDF  612010000
20561108      2.093  VOIDF  630010000
20561109      1.000  VOIDF  627010000
*
*
*                                                                 *********************
20561200  LSGBRI  SUM  1.   5.71  1                               ** LEVEL SGB  RISER *
20561201  O.  1.816  VOIDF  620010000   * CHECK?                  *********************
20561202      1.816  VOIDF  620020000   *
20561203      1.816  VOIDF  620030000   *
20561204      1.816  VOIDF  620040000   *
20561205      2.324  VOIDF  621010000   *
20561206      1.432  VOIDF  622010000   *
20561207     2.424  VOIDF  623010000
*
*
*
*                                                                   *****************
20561300 DPLSGB SUM 3.794E-5 O. 1 3 O  1                            ** SGB LEVEL DP *
20561301 -1068.9     4.6303 RHO 613010000                           *****************
20561302             23.779  RHO 611010000
20561303             7.2104  RHO 612010000
*
*
*
*
*                                                              ************************
20570000 SGBMASS  SUM  1.  O. 1                                ** SG A MASS INVENTORY *
20570001  O. 19.508 RHO 711010000                              ************************
20570002      5.596 RHO 713010000
20570003      5.015 RHO 715010000
20570004     1.2355 RHO 715020000
20570005     1.2355 RHO 715030000
20570006     1.2355 RHO 715040000
20570007     8.049   RHO 720010000
20570008     8.049   RHO 720020000
20570009     8.049   RHO 720030000
20570010     8.049   RHO 720040000
20570011     10.3    RHO 721010000
20570014    5.728    RHO 722010000
20570015    9.696   RHO 723010000
```

```
20570016      26.288 RHO 730010000
20570017       4.000 RHO 725010000
20570018       8.560  RHO 727010000
20570012    5.90940   RHO 712010000
*
*
*                                                                  ******************
20570300  G700  SUM  1.  0.  1                                     * ADDITION RATES *
20570301  0.  1.  MFLOWJ  707000000                                ******************
20570303      1.  MFLOWJ  708000000
20570310     -1.  MFLOWJ  791000000
*
*
20570400  INTG7  INTEGRAL  1.  0.  1
20570401  CNTRLVAR  703
*
*
*
*                                                          ****************************
20570900  SGAPOWPR  SUM  1.  5.96E8  0                     ** SGA  HEAT TRANSFER RATE *
20570901  0.  1.  Q  221010000                             ****************************
20570902      1.  Q  222010000
20570903      1.  Q  222020000
20570904      1.  Q  222030000
20570905      1.  Q  222040000
20570906      1.  Q  222050000
20570907      1.  Q  222060000
20570908      1.  Q  222070000
20570909      1.  Q  222080000
20570910      1.  Q  222090000
20570911      1.  Q  222100000
20570912      1.  Q  224010000
20570913      1.  Q  224020000
20570914      1.  Q  224030000
20570915      1.  Q  224040000
20570916      1.  Q  224050000
20570917      1.  Q  225010000
*
*
*
*
20571000  SGAPOW  SUM  1.  5.96E8  0
20571001  0.  1.  Q  720010000
20571002      1.  Q  720020000
20571003      1.  Q  720030000
20571004      1.  Q  720040000
20571005      1.  Q  721010000
*
*
*                                                          **************************
20571100  LSGA    SUM  1   11.662  1                       ** LEVEL  SGA  DOWNCOMER *
20571101  0.  2.424  VOIDF  711010000                      **************************
20571102      0.696  VOIDF  713010000
20571103      1.937  VOIDF  715010000
20571104      2.55   VOIDF  715020000
```

219

```
20571105       2.55   VOIDF  715030000
20571106       2.55   VOIDF  715040000
20571107       0.735  VOIDF  712010000
20571108       2.093  VOIDF  730010000
20571109       1.000  VOIDF  727010000
*
*
*                                                          *******************
20571200  LSGARI  SUM  1.  5.7  1                          ** LEVEL RISER SGA
20571201  O.   1.816  VOIDF  720010000                     *******************
20571202       1.816  VOIDF  720020000
20571203       1.816  VOIDF  720030000
20571204       1.816  VOIDF  720040000
20571205       2.324  VOIDF  721010000
20571206       1.432  VOIDF  722010000
20571207       2.424  VOIDF  723010000
*
*
20571300 DPLSGA SUM 3.794E-5 O. 1 3 O. 1.                   *****************
20571301 -1068.9    4.6303 RHO 713010000                    ** SGA LEVEL DP *
20571302           23.779  RHO 711010000                    *****************
20571303            7.2104 RHO 712010000
*
*
*
*                                                         **********************
20590000 LE1PRESS  SUM  0.048209  O. 1                    ** PRESSURIZER LEVEL *
20590001  -2.906086  4.44396  VOIDF 312010000             **********************
20590002             4.44396        VOIDF 313010000
20590003             3.873          VOIDF 314010000
20590004             3.81208        VOIDF 315010000
20590005             2.01312        VOIDF 316010000
20590006             1.50984        VOIDF 317010000
20590007             1.00656        VOIDF 320010000
20590008             5.0892E-1      VOIDF 320020000
20590009             3.3928E-1      VOIDF 320030000
20590010             2.5446E-1      VOIDF 320040000
20590011             1.6964E-1      VOIDF 320050000
20590012             1.6964E-1      VOIDF 320060000
20590013             8.4620E-2      VOIDF 330010000
20590014             1.0178         VOIDF 311010000
20590015             0.24593        VOIDF 301010000
20590016             0.24593        VOIDF 301020000
20590017             0.15771        VOIDF 301030000
20590018             0.50892        VOIDF 310010000
*
20590100 LE2PRES   SUM  2.515E-5   O.   1   3   O
20590101 -8248.     14.4796        RHO 312010000
20590102            17.324         RHO 313010000
20590103            15.0976        RHO 314010000
20590104            14.862         RHO 315010000
20590105             7.848         RHO 316010000
20590106             5.886         RHO 317010000
20590107             3.924         RHO 320010000
20590108             1.4224        RHO 320020000
```

```
*
20590200 LE3PRES  SUM  1.2459E-5  O.   1    3    O.     1.
20590201      O.      14.4796         RHO 312010000
20590202              17.324          RHO 313010000
20590203              15.0976         RHO 314010000
20590204              14.862          RHO 315010000
20590205               7.848          RHO 316010000
20590206               5.886          RHO 317010000
20590207               3.924          RHO 320010000
20590208               1.4224         RHO 320020000
*
*                                                        *******************
*                                                        *  SG B  FW + AFW *
*                                                        *******************
20596900 (AFW+FW) SUM  1.  O. 1
20596902 O.  1.  MFLOWJ 607000000
20596903     1.  MFLOWJ 608000000
*
*                                                        *******************
*                                                        *  SG A  FW + AFW *
*                                                        *******************
20597900 (AFW+FW) SUM  1.  O. 1
20597902 O.  1.  MFLOWJ 707000000
20597903     .   MFLOWJ 708000000
*
*                                                        *******************
*                                                        *  HEAT  LOSSES   *
*                                                        *******************
20598900 HEATLOSGA SUM  1.        O. 1
20598901  O.           1.         Q        970010000
*
20599000 HEATLOSGB SUM  1.        O. 1
20599001  O.           1.         Q        960010000
*
20599100 HEATLOSPR SUM  1.        O. 1
20599101  O.           1.         Q        950010000
*
*                                                  ***********************
*                                                  * WALLS HEAT TRANSFER *
*                                                  ***********************
*
*
20599200 QPRIM1     SUM  1. O. 1                       **  VESSEL    **
20599201  O.  1.  Q   011010000
20599202      1.  Q   013010000
20599203      1.  Q   015010000
20599204      1.  Q   015020000
20599205      1.  Q   015030000
20599206      1.  Q   021010000
20599207      1.  Q   023010000
20599208      1.  Q   025010000
20599209      1.  Q   035010000
20599210      1.  Q   039010000
20599211      1.  Q   041010000
20599212      1.  Q   043010000
```

```
20599213       1.  Q   045010000
*
*
20599300 QLOOPB SUM 1. O. 1                                   **   LOOP  B  **
20599301  O.   1.  Q   132010000
20599302       1.  Q   133010000
20599303       1.  Q   133020000
20599304       1.  Q   140010000
20599305       1.  Q   151010000
20599306       1.  Q   151020000
20599307       1.  Q   152010000
20599308       1.  Q   153010000
20599309       1.  Q   111010000
20599310       1.  Q   112010000
20599311       1.  Q   113010000
20599312       1.  Q   131010000
*
*
*
20599400 QPRESS  SUM 1. O. 1                                    **  PRESSURISER**
20599401  O.   1.  Q   330010000
20599402       1.  Q   310010000
20599404       1.  Q   301010000
20599405       1.  Q   301020000
20599406       1.  Q   301030000
20599407       1.  Q   311010000
20599408       1.  Q   312010000
20599409       1.  Q   313010000
20599410       1.  Q   314010000
20599411       1.  Q   315010000
20599412       1.  Q   316010000
20599413       1.  Q   317010000
20599414       1.  Q   320010000
20599415       1.  Q   320020000
20599416       1.  Q   320030000
20599417       1.  Q   320040000
20599418       1.  Q   320050000
20599419       1.  Q   320060000
*
*
*
20599500 QLOOPA SUM 1. O. 1                                  **  LOOP  A  **
20599501 O.    1.  Q   251020000
20599502       1.  Q   252010000
20599503       1.  Q   253010000
20599504       1.  Q   211010000
20599505       1.  Q   211020000
20599506       1.  Q   211030000
20599507       1.  Q   231010000
20599508       1.  Q   231020000
20599509       1.  Q   231030000
20599510       1.  Q   231040000
20599511       1.  Q   240010000
20599512       1.  Q   251010000
*
```

```
20599600 QPRIMT SUM 1. 0. 1                                        **  TOTAL   **
20599601 0. 1.  CNTRLVAR 993
20599602    1.  CNTRLVAR 995
20599603    1.  CNTRLVAR 994
20599604    1.  CNTRLVAR 992
*
*
*
*
*******************************************************************
*TURBO PUMP MODEL                                                 *
*******************************************************************
*
6080000  J608  TMDPJUN
6080101  606000000  613000000  1.
6080200  1   0   CNTRLVAR  870
6080201  -1.  0.  0.  0.
6080202  0.  0.  0.  0.
6080203  50.  50.  0.  0.
*
7080000  J708  TMDPJUN
7080101  706000000  713000000  1.
7080200  1  0    CNTRLVAR  871
7080201  -1.  0.  0.  0.
7080202  0.  0.  0.  0.
7080203  50.  50.  0.  0.
*
20586200 TRIPB  TRIPUNIT 1. 1. 0
20586201 661
*
20586300 TRIPA  TRIPUNIT 1. 1. 0
20586301 661
*
20586400  P-PB  SUM   1.   0.   0
20586401   0.    1.   CNTRLVAR 882
20586402        -1.   P 613010000
*
20586500  P-PA  SUM   1.   0.   0
20586501   0.    1.   CNTRLVAR 882
20586502        -1.   P 713010000
*
20586600  WPB2  SUM   7.22E-5   0.   0
20586601   0.    1.   CNTRLVAR 864
20586602      -181.   CNTRLVAR 873
*
20586700  WPA2  SUM   7.22E-5   0.   0
20586701   0.    1.   CNTRLVAR 865
20586702      -181.   CNTRLVAR 873
*
20586800  WPB   POWERR 1.   0.   0
20586801              CNTRLVAR 866  0.5
*
20586900  WPA   POWERR 1.   0.   0
20586901              CNTRLVAR 867  0.5
*
```

```
20587000  WPB  MULT 1. 0. 1
20587001 CNTRLVAR 868    CNTRLVAR 862
*
20587100  WPA  MULT 1. 0. 1
20587101 CNTRLVAR 869    CNTRLVAR 863
*
20587200  WPA+WPB   SUM    0.5   0.  0,
20587201   0.     1.  CNTRLVAR   870
20587202          1.  CNTRLVAR   871
20587203          1.  CNTRLVAR   872
*
20587300  WP2   POWERI 1.   0.   0
20587301              CNTRLVAR 872  2
*
20587400  EQ18  MULT   4.734  0.   0    '
20587401  CNTRLVAR 872        CNTRLVAR 878
*
20587500  VP         SUM    0.5   368.   0
20587501   0.  244.  CNTRLVAR   876
20587502          1.  CNTRLVAR   874
20587503          1.  CNTRLVAR   875
*
20587600  VT/VP  DIV  368.  1.   0    2    1.
20587601              CNTRLVAR 875
*
20587700  N/NO  POWERR  1.  1.   0    3    0.5   1.
20587701              CNTRLVAR 876  0.33333
*
20587800 (N/NO)2  POWERI  1.   1.   0    2    1.
20587801              CNTRLVAR 877  2
*
20588000  EQ17     SUM      1.   0.   0
20588001   0.    1.     CNTRLVAR 872
20588002        -8.89   CNTRLVAR  877
*
20588100  EQ17     POWERI  1.   1.   0
20588101              CNTRLVAR 880   2
*
20588200  PPUMP      SUM    0.5   92.4E5   0    2    92.4E5
20588201   0.     1.  CNTRLVAR   882
20588202      -1918.  CNTRLVAR   881
20588203   92.4E5     CNTRLVAR   878
*
20588300  WT         SUM    1.     0.      0    2     2.344
20588301  0.75   0.00433   CNTRLVAR 875
*
*
*
*******************************************************************************
*GENERAL TABLES                                                               *
*******************************************************************************
*
*
*POWER TABLE
*
```

224

```
20210000  POWER
20210001    O.              6.E6
*
*
* PRESSURIZER HEATERS
20231100  POWER  642
20231101  -1.    O.
20231102   O.  850.E3
*
*HEAT TRANSFER COEFF.  PRESSU-CONTAINEMENT
*
20295000 HTC-T
20295001 O.  1.91
*
*
*HEAT TRANSFER COEFF.  SG-CONTAINEMENT
*
20296000 HTC-T
20296001 O.  0.95
*
*
 *
**********************************************************************
** PLOT REQUEST
**********************************************************************
20300010  DOTGRID
*
*
20302100  P          330010000
*
20303100  CNTRLVAR   900   901 902
20303200  CNTRLVAR    901
*
20304100  P          211020000
*
20305200  TEMPF      015030000   041010000
20305400  TEMPF      211030000
20305500  TEMPF      113010000
20305600  TEMPF      251020000
20305700  TEMPF      151020000
20305800  CNTRLVAR   113
20305900  TEMPG      330010000
*
20306000  CNTRLVAR   002
20306100  CNTRLVAR   012
20306200  MFLOWJ     618000000
20306300  CNTRLVAR   010
20306400  CNTRLVAR   079
20306500  MFLOWJ     181000000  183000000
20306600  CNTRLVAR   012  078
*
20307100  CNTRLVAR   031
20307200  CNTRLVAR   007
20307300  CNTRLVAR   710    610
20307500  CNTRLVAR   009
```

```
20307600  CNTRLVAR  996   994
20307700  CNTRLVAR  031   007
*
20308100  MFLOWJ    013020000  013030000
20308300  MFLOWJ    301010000
20308400  PMPVEL  140  240
20308500  MFLOWJ    345000000  3460000000
*
20309200  CNTRLVAR 114
20309300  P  015030000
20309310  TEMPF
20309900  CNTRLVAR 050
*
20310100  P         730010000  630010000
20310200  P         730010000
20310300  P         630010000
*
20311100  CNTRLVAR  711   611 712 612
20311500  CNTRLVAR  713     613
20311600  CNTRLVAR  711
20311700  CNTRLVAR  611
20311800  CNTRLVAR  713
20311900  CNTRLVAR  613
*
20312100  TEMPG  630010000  730010000
20312200  TEMPF  121010000  620040000  125010000
20312300  TEMPF  121010000  720040000  225010000
20312400  TEMPF  620010000 621010000  623010000 630010000
*
20314700  MFLOWJ 865000000
20314800  CNTRLVAR  979 969
20314900  MFLOWJ 791000000
*
20315100  CNTRLVAR  600 700
20315200  CNTRLVAR  603 703
*
20318300  CNTRLVAR 001
20318400  TEMPF     043010000  999010000
*
20320000  CPUTIME  0
*
*
***********************************************************************
*   TITLES                                                            *
***********************************************************************
*
20302130  "FIG 2.1 PRESSURE EVOLUTION IN PRESSURIZER "
*
20303130 " FIG 3.1  WATER LEVEL IN PRESSURIZER "
20303230 " FIG 3.2 MEASURED  WATER LEVEL IN PRESSURIZER "
*
20304130 " FIG 4.1 PRESSURE EVOLUTION IN  HOT LEG A"
*
20305230 "FIG 5.2 TEMPERATURE EVOLUTION IN REACTOR VESSEL "
20305430 " FIG 5.4 TEMPERATURE EVOLUTION IN HOT LEG A"
```

```
20305530 " FIG 5.5 TEMPERATURE EVOLUTION IN HOT LEG B"
20305630 " FIG 5.6 TEMPERATURE EVOLUTION IN COLD LEG A"
20305730 " FIG 5.7 TEMPERATURE EVOLUTION IN COLD LEG B"
20305830 " FIG 5.8 AVERAGED PRIMARY TEMPERATURE EVOLUTION "
20305930 " FIG 5.9 PRESSURIZER STEAM TEMPERATURE EVOLUTION "
*
20306030 " FIG 6.10 MASS BALANCE IN PRIMARY SYSTEM "
20306130 " FIG 6.1 BREAK MASS FLOW RATE (CORRECTED)"
20306230 " FIG 6.2 BREAK MASS FLOW RATE "
20306330 " FIG 6.3 PRIMARY SYSTEM MASS ADDITION AND DEPLETION RATES "
20306430 " FIG 6.4 INTEGRAL OF HPSI MASS FLOW RATE"
20306530 " FIG 6.5 CHARGING AND LETDOWN MASS FLOW RATE "
20306630 " FIG 6.6 BREAK AND HPSI MASS  FLOW RATE "
*
20307130 " FIG 7.1 CORE THERMAL POWER "
20307230 " FIG 7.2 BREAK ENERGY EVOLUTION "
20307330 " FIG 7.3 HEAT TRANSFER RATE FROM PRIMARY TO SG  "
20307530 " FIG 7.5 PRIMARY SYSTEM ENERGY BALANCE "
20307630 " FIG 7.6 HEAT ADDITION RATE FROM PRIMARY METAL STRUCTURES "
20307730 " FIG 7.7 CORE AND BREAK POWER "
*
20308130 " FIG 8.1 COLD LEG MASS FLOW RATE (VESSEL INLET)"
20308330 " FIG 8.3 SURGELINE MASS FLOW RATE "
20308430 " FIG 8.4 PUMP VELOCITY"
20308530 " FIG 8.5 SPRAY MASS FLOW RATE "
*
20309230 " FIG 9.2 SUBCOOLING IN PRIMARY SYSTEM      "
20309330 " FIG 9.3 PRESSURE VERSUS TEMPERATURE IN DOWNCOMER"
20309930 " FIG 9.9 MASS BALANCE IN PRIMARY SYSTEM"
*
20310130 " FIG 10.1 PRESSURE EVOLUTION IN STEAM GENERATOR  (DOME) "
20310230 " FIG 10.2 PRESSURE EVOLUTION IN STEAM GENERATOR A(DOME) "
20310330 " FIG 10.3 PRESSURE EVOLUTION IN STEAM GENERATOR B(DOME) "
*
20311130 "FIG 11.1 COLLAPSED WATER LEVEL IN STEAM GENERATORS"
20311530 " FIG 11.5 MEASURED WATER LEVEL IN STEAM GENERATORS "
20311630 "FIG 11.6 COLLAPSED WATER LEVEL IN STEAM GENERATOR A"
20311730 "FIG 11.7 COLLAPSED WATER LEVEL IN STEAM GENERATOR B"
20311830 " FIG 11.8 MEASURED WATER LEVEL IN STEAM GENERATOR A"
20311930 " FIG 11.9 MEASURED WATER LEVEL IN STEAM GENERATOR B"
*
20312130 " FIG 12.1 STEAM TEMPERATURE IN STEAM GENERATORS(DOME)"
20312230 " FIG 12.2 LOOP B AND SG B TEMPERATURES"
20312330 " FIG 12.3 LOOP A AND SG A TEMPERATURES"
20312430 " FIG 12.4 TEMPERATURE STRATIFICATION IN SG B"
*
20314730 " FIG 14.7 STEAM MASS FLOW RATE FROM SGB TO TURBOPUMP"
20314830 " FIG 14.8 FW AND AFW TO STEAM GENERATOR  "
20314930 " FIG 14.9 SG A RELIEF VALVE MASS FLOW RATE "
*
20315130 " FIG 15.1 STEAM GENERATORS MASS EVOLUTION"
20315230 " FIG 15.2 SG'S MASS ADDITION AND DEPLETION RATES"
*
20318330 " FIG 9.12 INTEGRAL OF BREAK MASS FLOW RATE "
20318430 " FIG 18.4 SUBCOOLING"
```

```
*
*
20320030 " FIG 20 CPUTIME VERSUS TRANSIENT TIME "
************************************************************************
*     LINE AND CURVE SPECIFICATIONS                                    *
************************************************************************
*
20303150   "COLLAPSED"    "LEVEL"     LINE  1   40
20303151   "HOT CELL"     "LEVEL"     LINE  2   40
20303152   "COLD CELL"    "LEVEL"     LINE  3   40
*
20303250   "HOT CELL"     "LEVEL"     LINE  1   40
*
20304150   "  P      "    "21102"    LINE   1   40
*
20305250   "DOWNC."       "TEMP"      LINE  1   40
20305251   "CORE OUTL."   "TEMP"      LINE  2   40
*
20305450   "LOOP "        "A"         LINE  1   40
*
20305550   "LOOP "        "B"         LINE  1   40
*
20305650   "LOOP "        "A"         LINE  1   40
*
20305750   "LOOP "        "B"         LINE  1   40
*
20306550   "MFLOW "       "CV"        LINE  1   40
20306551   "MFLOW "       "LETD."     LINE  2   40
*
20306650   "BREAK "       "FLOW"      LINE  1   40
20306651   "HPSI "        "FLOW"      LINE  2   40
*
*
20307350   "SG "          "A"         LINE  1   40
20307351   "SG "          "B"         LINE  2   40
*
20307650   "PRIMARY"      "SYST"      LINE  1   40
20307651   "PRESSU "      "SYST"      LINE  2   40
*
20307750   "CORE"         "POWER"     LINE  1   40
20307751   "BREAK         "POWER"     LINE  2   40
*
20308150   "LOOP "        "B"         LINE  1   40
20308151   "LOOP "        "A"         LINE  2   40
*
20308450   "LOOP "        "B"         LINE  1   40
20308451   "LOOP "        "A"         LINE  2   40
*
20308550   "LOOP "        "B"         LINE  1   40
20308551   "LOOP "        "A"         LINE  2   40
*
*
20310150   " P    "       "SG A"      LINE  1   35
20310151   " P    "       "SG B"      LINE  1   40
*
```

```
20310250    " P     "        "SG A"       LINE  1   35
*
20310350    " P     "        "SG B"       LINE  1   40
*
20311150    "DOWNC "         "SG A"       LINE  1   40
20311151    "DOWNC "         "SG B"       LINE  2   40
20311152    "RISER "         "SG A"       LINE  3   40
20311153    "RISER "         "SG B"       LINE  4   40
*
20311550    "DOWNC "         "SGA"        LINE  1   40
20311551    "DOWNC "         "SGB"        LINE  2   40
*
20311650    "LEVEL "         "711"        LINE  1   40
20311750    "LEVEL "         "611"        LINE  1   40
20311850    "LEVEL "         "713"        LINE  1   40
20311950    "LEVEL "         "613"        LINE  1   40
*
20312150    " SG    "        "B"          LINE  1   40
20312151    " SG    "        "A"          LINE  2   40
*
20312250    "INLET"          "BOX"        LINE  1   40
20312251    "RISER "         "SG B'       LINE  2   40
20312252    "OUTLET"         "BOX"        LINE  3   40
*
20312350    "INLET"          "BOX"        LINE  1   40
20312351    "RISER "         "SG A"       LINE  2   40
20312352    "OUTLET"         "BOX"        LINE  3   40
*
20312450    "TUBE BUNDLE"    "BOT."       LINE  1   40
20312451    "TUBE BUNDLE"    "TOP"        LINE  2   40
20312452    "SEPARATOR"      "   "        LINE  3   40
20312453    "DOME"           "   "        LINE  4   40
*
20314850    "SG "            "A"          LINE  1   40
20314851    "SG "            "B"          LINE  2   40
*
20315150    "SG "            "B"          LINE  1   40
20315151    "SG "            "A"          LINE  2   40
*
20315250    "SG "            "B"          LINE  1   40
20315251    "SG "            "A'          LINE  2   40
*
20318450    "CORE"           "TEMP"       LINE  1   40
20318451    "SAT."           "TEMP"       LINE  2   40
*
*
*************************************************************************
*     AXES TITLES                                                        *
*************************************************************************
*
20303132   "LEVEL "           "(%)"
20303232   "LEVEL "           "(%)"
*
20305832   "TEMP  "           "(K)"
*
```

```
20306032  "MASS  "          "(KG)"
*
20306132  "MFLOW "          "(KG/SEC)"
*
20306332  "MFLOW "          "(KG/SEC)"
*
20306632  "MFLOW "          "(KG/SEC)"
*
20307132  "POWER "          "(WATT)"
*
20307232  "BREAK POWER"     "(WATT)"
*
20307332  "POWER "          "(WATT)"
*
20307532  "POWER "          "(WATT)"
*
20307632  "POWER "          "(WATT)"
*
20307732  "POWER "          "(WATT)"
*
*
20309232  "DELTA TEMP"      "(K)"
*
20311132  "LEVEL "          "(M)"
*
20311532  "LEVEL "          "(%)"
*
20314832  "MFLOW "          "(KG/SEC)"
*
20315132  "MASS "           "(KG)"
*
20318332  "MASS"            "(KG)"
*
*
*****************************************************************************
*   Y-AXE LIMITS                                                            *
*****************************************************************************
*
*
*********************************************************************************
*   PLOTS  COMPARISON
*********************************************************************************
*
20304120  04100 *FIG.14 PRESSURE EVOLUTION HOT LEG (LOOP-A)(PRA-RC 11)
20404100  P    * 211020000
20404119 "PRA-RC" "11" CDOTS
20404120  O. 155.E05 152. 148.E05  422.  138.E05  828.  128.E05  980.  128.E05
20404121 1132. 108.E05 1470. 107.E05 2100. 107.E05 2281. 74.E05 2417.  99.E05
20404122  2636.  105.E05
*
20303120  03100 *FIG.15 WATER LEVEL IN PRESSURIZER (LRCA/PR11)
20303220  03100 *FIG.15 WATER LEVEL IN PRESSURIZER (LRCA/PR11)
20403100  CNTRLVAR
20403119 "LRCA-PR" "11" CDOTS
20403120  0.0    0.25
```

```
20403121  47.4  .197  284.2  .065  362.  .032  442.  0.  2196.  0.
20403122  2368.    1.   2700.  1.
*
20312620  11200 *FIG.17 WATER LEVEL IN INTACT S.G. A  (2 FW 9A)
20412600  CNTRLVAR
20412619 "2 FW " "9A" CDOTS
20412620  0.  11.217  871.  11.21  888.  11.187  890.  11.402  1006.  11.115
20412621  1008. 11.053 1142. 11.112 1260. 10.834 1429.  10.583  1716.  11.184
20412622  1817.  11.379  2021.  11.608  2190.  11.608  2527.  11.953
*
20311720  11300 *FIG.18 WATER LEVEL IN BROKEN S.G. B  (2 FW 9B)
20411700  CNTRLVAR
20411719 "2 FW " "9B" CDOTS
20411720  0.  11.229  1484.  13.231  1535.  13.443  2700.  13.443
*
20311820  11500 *FIG.17 WATER LEVEL IN INTACT S.G. A  (2 FW 9A)
20411800  CNTRLVAR
20411819 "2 FW " "9A" CDOTS
20411820  0.  0.39  871.  0.385  888.  0.379  890.  0.438  1006.  0.359
20411821  1008.  0.342  1142.  0.358  1260.  0.282  1429.  0.213  1716.  0.378
20411822  1817.  0.432  2021.  0.495  2190.  0.495  2527.  0.590
*
20311920  11600 *FIG.18 WATER LEVEL IN BROKEN S.G. B  (2 FW 9B)
20411900  CNTRLVAR
20411919 "2 FW " "9B" CDOTS
20411920  0.  0.39   1484.  0.94   1535.  1.
*
20305620  05600 *FIG.19 TEMPERATURE IN COLD LEG A (2 RC 09)
20405600  TEMPF *251020000
20405619 "2 RC " "09" CDOTS                          *!!!!!!!!!!!CHECK
20405620  0.  529.  763.  528.  1255.  524.  1565.  514.  1843.  502.
20405621  2155.  493.  2395.  482.  2816.  472.
*
20305420  05400 *FIG.20 TEMPERATURE IN COLD LEG A (2 RC 05)
20405400  TEMPF *211040000
20405419 "2 RC " "05" CDOTS                          *!!!!!!!!!!!CHECK
20405420  0.  529.  763.  528.  1255.  524.  1565.  514.  1843.  502.
20405421  2155.  493.  2395.  482.  2816.  472.
*
20305720  05700 *FIG.21 TEMPERATURE IN COLD LEG B (2 RC 29)
20405700  TEMPF *151020000
20405719 "2 RC " "29" CDOTS                          *!!!!!!!!!!!CHECK
20405720  0.  529.  763.  528.  1255.  524.  1565.  514.  1843   502.
20405721  2155.  493.  2395.  482.  2816.  472.
*
20305520  05500 *FIG.22 TEMPERATURE IN HOT LEG B (2 RC 25)
20405500  TEMPF *211040000
20405519 "2 RC " "25" CDOTS                          *!!!!!!!!!!!CHECK
20405520  0.  529.  763.  528.  1255.  524   1565.  514.  1843.  502.
20405521  2155.  493.  2395.  482.  2816.  472.
*
20310120  10100 10200 *FIG.23 PRESSURE IN S.G. A (2 MS 04 A)
20410100  P    * 734010000
20410119 "2 MS " "04A" CDOTS
20410120  0. 43.1E05 412. 44.4E05 1000. 45.2E05 1084.  43.4E05  1237   43.1E05
```

```
20410121  1338. 40.6E05 1591. 35.8E05 1744. 30.7E05 1845. 29.E05 1946. 25.8E05
20410122  2183 23.5E05 2183. 22.2E05 2301. 20.8E05 2453. 18.4E05 3112. 14.6E05
*
20310220  10100
20310320  10200
*
20410200  P    * SG B
20410219 "2 MS " "04B" DASHES
20410220  0. 42.85E05 149. 43.1E05  369. 44.1E05  673.  44.7E05  876.  45.E05
20410221 1197. 44.9E05 1484. 45.E05 1687. 40.4E05 1890. 35.63E05 2177. 37.95E05
20400222  2397 38.71E05 2598. 39.86E05
*
*
*
*  END  OF  DATA
*
*
/*EOR
/*EOI
```

NRC FORM 335 (2-84) NRCM 1102, 3201, 3202 U.S. NUCLEAR REGULATORY COMMISSION **BIBLIOGRAPHIC DATA SHEET** SEE INSTRUCTIONS ON THE REVERSE.	1. REPORT NUMBER (Assigned by TIDC, add Vol No., if any) NUREG/IA-0008
2. TITLE AND SUBTITLE Assessment Study of RELAP-5 MOD-2 Cycle 36.01: Based on the Doel-2 Steam Generator Tube Rupture Incident of June 1979	3. LEAVE BLANK 4. DATE REPORT COMPLETED MONTH / YEAR
5. AUTHOR(S) E.J. Stubbe	6. DATE REPORT ISSUED MONTH October YEAR 1986
7. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) Tractionel Rue de la Science 31 B-1040 Brussels, Belgium	8. PROJECT/TASK/WORK UNIT NUMBER 9. FIN OR GRANT NUMBER
10. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) Office of Nuclear Regulatory Research U.S. Nuclear Regulatory Commission Washington, DC 20555	11a. TYPE OF REPORT b. PERIOD COVERED (Inclusive dates)
12. SUPPLEMENTARY NOTES	

13. ABSTRACT (200 words or less)

The code assessment results in this report were based on all the available data (from plant computer and plant recordings) from the Doel-2 steam generator tube rupture incident of June 1979. The study revealed that the code is capable to simulate the observed phenomena reasonably well and can be used to predict similar transients. However, lack of precise boundary conditions does not allow one to quantify the error margin from this analysis.

14. DOCUMENT ANALYSIS – a. KEYWORDS/DESCRIPTORS	15. AVAILABILITY STATEMENT
RELAP5/MOD2 steam generator tube rupture Doel-2 plant ICAP code assessment	Unlimited
b. IDENTIFIERS/OPEN-ENDED TERMS	16. SECURITY CLASSIFICATION (This page) Unclassified (This report) Unclassified
	17. NUMBER OF PAGES
	18. PRICE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

SPECIAL FOURTH-CLASS RATE
POSTAGE & FEES PAID
USNRC
WASH. D.C.
PERMIT No. G-67