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International Agreement Report

Assessment of RELAP5/MOD2 Against a Turbine Trip From 100% Power in the Vandellos II Nuclear Power Plant

Prepared by
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Madrid, Spain

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

June 1993

Prepared as part of
The Agreement on Research Participation and Technical Exchange
under the International Thermal-Hydraulic Code Assessment
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EXECUTIVE SUMMARY

An assessment of RELAP5/MOD2 cycle 36.04 against a turbine trip from 100 % power in the Vandellós II nuclear power plant is presented. The work is inscribed in the framework of the spanish contribution to ICAP Project.

Vandellós II is a plant owned by ENDESA (72 %) and HIDROELECTRICA ESPAÑOLA (28 %) located in Tarragona (Spain).

The transient under study was part of the preoperational test program and a large number of plant signals were recorded by the Signal Acquisition System.

The model used consisted of a single loop, a steam generator and a steam line up to the steam header all of them enlarged on a scale of 3:1, and full-scaled reactor vessel and pressurizer.

The analysis followed the usual steps: modelling of the plant; calculation of the plant steady state previous to the test; calculation of the transient; comparison with plant measurements; and performance of sensitivity studies.

Calculations were carried out using Cycle 36.04 of RELAP5/MOD2 code installed in the CDC CYBER 830 computer owned by the CSN.

The steam dump demand signals recorded in plant showed a perturbation, inconsistent with the average temperature behaviour. This was attributed to a malfunction in the Signal Acquisition System. The actual response of the steam dump banks under demand was uncertain.

The results of the calculations have been in reasonable agreement with plant measurements. An additional study has been performed, to check the ability of a model in which all the plant components are full-scaled to reproduce the transient. A second study has been performed, using the Homogeneous Equilibrium Model in the pressurizer, trying to elucidate the influence of the phasic velocity slip in the primary depressurization rate.

ABSTRACT .

An assessment of RELAP5/MOD2 cycle 36.04 against a turbine trip from 100% power in Vandellós II NPP (Spain) is presented. The work is inscribed in the framework of the spanish contribution to ICAP Project.

The model used in the simulation consists of a single loop, a steam generator and a steam line up to the steam header all of them enlarged on a scale of 3:1; and full-scaled reactor vessel and pressurizer.

The results of the calculations have been in reasonable agreement with plant measurements. An additional study has been performed, to check the ability of a model in which all the plant components are full-scaled to reproduce the transient. A second study has been performed using the Homogeneous Equilibrium Model in the pressurizer, trying to elucidate the influence of the velocity slip in the primary depressurization rate.

FOREWORD

This report represents one of the assessment/application calculations submitted in fulfilment of the bilateral - agreement for cooperation in thermalhydraulic activities between the Consejo de Seguridad Nuclear of Spain (CSN) and the United States Nuclear Regulatoy Commission (US-NRC) in - the form of Spanish contribution to the International Code Assessment and Applications Program (ICAP) of the US-NRC whose main purpose is the validation of the TRAC and RELAP system codes.

The Consejo de Seguridad Nuclear has promoted a coordinated - Spanish Nuclear Industry effort (ICAP-SPAIN) aiming to - satisfy the requirements of this agreement and to improve the quality of the technical support groups at the Spanish - Utilities, Spanish Research Establishments, Regulatory Staff and Engineering Companies, for safety purposes.

This ICAP-SPAIN national program includes agreements between CSN and each of the following organizations:

- EMPRESARIOS AGRUPADOS, S.A.
- Unidad Eléctrica (UNESA)
- Unión Iberoamericana de Tecnología Eléctrica (UITESA)
- Empresa Nacional del Uranio (ENUSA)
- TECNATOM
- LOFT-ESPAÑA

The program is executed by 13 working groups and a generic code review group and is coordinated by the "Comité de Coordinación". This committee has approved the distribution of this document - for ICAP purposes.

1. INTRODUCTION .

The results of an assessment of the RELAP5/MOD2 code against a turbine trip are presented in this report. This work is inscribed in the Spanish contribution to the International Code Assessment and Applications Program (ICAP). Its main additional objective is to promote the elaboration of a Vandellós II plant model with RELAP5/MOD2 code.

The transient under study was one of the preoperational tests of the Vandellós II nuclear power plant. A Signal Acquisition System recorded a large number of plant signals.

The analysis followed the usual steps: modelling of the plant; calculation of the plant steady state previous to the test; calculation of the transient; comparison with the plant measurements; and performance of sensitivity studies.

Calculations were carried out using Cycle 36.04 of RELAP5/MOD2 code installed in the CDC CYBER 830 computer owned by the CSN .

This same turbine trip test has been analyzed using the TRAC-PF1/MOD1 code by UITESA, in the framework of the Spanish contribution to ICAP [8].

2. PLANT AND TRANSIENT DESCRIPTION .

2.1 PLANT DESCRIPTION .

Vandellós II is a three-loop Westinghouse PWR nuclear power plant owned by ENDESA (72%) and HIDROELECTRICA

ESPAÑOLA (28%). It is located in Tarragona, in the North-East of Spain, and uses the Mediterranean Sea as the final heat sink. The plant started its commercial operation in 1988. The nominal power is 982 MWe (2775 MWt).

The reactor vessel is cold head type . The plant is equipped with three Westinghouse U-tube steam generators (model F) without preheaters. The feedwater is fed directly to the upper part of the downcomer via J-tubes. The circulation ratio on the secondary side of the steam generators is 3.27 at rated power.

The Auxiliary Feedwater System consists of one turbopump and two motorpumps.

In the plant there are, among others, control systems for the reactivity (rods and boron), primary pressure, pressurizer level, steam dump and steam generator level. The Reactor Protection System includes safety valves in the pressurizer and the steam generator.

The main plant features are shown in Table I.

2.2 PLANT SIGNAL ACQUISITION SYSTEM DESCRIPTION .

To record the main parameters of the plant, during the startup period (including the transient under study), a temporary Signal Acquisition System was installed. It consisted of a digital system with an up to 0.05 seconds and 144 signals trail capacity.

The recorded parameters depended on the test carried out.

The quickness of data attainment was very important to improve the time required for data interpretation.

For this reason, once the nuclear plant tests had finished, Vandellós II NPP decided to install a permanent equipment in order to interpret and analyze the transients.

The availability of this great number of signals allows to check the partial performances of the control blocks, specially those of feedwater control, rod control and steam dump.

2.3 TRANSIENT DESCRIPTION .

The transient under study is a startup turbine trip from 100% power. It was conducted on February 27th, 1988.

Objectives of this test were to verify the ability of the plant to accept a total load rejection, reaching stable conditions; and to make some evaluations (response times of RTD's, changes in control systems setpoints...).

Previously to the test, the plant was in stable regime, at 100% power. All control systems were correctly performing in automatic mode.

The transient started with a manual turbine trip. The trip signal produced the closure of the turbine control valves, and the reactor scram. After this, the hot leg temperature decreased, and so did pressurizer pressure and level. The spare heaters activated when the corresponding setpoints were reached.

The turbine trip produced a quick secondary pressure increase. This fact deteriorated the primary-to -secondary side heat transfer in the steam generator, and had as a consequence a slight increase in the cold leg temperature during the early seconds of the transient.

As a result of the turbine trip, the reference temperature suddenly changed from full load to zero load, and there was a significant temperature error which produced the quick opening of the steam dump valves. The heat removed through these valves reduced the primary average temperature below the reference value.

The primary-to-secondary heat transfer decrease (and, in a lower scale, the secondary pressurization) originated a void collapse in the steam generator, resulting in a quick fall of the downcomer liquid level. The low-low level signal was reached, and the Auxiliary Feedwater System was activated. The main feedwater pumps were tripped at low average temperature signal in coincidence with reactor trip signal.

During the transient 144 plant signals were monitored by means of a Signal Acquisition System, with a frequency of 0.05 seconds, and stored in a computer.

The demand signals of steam dump banks 1 and 2 had an irregularity at 10.5 seconds, detaching for few seconds from the evolution of the compensated average temperature. At this time, the signals suddenly fell to zero, and rose again in 0.2 seconds. Until around 30 seconds, the signals did not follow the average temperature evolution.

As stated in [8], the origin of these abnormal signals could be :

a) A malfunction of the Signal Acquisition System or

b) A malfunction of the control block transmitting to the bank positioners, which modified the closure sequence required by the average temperature.

In addition to this, the actual response (dead times and movement velocity) of the steam dump valves was not certain, and the valve positions were not recorded.

3. CODE INPUT MODEL DESCRIPTION .

The plant model (Fig.1) consists of a single loop, a steam generator, and a steam line up to the steam header, all of them enlarged on a scale of 3:1; and full-scaled reactor vessel and pressurizer. It derives from the 1:1 nodalization of each individual component, separately elaborated and tested. The scaling was done by triplicating the values of flow cross sections and heat transmission areas; pump torque, flow and inertia were also multiplied by 3. Such a model is appropriate to the transient under study, which is basically symmetric. The nodalization includes 116 hydrodynamic volumes, 121 junctions and 78 heat structures, with 316 mesh points.

The boundaries of the model are feedwater collector, turbine and CVCS tank, simulated by means of RELAP Time Dependent Volumes (TMDPVOL).

Point kinetics is used to simulate the source of power. So, the plant model will be unable to reproduce the axial power distribution change that takes place as the control rods are going up or down through the core and the effect that thid change produces in reactivity coefficients.

This plant model was based on a RETRAN two-loop model [3], and incorporated additional plant data. The corresponding nodalization studies are detailed in [6].

3.1 PRIMARY SYSTEM .

It includes the reactor vessel, loops, steam generator primary side, pumps and pressurizer.

The loop is scaled-up 3:1, excluding the vessel and pressurizer, which are full-scaled. Each component of the model has been separately tested.

The reactor vessel is cold head type. The dome has been separated in three nodes, representing the upper zone, the inner circular one and the surrounding annulus, respectively. The upper plenum consists of two volumes, to ensure the proper connection of the outlet junction. The lower plenum has been also split in two nodes: one previous to the active core and the other one representing the hemispheric zone.

The reactor core has been simulated with six control volumes and a heat structure with six axial nodes. Use of the point kinetics model of the code has been done, with a null moderator temperature coefficient (because the test under study was done at beginning of life). The scram reactivity has been input through a table in function of time.

The core bypass path is divided in six nodes. Both the core bypass and bypass-to-head flow rates have been tuned through the energy loss coefficients.

Cylindric heat structures represent the heat losses through the vessel walls.

The pressurizer nodalization includes ten hydrodynamic volumes. The surge line is split in two PIPE components, accounting for the horizontal and vertical zone, respectively. Heat structures are used to represent the heaters and heat losses to the environment, trying to obtain a realistic temperature distribution. Relief and safety valves have also been simulated.

Homologous curves for the primary coolant pumps performance have been obtained through characteristic curves. Only data for normal operation conditions were included in the input deck. The moment of inertia, and rated flow, torque and motor torque have been triplicated.

The primary side of the steam generator has been split in 12 nodes, two of which represent the inlet and outlet chambers. The U-tubes have 10 nodes, with increasing length in the flow direction, in order to reproduce in detail the temperature profile and enhance the primary-to-secondary heat transfer.

3.2 SECONDARY SYSTEM .

The three steam generators have been unified, and so have been the steam lines up to the collector. Mean values have been assumed in the pipe simulation, because they are not exactly equal in the plant.

The steam generator has been modelled in a great detail [6]. Heat losses to the environment are represented by RELAP heat structures. It is interesting to point the existence of a heat structure which connects the boiler volumes and those of the downcomer, representing the wrapper.

The moisture separators zone has been modelled by means of an "ideal" SEPARATR component.

Relief valves are simulated by VALVE components; and safety valves, by Time Dependent Junctions (TMDPJUN). No one was activated during the transient under study.

Downstream the collector, the four turbine admission valves are assimilated to one VALVE. Four VALVE components represent the four banks in which gather the 12 steam dump valves, and account for the modulate behaviour of this system. Its capacity is adjusted to ≈30% of the full power steam mass flow at nominal pressure. A Time Dependent Junction accounts for the steam extraction towards the MSR, ejectors, turbopumps, etc...

3.3 CONTROL SYSTEMS

The following control systems have been included in the plant model :

- Control rods.
- Pressurizer level control.
- Pressurizer pressure control.
- Steam dump control.
- Steam generator level control.

The five groups have been simulated according to the plant design [6]. The plant actual control setting values during the test have been used as setpoints.

The CVCS charge was simulated by means of a VALVE and a TMDPVOL. The discharge was represented by a TMDPJUN extracting a continuous mass flow of 2.6 Kg/s from the primary system. Such a model is judged right for the purposes of this analysis.

The steam generator level control system did not include the speed control of the turbine driven pumps, which were not modelled.

The steam mass flow has been used as a measure of the turbine power. It is more closely related to the impulse chamber pressure than the valve position.

4. STEADY STATE CALCULATION .

Before the test simulation, a null transient was run to establish the initial conditions.

The STDY-ST code option was used. To adjust the 100% power steady state, use was made of the data measured in the plant previously to the test, and showed in Table II. Other data that were used are :

- Design values of the core bypass **mass** flow rates
- Standard pressure losses in a PWR-W vessel and loops [3].
- Design steam generator recirculation ratio.
- Design heat losses to the environment.

In this job was very useful the achievement of steady states for isolated components, such as reactor vessel, steam generator and pressurizer.

The energy loss coefficients in the junctions were assigned Handbook values [5], and then tuned to adjust pressure losses or bypass flows. For instance, the core bypass mass flows were adjusted by properly tuning the energy loss coefficients in the reactor vessel.

To adjust the steady state use was made of the real plant control systems. In addition, a dummy control system was added to adjust the primary mass flow rate by tuning the pump speed.

Known shortcomings in the RELAP5/MOD2 heat transfer correlations [2] forced to increase the primary-to-secondary heat transfer area in about 10 % to achieve the desired steady state.

Table II shows the comparison between the steady state values calculated by the code and those measured in plant. Signed with an asterisk are the parameters used to define the steady state [9]; they were thus controlled or imposed in the calculation. The agreement is good. Nevertheless, it is important to point that the calculated steam generator water mass is 30% lower than the reference full power value.

5. BASE CASE RESULTS .

5.1 BOUNDARY CONDITIONS .

The simulation started with the turbine valve closure in 0.5 seconds, according to the data recorded in the plant. The closure rate was supposed constant.

A Time Dependent Junction was kept extracting a mass flow of 37.06 Kg/s from the steam collector volume, trying to represent the MSR's effect during the transient.

The reactor scram was supposed at 0. seconds. At this time, the turbine valve started to close. The total duration of the rod insertion was 1.66 seconds (including an initial dead time of 0.16 seconds). The total inserted reactivity was 7208 pcm (10.22556 $). The decay heat was that calculated by the code according to a 1000. seconds at full power history.

Header measured temperature and pressure were imposed as boundary conditions in the TMDPVOL representing the main feedwater source.

Auxiliary feedwater mass flow and temperature were not recorded in plant. Design values of 95 Kg/s and 300 K, respectively, were taken, assuming the performance of two motorpumps and the turbopump. The auxiliary feedwater started by low-low steam generator level signal. In the simulation, this system was activated 18.6 seconds after the turbine trip, according to plant data.

The abnormal demand signals for steam dump banks 1 and 2 were considered a malfunction of the Signal Acquisition System and given no credit. Nevertheless, a run performed imposing these demand signals as boundary conditions showed small influence on the general transient evolution. This fact is also stated as one of the conclusions in the TRAC analysis by UITESA [8]. The response of these valves was supposed as follows :

- After the "trip open" signal, 3.9 seconds to open.
- After modulation signal, 5 seconds to fully open (or to fully close).

The steam dump capacity was adjusted to 30% of the full power steam mass flow at nominal pressure.

According to recorded data, there was a partial opening demand for one of the three relief valves during a few seconds. The secondary pressure in that loop was slightly higher than in the other two, and the pressure setpoint was reached. In the simulation this relief was not included, because the steam mass so released was negligible in comparison with steam dump flow.

5.2 TRANSIENT RESULTS .

The simulation was initiated from the already described steady state. The calculated sequence of events is compared with the measured one in Table III.

The steam dump demand signals were given no credit from 10.5 seconds on. So, some signals on the Table III have been derived from the recorded average temperature.

The plant data which appear in the figures are mean values of the three loops. No data uncertainty was available. Some calculation results have been filtered. The hot and cold leg temperatures are filtered by means of a 4 seconds LAG to evaluate the average temperature recorded by the control systems. The steam generator level, feedwater mass flow and steam mass flow, are lagged 0.25 seconds.

The turbine valve began to close at 0. seconds, and reactor scrammed. Steam line pressure rose, and steam flow decreased, until steam dump valves opened.

Fig. 2 compares the calculated reactor power with the measured neutronic flux.

The vapour generation in the boiler decreased following the primary-to-secondary power.

The global effect was that secondary side pressure had a maximum at ≃ 6 seconds (Fig. 3). This point depends on the opening velocity and dead times of the steam dump valves. Velocities and delays assumed in the calculation are mean values derived from the measures (in trip mode) taken for each valve during the preoperational tests program.

After the scram, the heat removed through the steam dump valves quickly reduced the average temperature. Few seconds later, the valves were demanded to start closing.

In the lapse between 20 and 70 seconds the secondary pressure was underestimated. This may be attributed to an excessive steam release. The pressure took a minimum short time before the loss of recirculation in the steam generator (about 26 seconds) (Fig. 4).

Fig. 5 shows the filtered hot and cold leg temperatures, compared with the measured ones. Both are underestimated from 20 seconds on. The reason may be the overprediction of the discharge through the steam dump valves. The average temperature is compared with the plant data in Fig. 6

The calculated feed mass flow coincides fairly well with the measured one (Fig. 7). It decreased in the early seconds, due to the mismatch with the steam mass flow. However, the steam generator liquid level rapidly dropped to zero, and the valve opened again. When the narrow range level became lower than zero (Fig. 8), the mass flow remained stable until the valve tripped. That did not happen in the calculation, where the level fell faster and the mass flow became larger than the measured one. This may be attributed to the mentioned mass default in the steam generator. The trip time was well predicted, due to the good agreement between the average temperatures.

The auxiliary feedwater flow started, as imposed, 18.6 seconds after the turbine trip.

The pressurizer pressure and level are in a reasonable agreement with the plant data (Figs. 9 and 10). The level is overpredicted in about 5% . During the initial decrease in the level the calculated primary depressurization rate was slightly lower than the observed one, in coincidence with strong flashing in the upper liquid zone of the pressurizer (Fig. 11). This vapour generation was partly due to a large relative velocity between both phases (Fig. 12). A sensitivity study has been performed using the Homogeneous Equilibrium Model in the pressurizer, to elucidate the influence of the velocity slip in the depressurization rate (see section 6).

6. ADDITIONAL STUDIES .

Some additional studies were performed in this analysis. First, a model was used consisting of full-scaled components, with the exception of the hot leg, enlarged on a scale of 3:1. Second, a run was performed using the 3:1 scheme and applying the Homogeneous Equilibrium Model (HEM) to the pressurizer junctions.

6.1 STUDY 1 : FULL SCALE COMPONENTS MODEL

A study was performed to verify the influence of the spatial scaling on the analysis. A model was employed in which only the hot leg was enlarged on a scale of 3:1. The steam generator, steam line, pressurizer, reactor vessel, pump and cold leg were kept full-scaled. Two TMDPJUN were used to triplicate the primary flow entering and leaving the 1:1 cold leg. Fig.13 shows the noding diagram.

This model was built in a straightforward way, simply by connecting the separated 1:1 component models previously tested.

Results obtained in this study are showed in Figs. 14 to 17. Until 30 seconds, they are reasonably close to those of Base Case and plant. Afterwards, an excessive primary system cooling is appreciated. The consequence is a steady decrease in the pressurizer pressure and level. The reason of this trend is that in RELAP5 it is not possible to reproduce exactly the thermodynamic state of a volume through a TMDPVOL component. So, the TMDPJUN 184 was injecting water in the vessel inlet with an enthalpy lower than that of the simulated cold leg.

6.2 STUDY 2 : PRESSURIZER WITH HOMOGENEOUS MODEL.

As mentioned in 5.2, in the Base Case a primary depressurization rate slightly lower than the measured one was observed. This was attributed to the strong flashing found in the upper part of the pressurizer. Such a vapour generation stems mainly from the superheated liquid in that upper zone.

RELAP5/MOD2 calculates the bulk vapour generation through some interfacial heat transfer coefficients, which are flow regime dependent [2]. These coefficients are proportional to the interfacial area per unit volume, and this area is, for bubbly flow, proportional to the void fraction and to the square of the phasic relative velocity. Fig. 12 shows the relative velocity between the phases in the upper liquid zone of the pressurizer, and indicates that the volumetric interfacial area took a maximum in the early seconds of the transient.

To check the influence of the phasic relative velocity on the depressurization rate, a run was performed using the 3:1 scheme and applying the Homogeneous Equilibrium Model (HEM) to the pressurizer junctions (by setting h = 2 in the junction flags). This action should eliminate the flashing due to the velocity slip effect.

The results of this case were not better than those of Base Case. Fig. 18 compares the vapour generation in pressurizer obtained with this model with the Base Case result. The main effect of the HEM use was the suppression of a peak at about 5 seconds, due to velocity slip. Nevertheless, the pressure slope (Fig. 19) basically did not improve with this change.

7. RUN STATISTICS .

The calculations were run on a CDC CYBER 830, owned by the CSN. The operating system was NOS 2.7 . The code cycle used was 36.04.

Table IV shows the run statistics for the steady-state run, the Base Case and the additional studies. In transient runs, it was specified a maximum time step of 0.05 seconds, lower than the Courant limit (about 0.06 seconds throughout the transient). So the code always used this maximum value. In the steady state run, the code reduced the time step to 0.025 seconds. The reason was an incorrect initialization in the nodes representing the steam dump discharge pipe, which reduced the Courant limit under 0.05 s.

The CPU time to transient time ratio has been around 42 (91. for the steady state run). The grind time was among 17.5 and 18. miliseconds .

The CPU time and time step are plotted versus transient time in Fig. 20 and 21, respectively, for Base Case.

8. CONCLUSIONS .

Three calculations have been performed, and the results are in reasonable agreement with the plant measurements.

The steam dump demand uncertainty has not affected significantly the results.

The first additional study reveals that a model consisting of full-scaled components , one loop and Time Dependent Junctions that triplicate the primary flow, reproduces the 3:1 model trends. But this model is unrealistic because the code cannot replicate exactly the thermodynamic state of a volume through a TMDPVOL component.

The second additional study shows that the use in this analysis of Homogeneous Equilibrium Model in pressurizer does not alter substantially the primary pressure evolution.

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TABLE I

MAIN CHARACTERISTICS OF VANDELLOS II PLANT.

Thermal Reactor Power (MWt)	2775.
Electrical Power (MWe)	992.
Fuel	UO2
Number of assemblies	157
Number of coolant loops	3
Cladding Tube Material	ZIRCALOY 4
Absorber Material	B4C + Ag-In-Cd
Reactor Operating Pressure (MPa)	15.4
Coolant Average Temperature	
Zero Load (K)	564.8
100% Load (K)	582.3
Steam Generator	WESTINGHOUSE TYPE F
Number of tubes in SG	5626
Total Tube Length (m)	98759.
Inner Diameter Tubes (m)	0.0156
Tube Material	INCONEL
Pumps Type	WESTINGHOUSE D 100
Discharge Head of Pumps (bar)	18.8
Design Flow Rate (m3/s)	6.156
Speed of Pumps (rad/s)	155.
Primary Volume (m3)	106.19
Pressurizer Volume (m3)	39.65
Heating Power of the Heaters Rods (KW)	1400.
Maximum Spray Flow (Kg/s)	44.2
Steam Mass Flow Rate at 100% (Kg/s)	1515.

TABLE II

STEADY STATE VALUES

PARAMETER	MEASURED ‡	CALCULATED	
PRIMARY SIDE			
Core Power (%)	99.1	99.8	(*)
Mass Flow Rate (Kg/s)	----	14602.	
RCP Speed (Rad/s)	----	158.2	
RCP Head (MPa)	----	0.645	
Hot Leg Temperature (K)	597.3	596.8	
Cold Leg Temperature (K)	564.1	563.7	
Average Temperature (K)	580.7	580.2	
Delta T (%)	99.4	99.2	
Pressurizer Pressure (MPa)	15.41	15.33	(*)
Pressurizer Level (%)	57.2	56.7	(*)
SECONDARY SIDE			
SG Dome Pressure (MPa)	----	6.69	
SG Outlet Pressure (MPa)	6.5	6.59	
Collector Pressure (MPa)	6.35	6.56	
Feedwater Mass Flow (Kg/s)	1542.9	1513.2	
Steam Mass Flow (Kg/s)	1471.8	1514.2	(*)
Feedwater Temperature (K)	494.1	493.3	(*)
SG Level (%)	50.5	50.	(*)
Recirculation Ratio	----	2.29	

‡ Average values.

(*) Controlled or imposed parameters.

T A B L E III

SEQUENCE OF EVENTS .

EVENT	TIME (SECONDS) PLANT	RELAP5/MOD2 BASE CASE
TURBINE TRIP	0.0	0.0
REACTOR TRIP	---	0.0
STEAM DUMP DEMAND SIGNALS:		
TO TRIP OPEN (4 BANKS)	0.1	0.0
TO START CLOSING BANK 4	3.5	3.5
TO START CLOSING BANK 3	5.8	5.0
TO START CLOSING BANK 2	8.4	8.0
TO START CLOSING BANK 1	11.8 (*)	12.5
LOW-LOW LEVEL IN SG.	7.0	8.4
LOW AVERAGE TEMPERATURE	18.5	18.2
MAIN FEEDWATER TRIP	19.0	18.2
AUXILIARY FEEDWATER INJECTION	---	18.6
STEAM DUMP VALVES FULLY CLOSED	---	38.5

(*) According to average temperature program.

TABLE IV

RUN STATISTICS

CALCULATION	TT (S)	CPU (S)	TS (S)	CPU / TT	CN	TSN	GT (mS)
Steady State	91.2	8301.8	0.025	91.0	116	4070	17.58
Base Case	100.	4190.1	0.05	41.9	116	2013	17.94
Additional Study 1	100.	4217.3	0.05	42.2	119	2023	17.52
Additional Study 2	100.	4174.2	0.05	41.7	116	2011	17.89

KEY :

TT : Transient Time
CPU : CPU Time
TS : Maximum Time Step
CN : Cells Number
TSN : Time Steps Number
GT : Grind Time (= CPU/(CN × TSN))

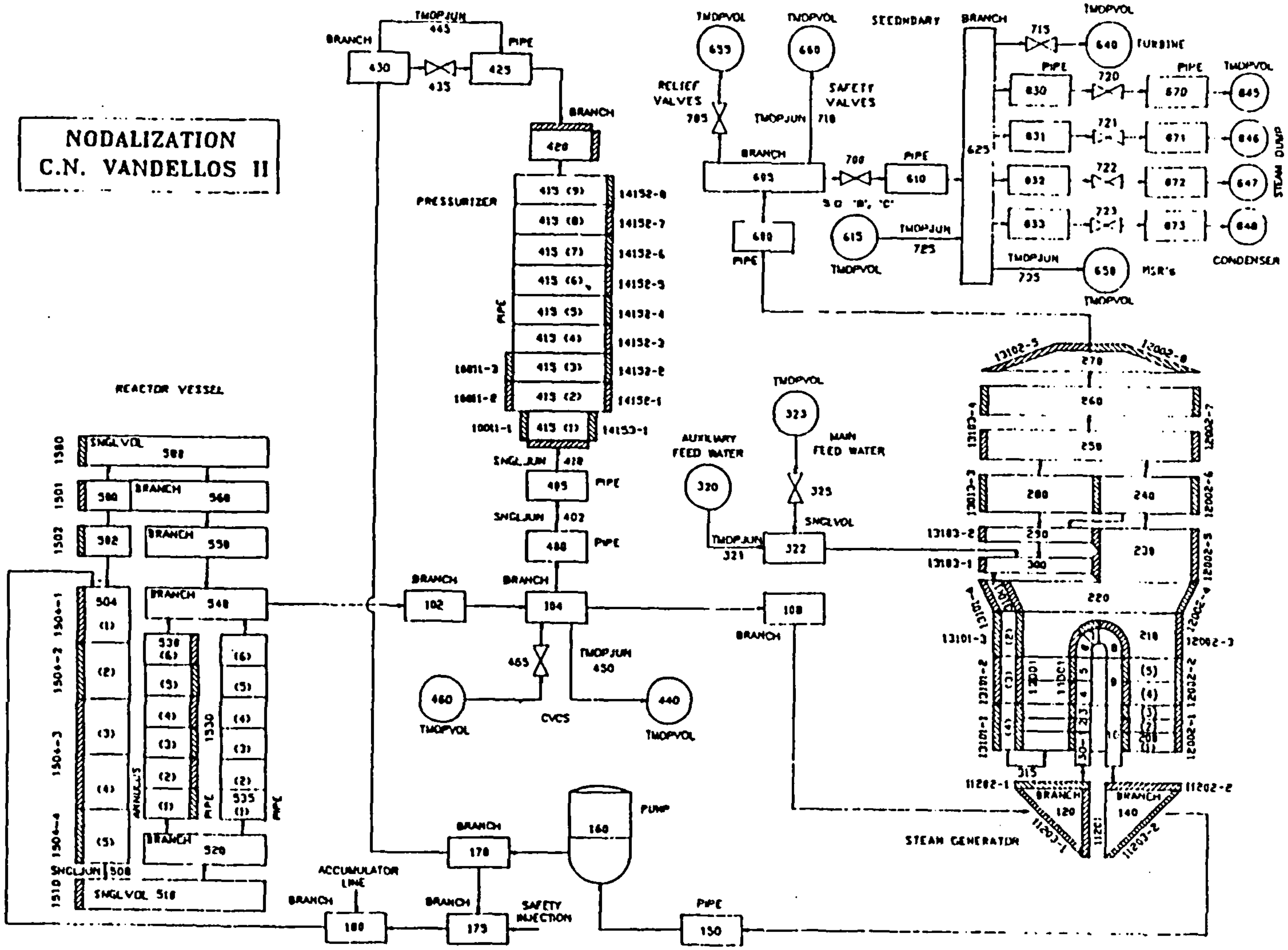

FIGURE 1. RELAP5 NODING DIAGRAM FOR VANDELLÓS II NPP.

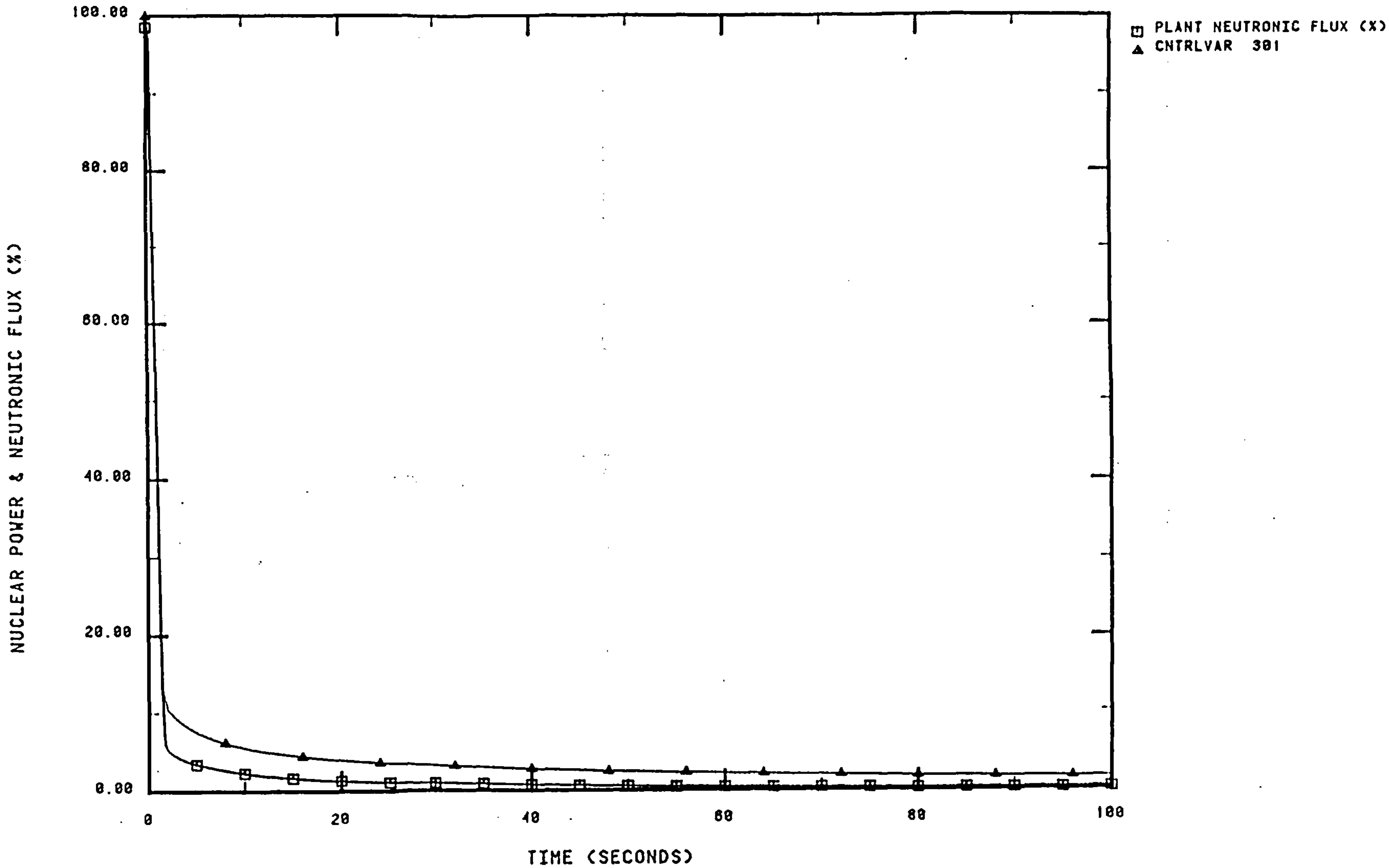

FIGURE 2. BASE CASE : REACTOR POWER.

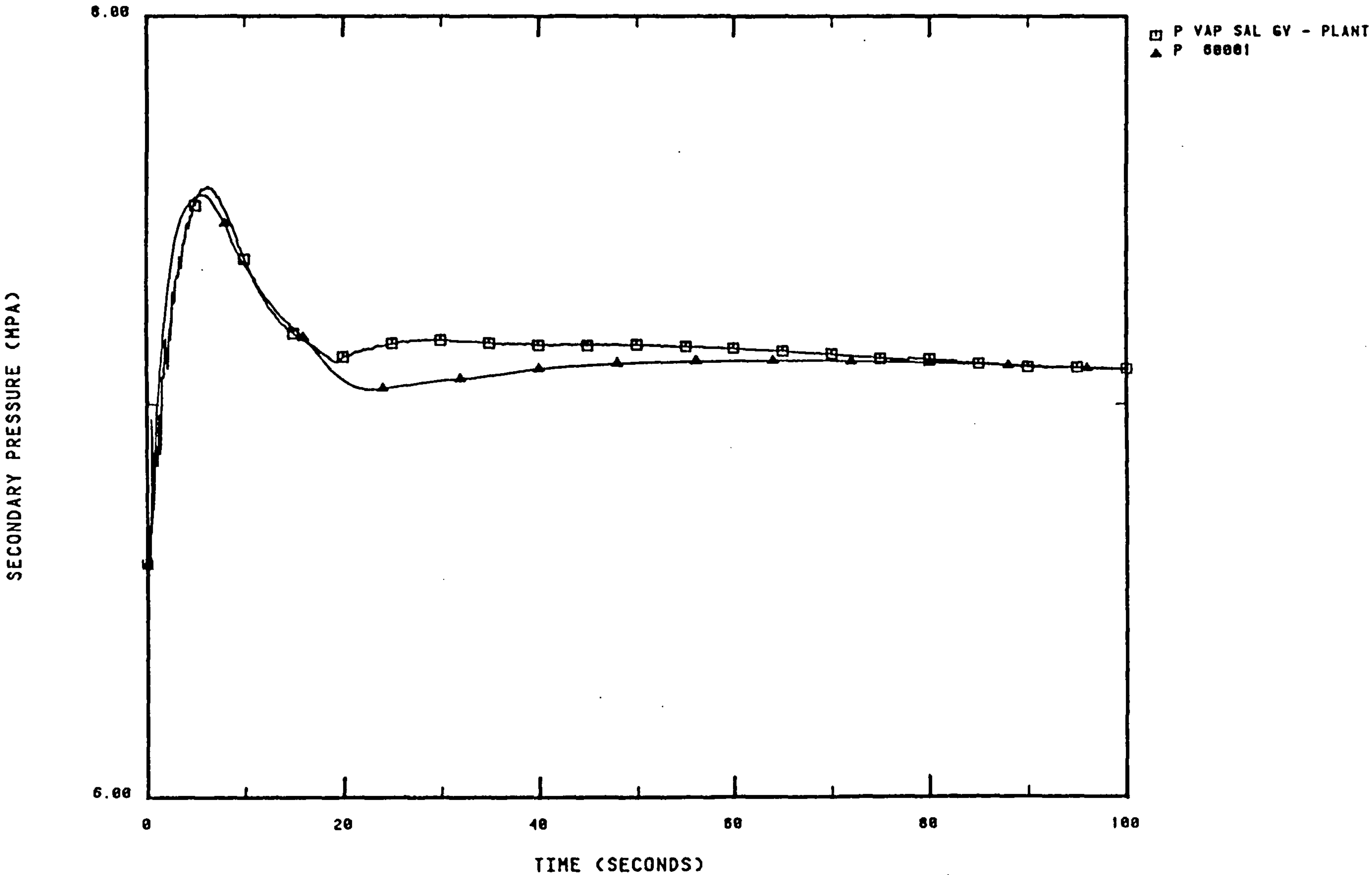

FIGURE 3. BASE CASE : SECONDARY PRESSURE.

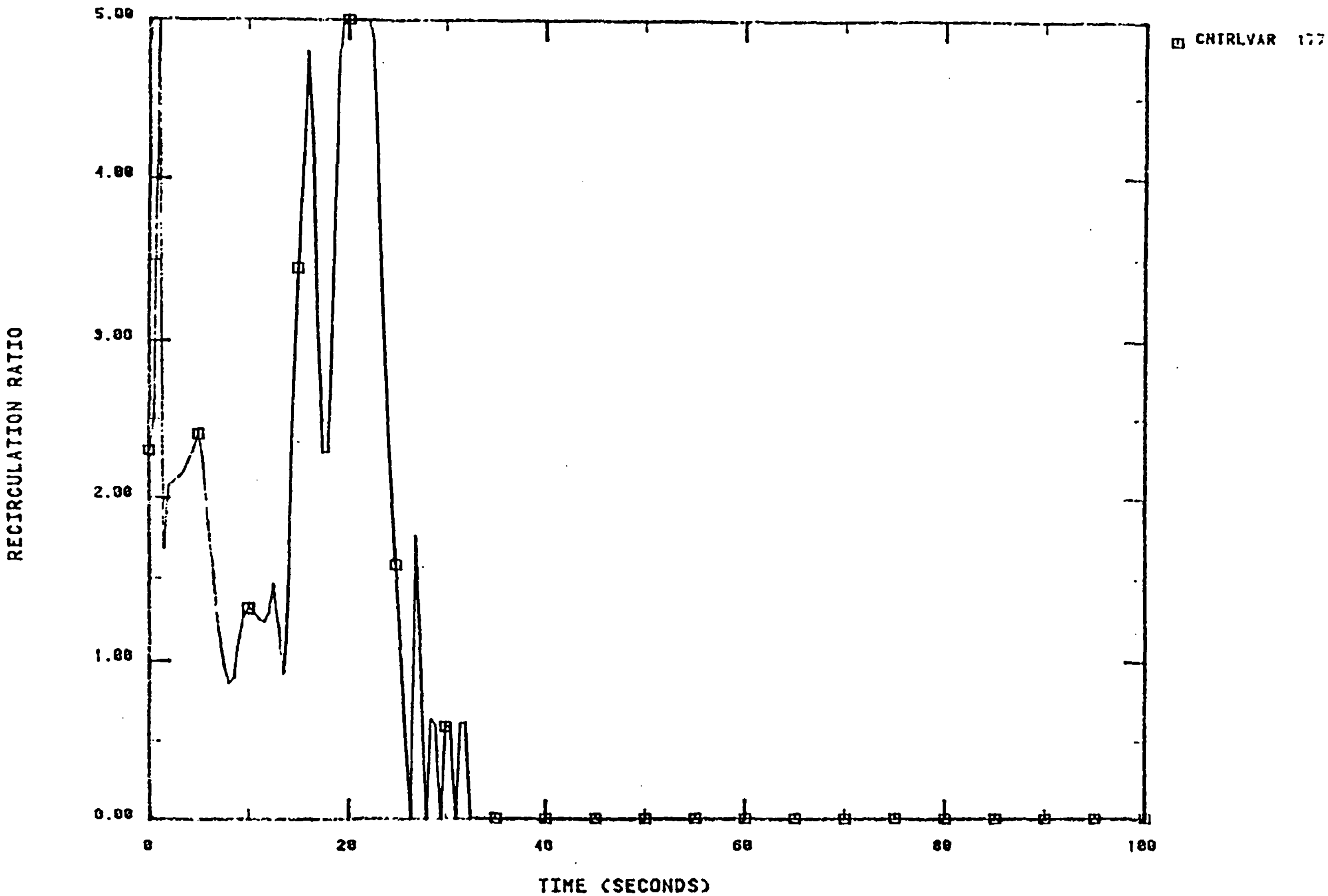

FIGURE 4 . BASE CASE : SG. RECIRCULATION RATIO .

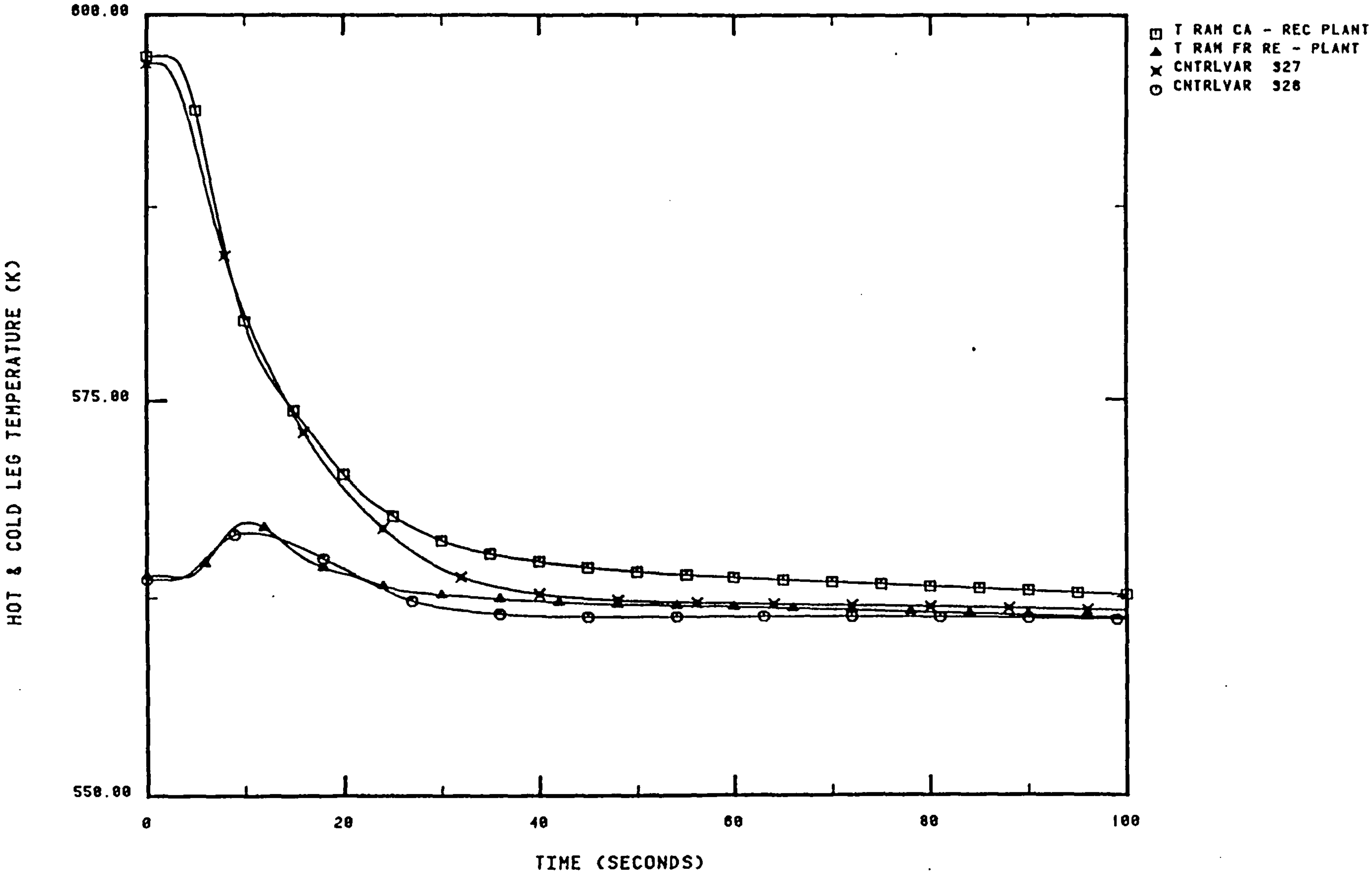

FIGURE 5. BASE CASE : PRIMARY TEMPERATURES.

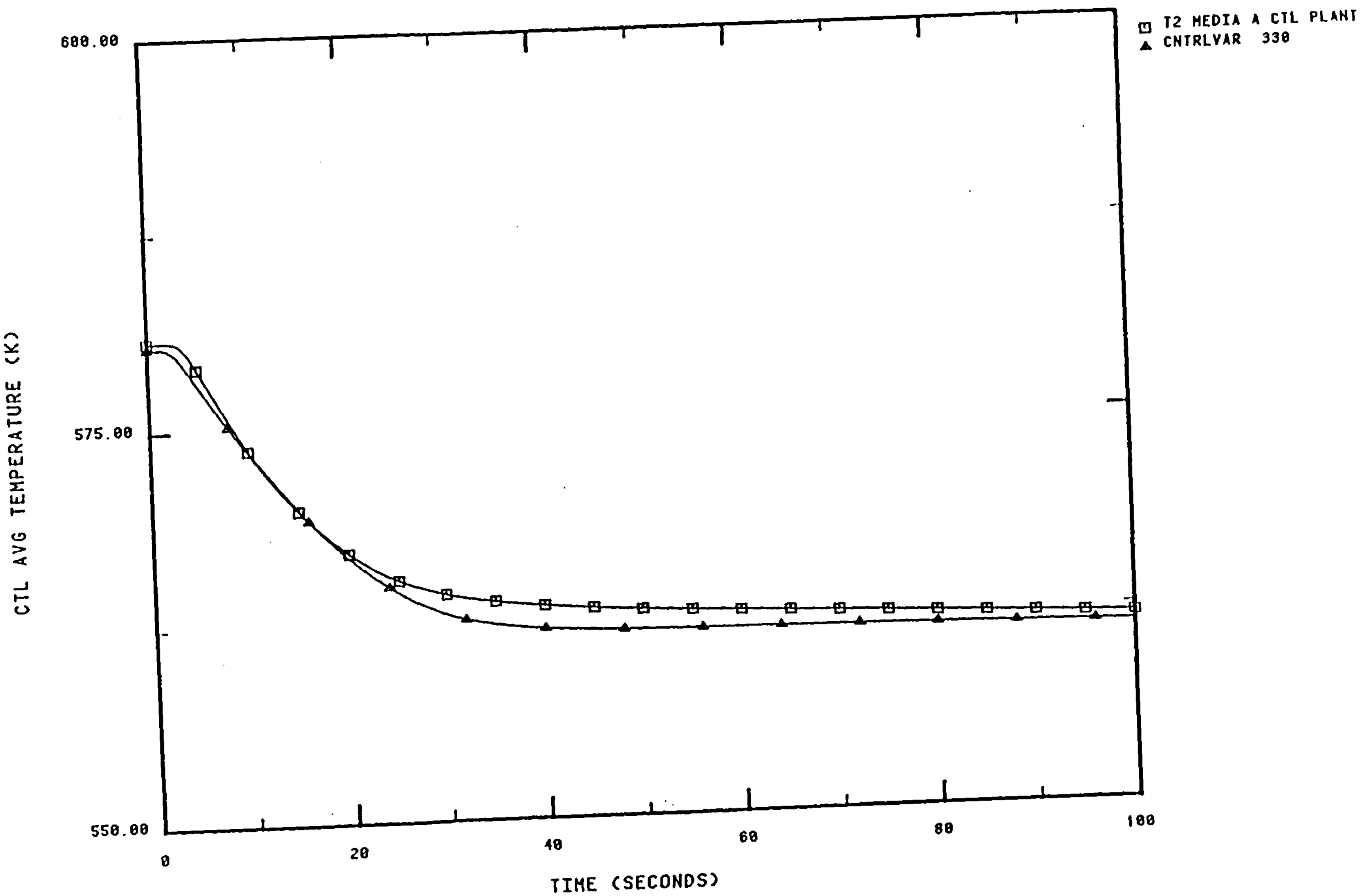

FIGURE 6. BASE CASE : PRIMARY AVERAGE TEMPERATURE

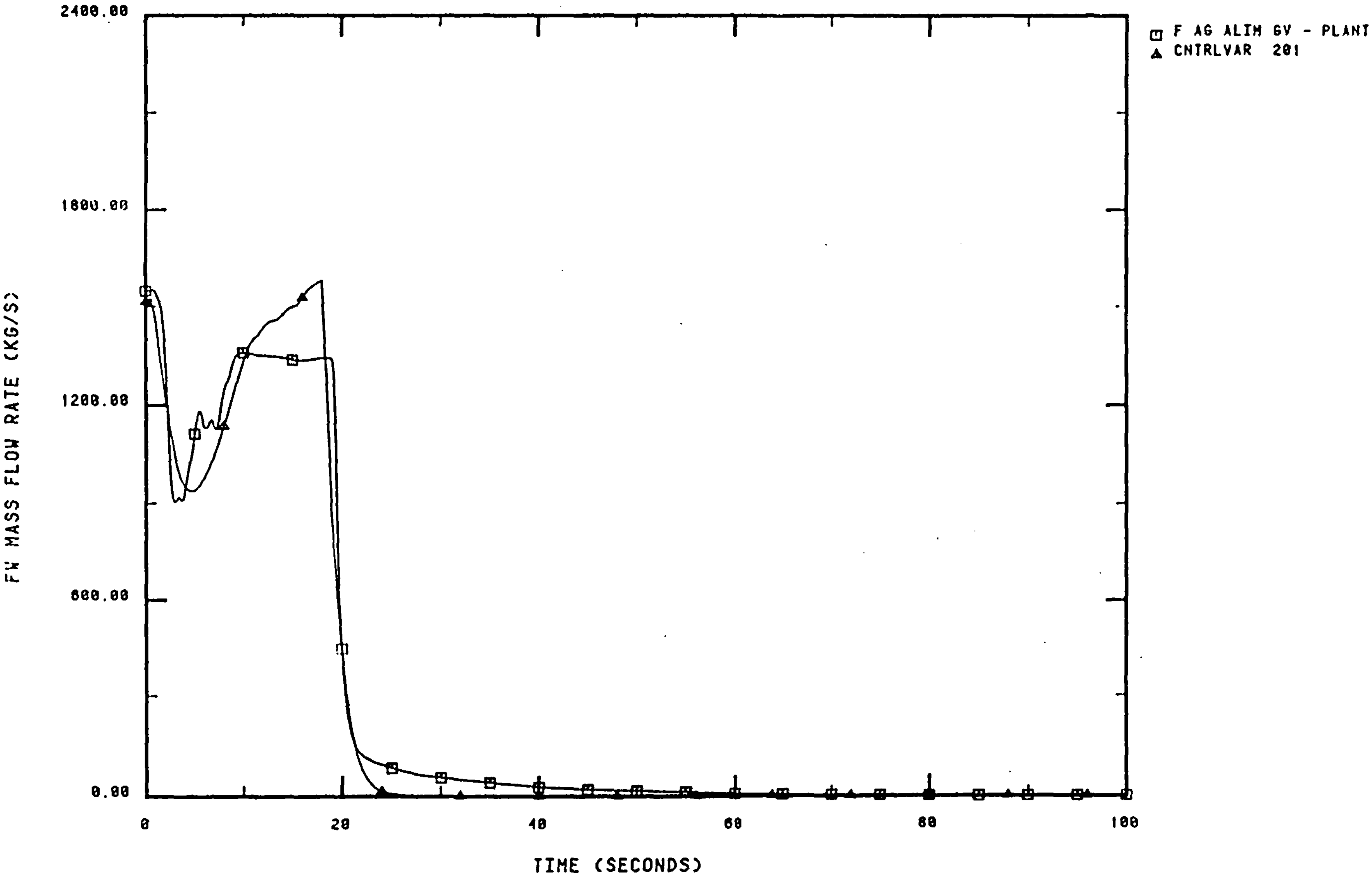

FIGURE 7. BASE CASE : FEEDWATER MASS FLOW.

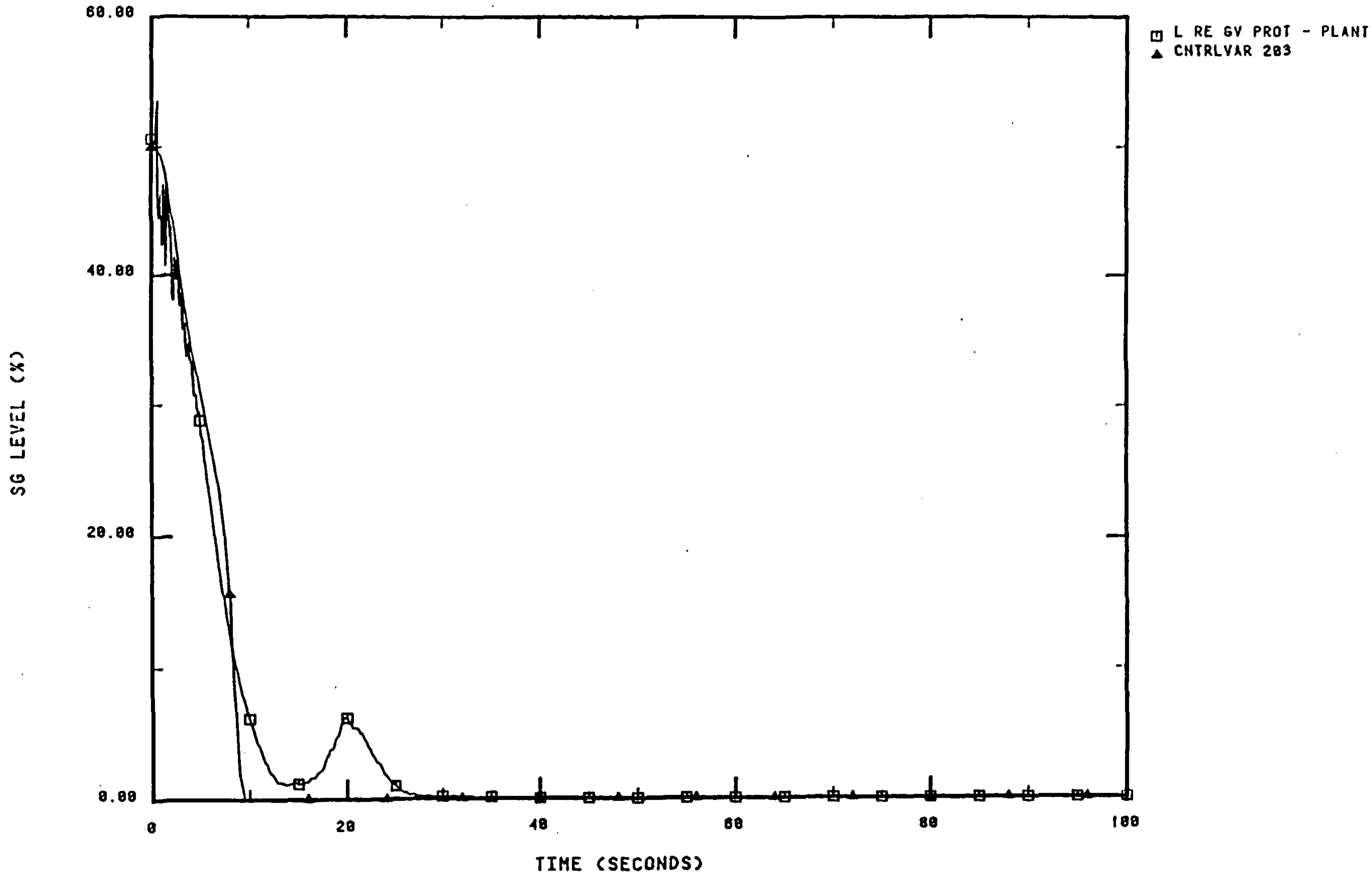

FIGURE 8. BASE CASE : SG. LEVEL.

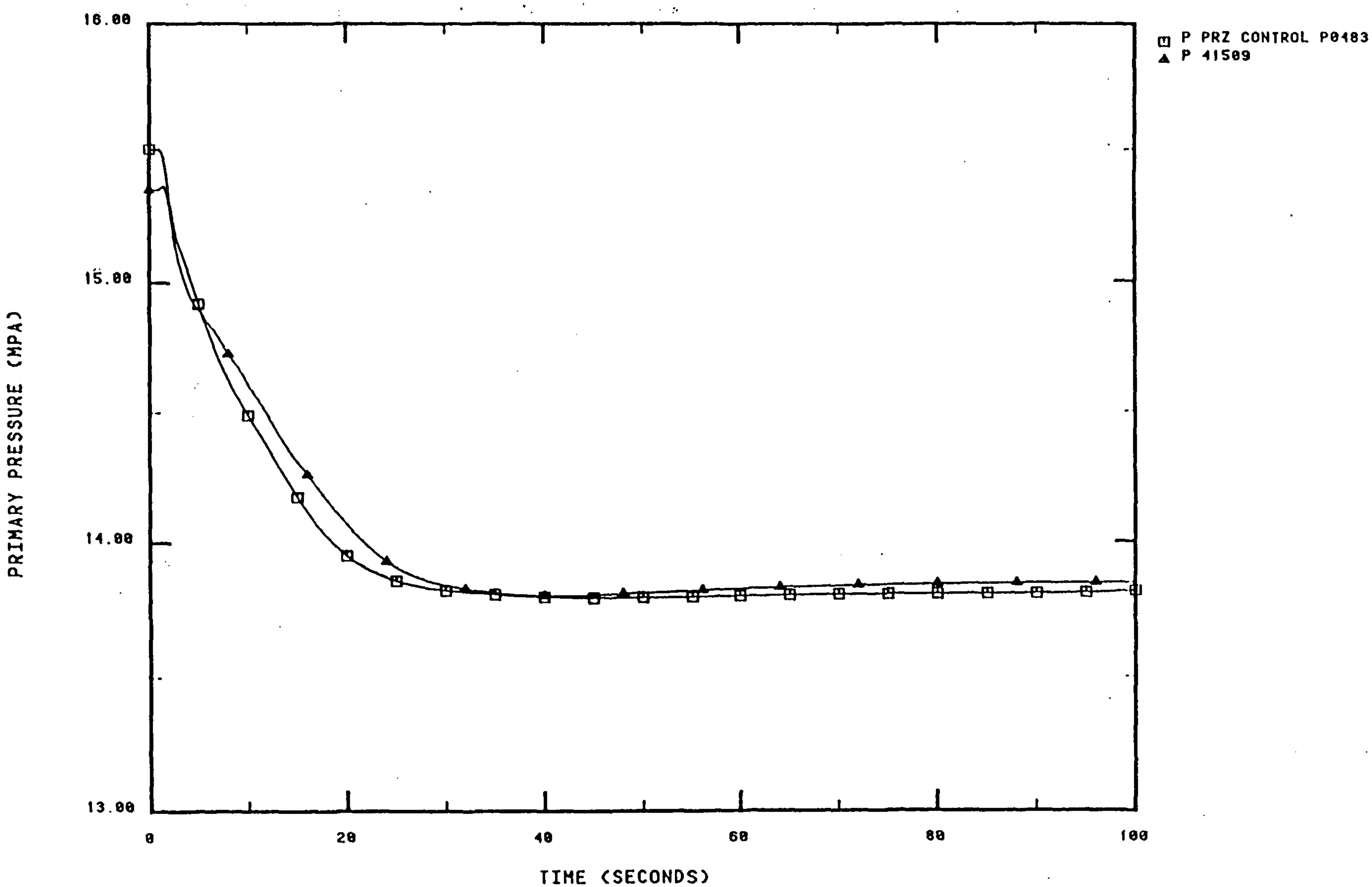

FIGURE 9 . BASE CASE : PRESSURIZER PRESSURE .

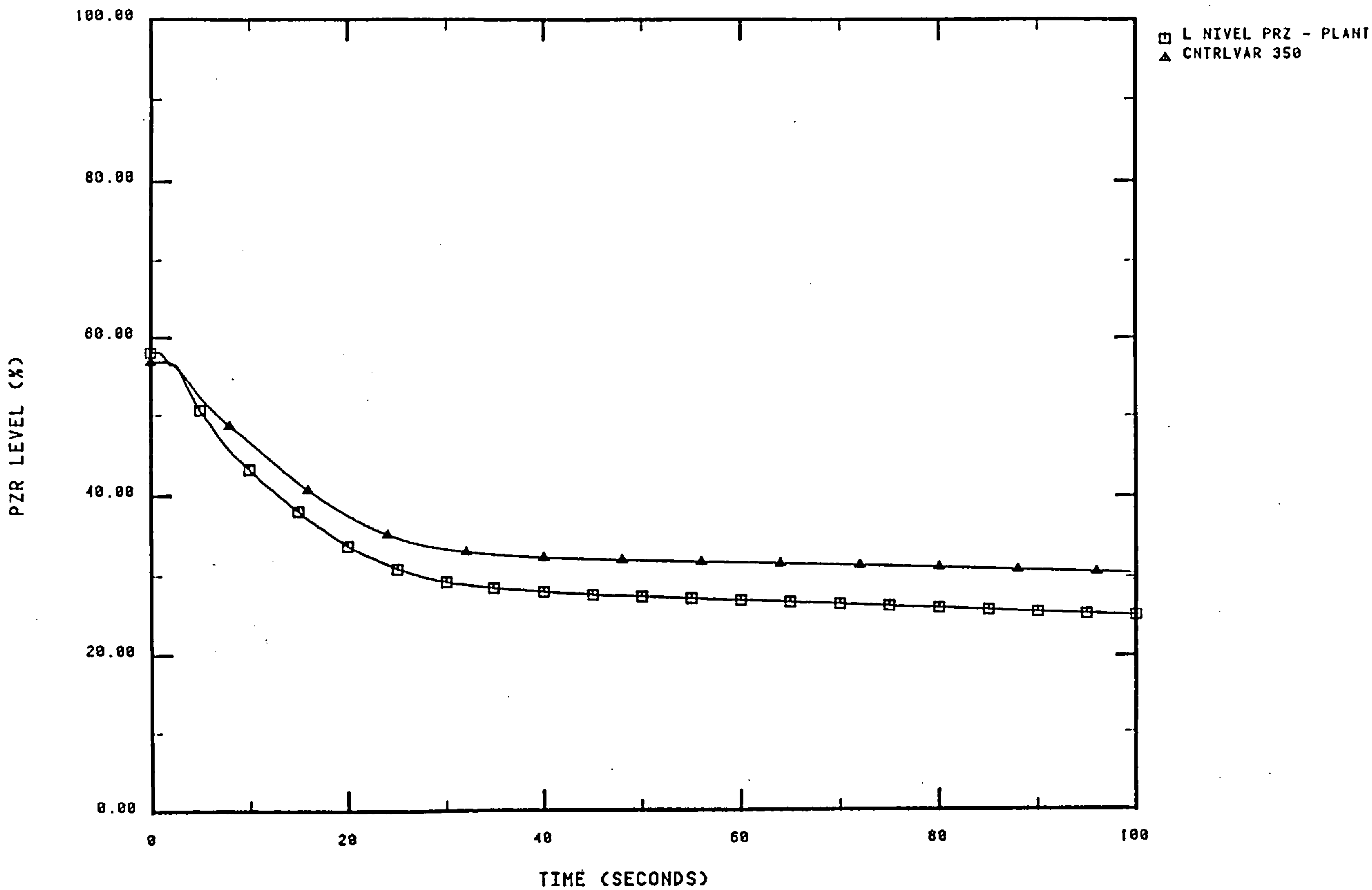

FIGURE 10 . BASE CASE : PRESSURIZER LEVEL .

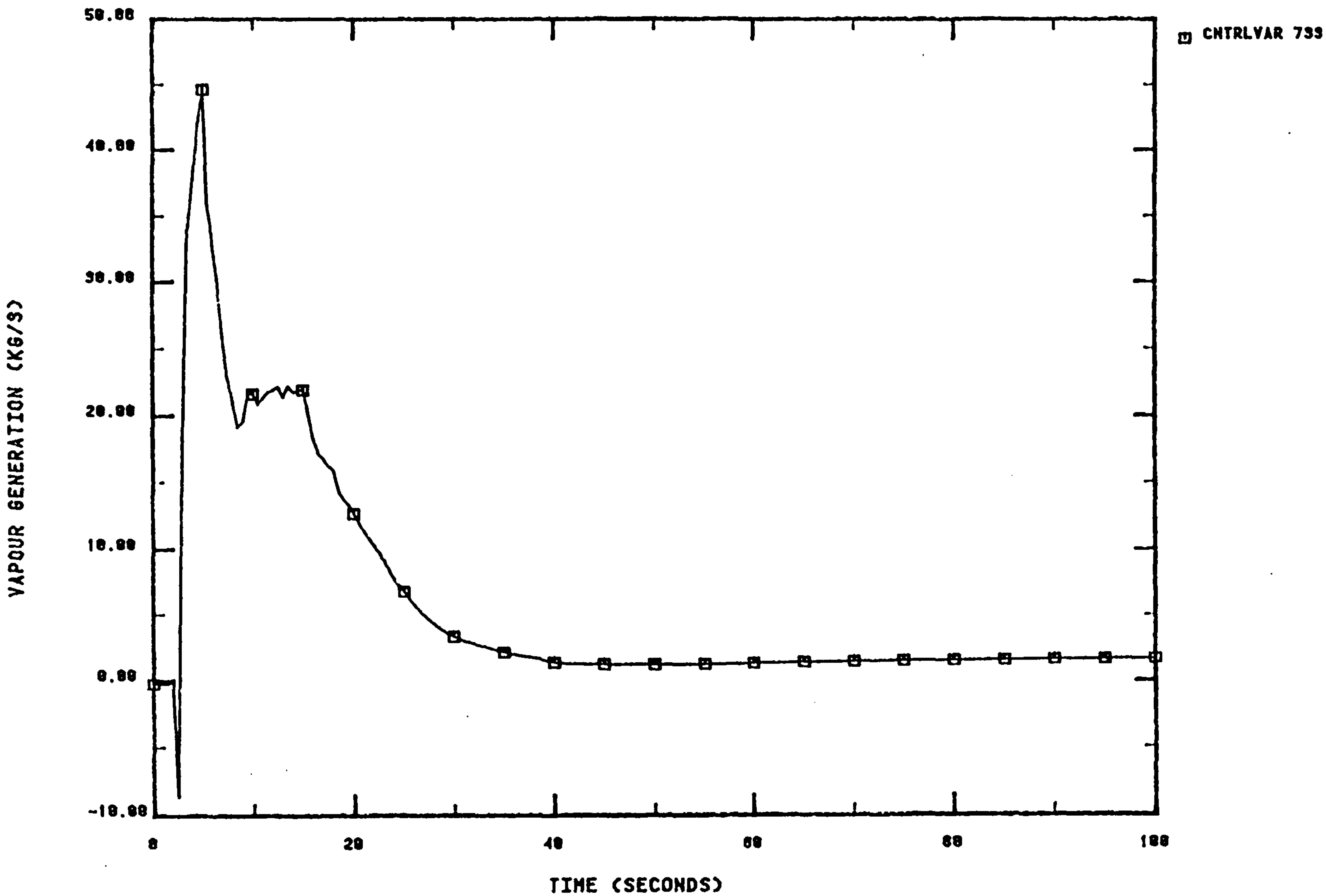

FIGURE 11. BASE CASE : PRESSURIZER VAPOUR GENERATION.

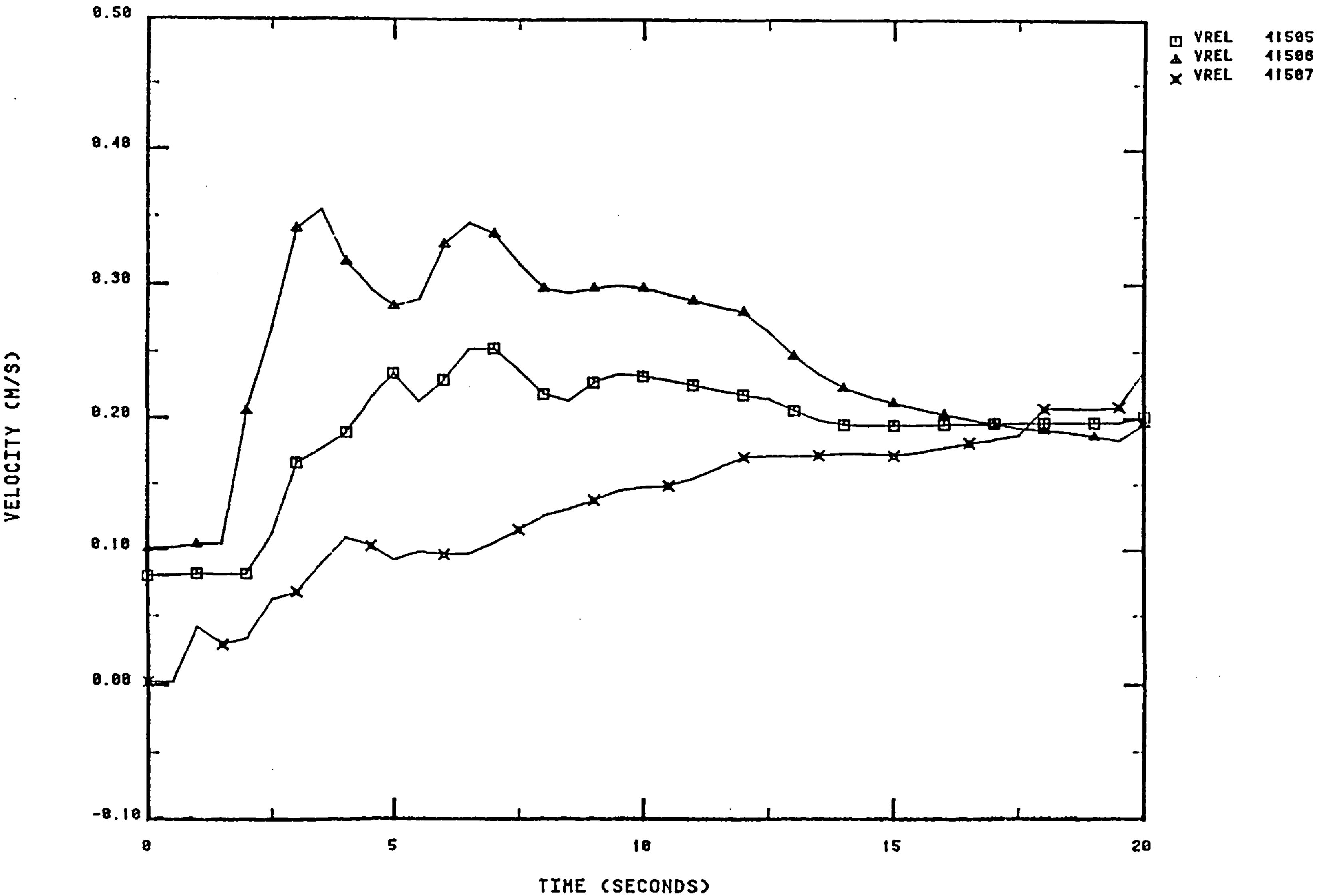

FIGURE 12. BASE CASE : PHASIC RELATIVE VELOCITY IN PRESSURIZER.

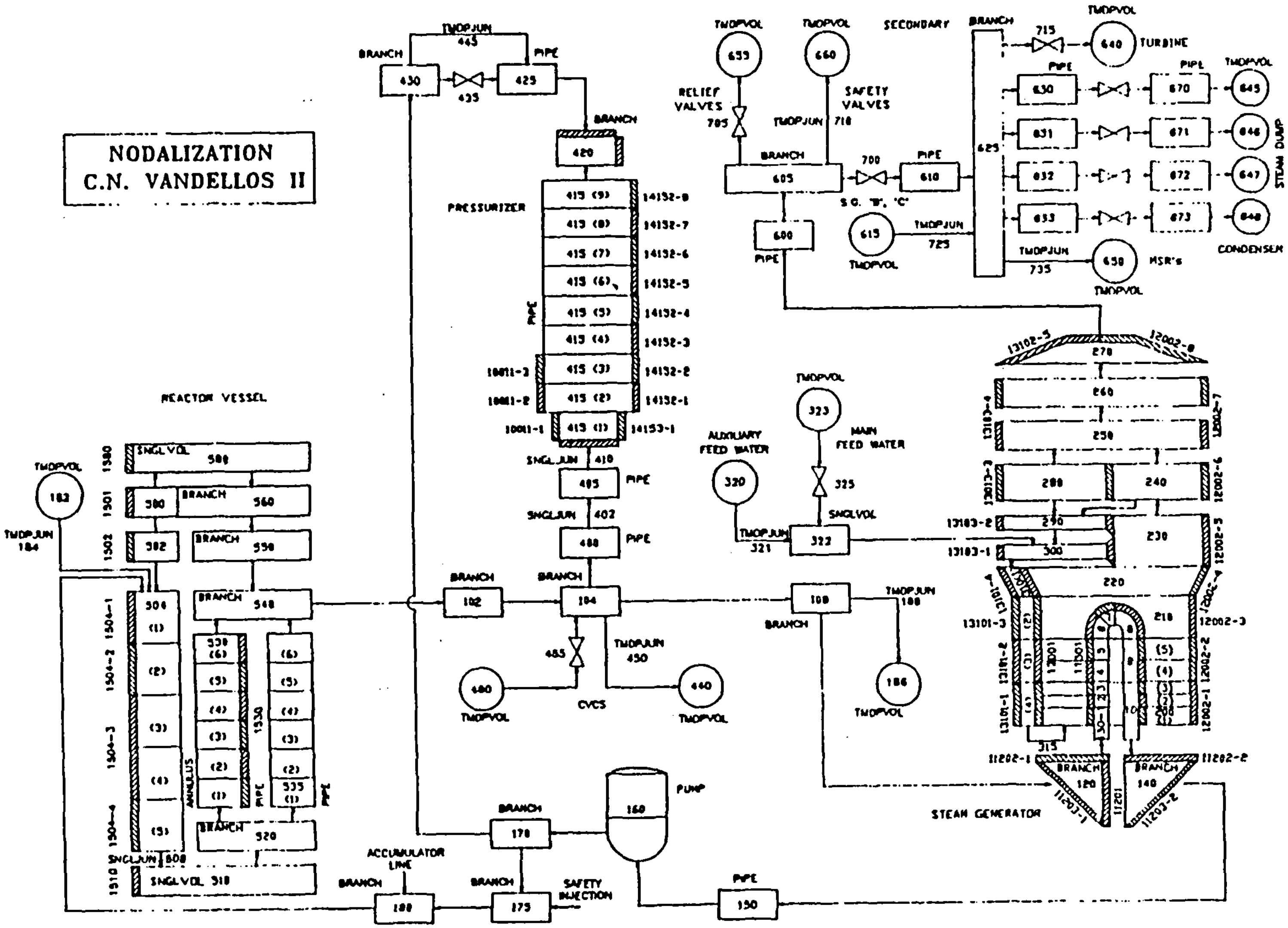

FIGURE 13 . 1ST. ADDITIONAL STUDY : NODING DIAGRAM .

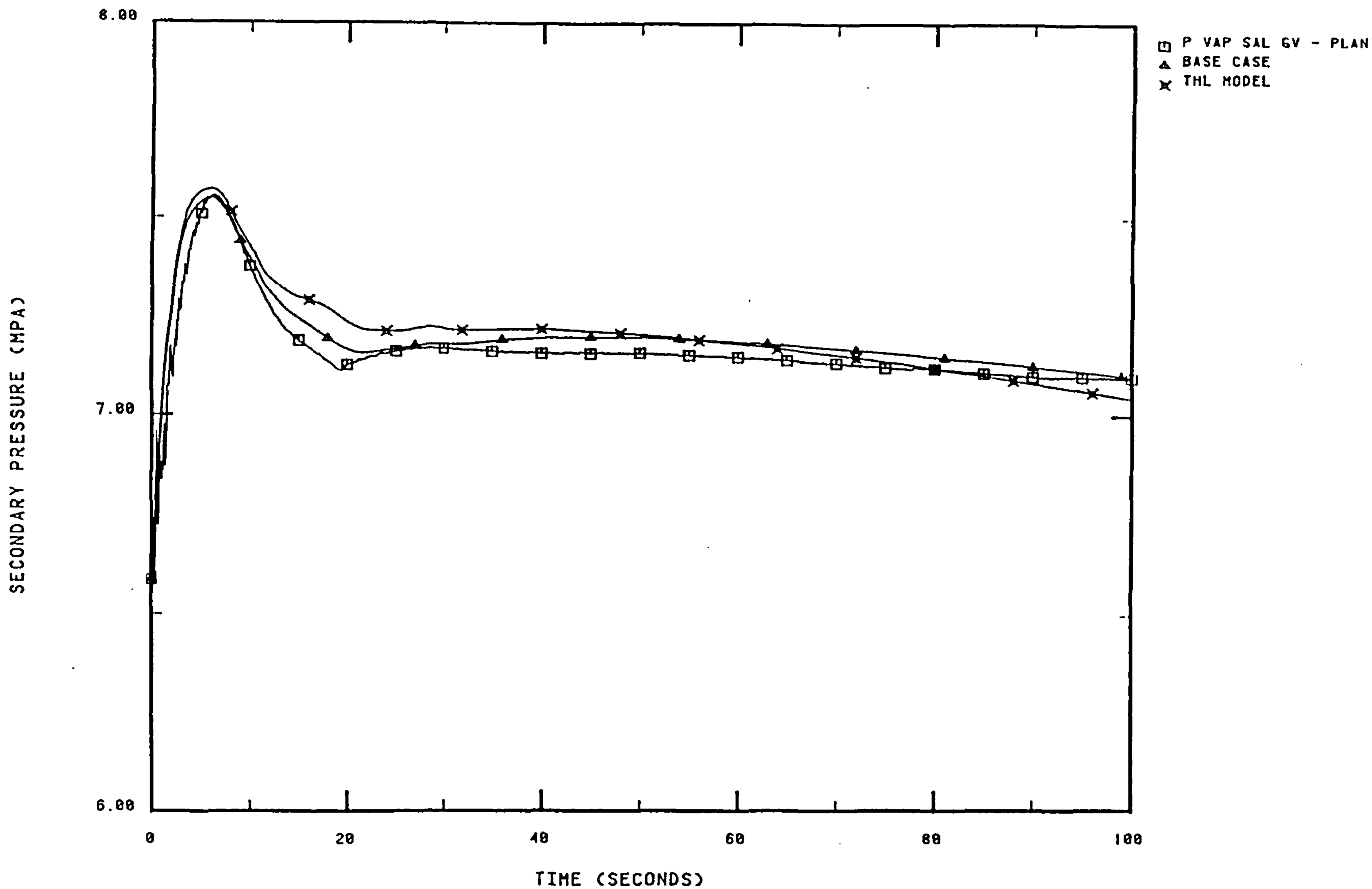

FIGURE 14 . 1ST. ADDITIONAL STUDY : SECONDARY PRESSURE .

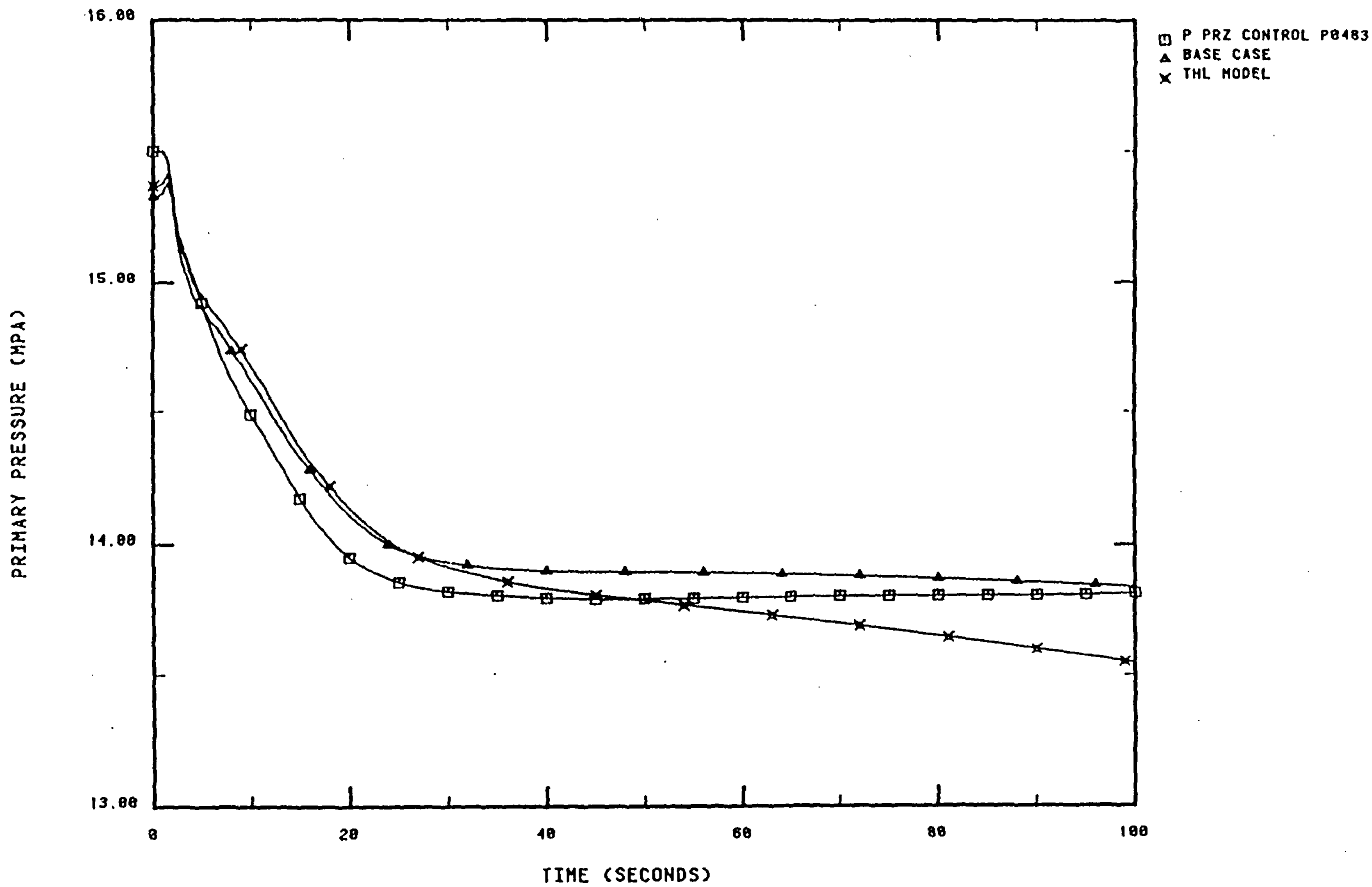

FIGURE 15 . 1ST. ADDITIONAL STUDY : PRIMARY AVERAGE TEMPERATURE

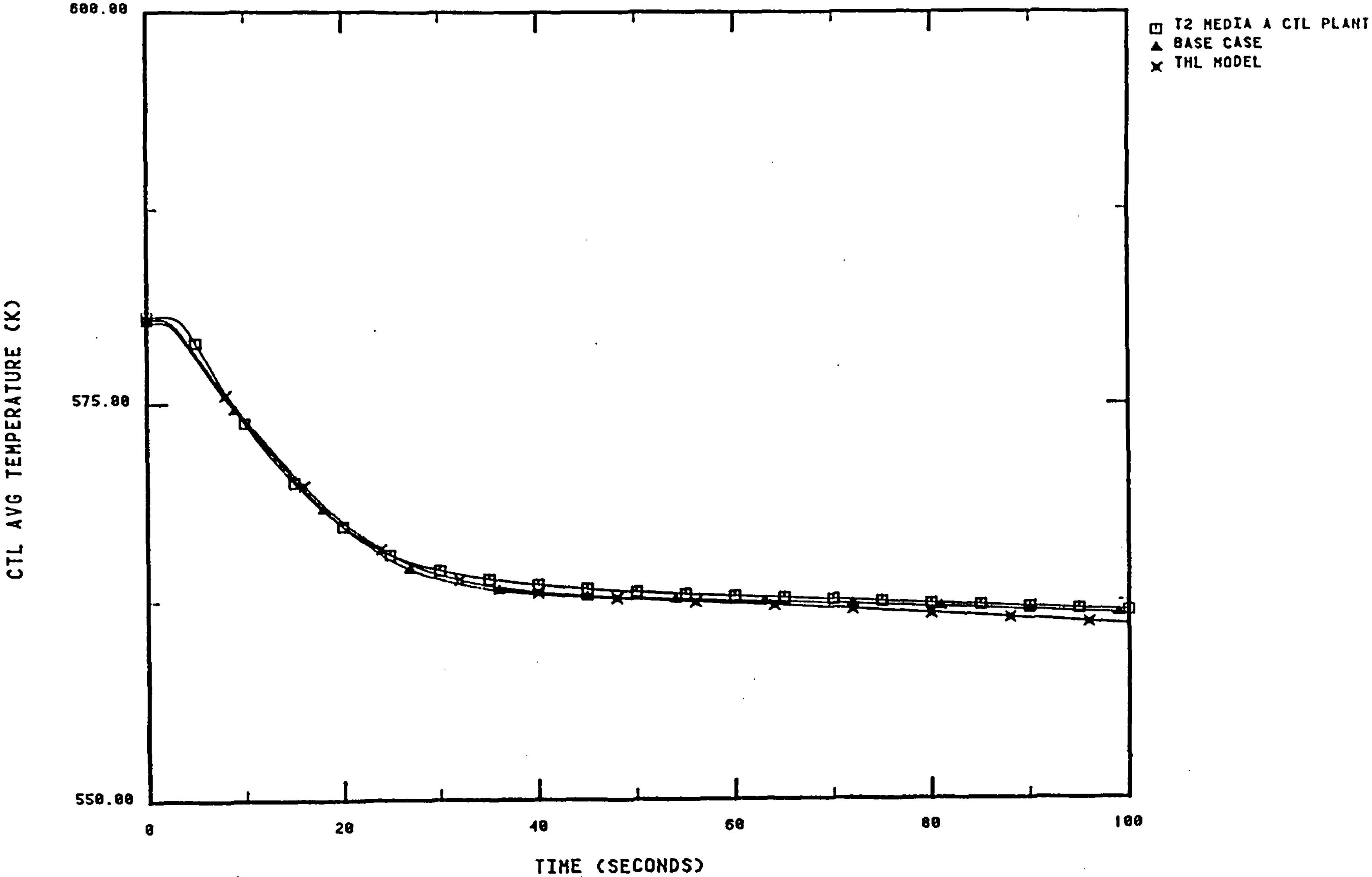

FIGURE 16 . 1ST. ADDITIONAL STUDY : PRESSURIZER PRESSURE .

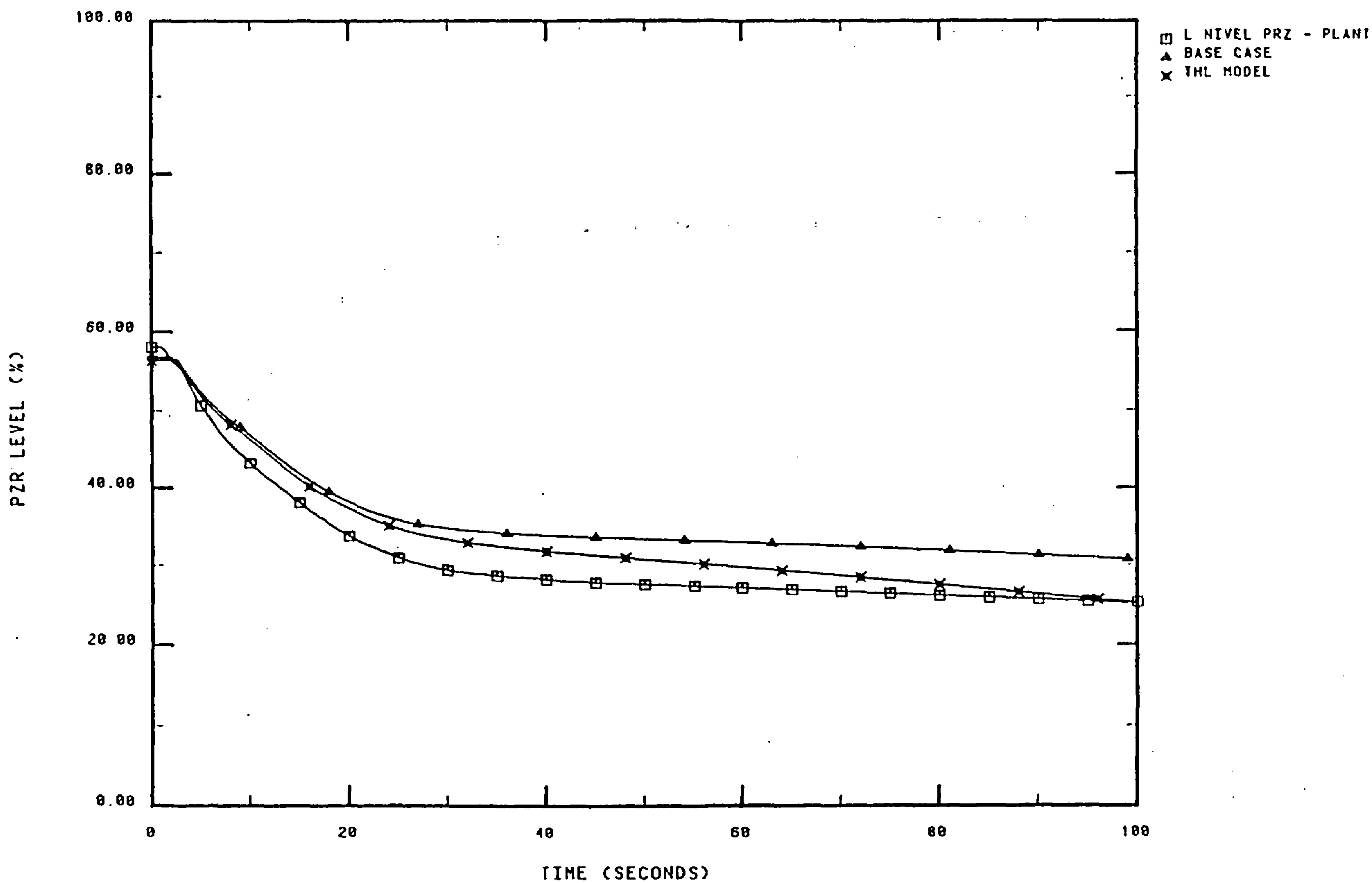

FIGURE 17 . 1ST. ADDITIONAL STUDY : PRESSURIZER LEVEL .

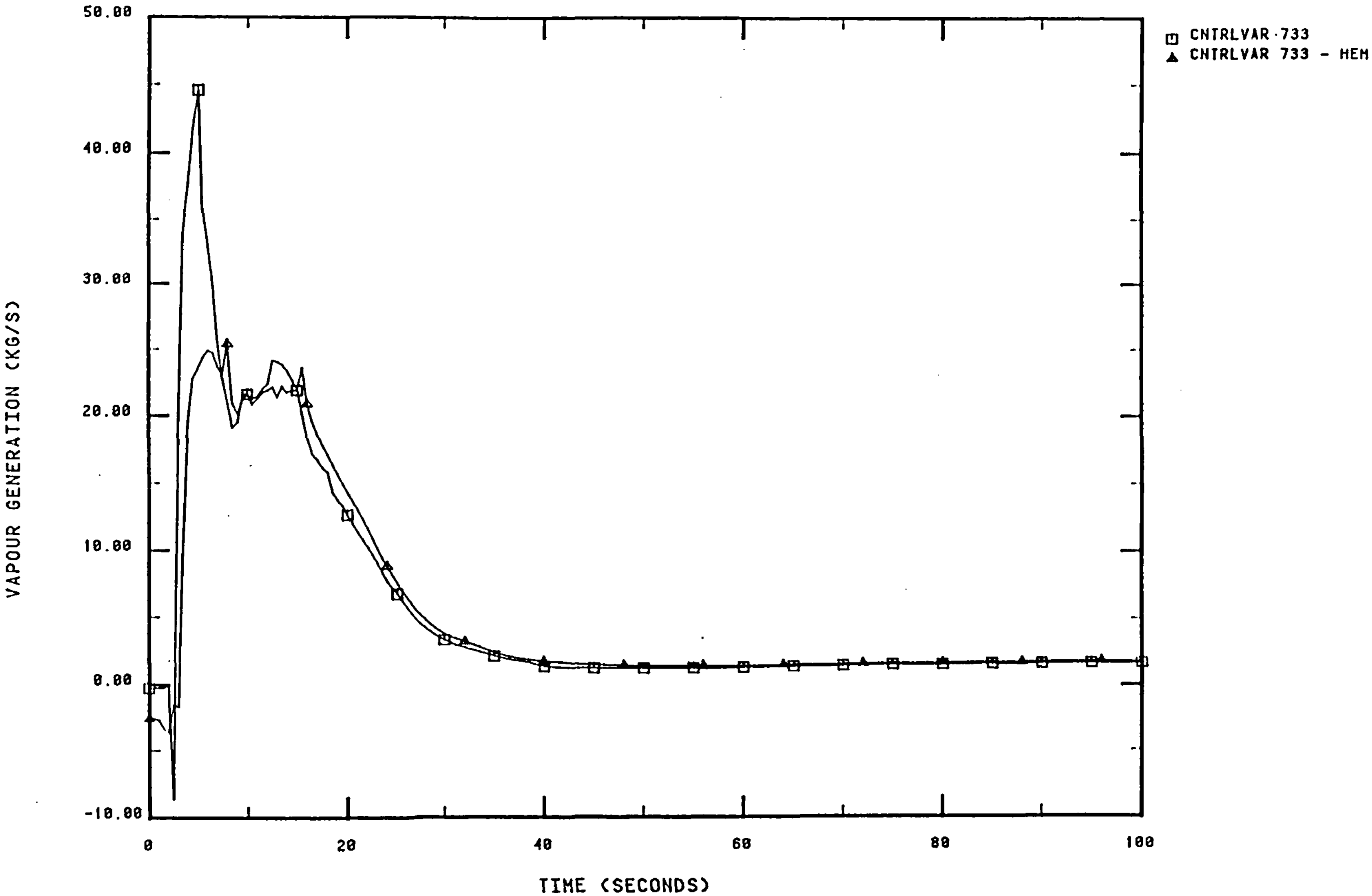

FIGURE 18 2ND ADDITIONAL STUDY : PRESSURIZER VAPOUR GENERATION .

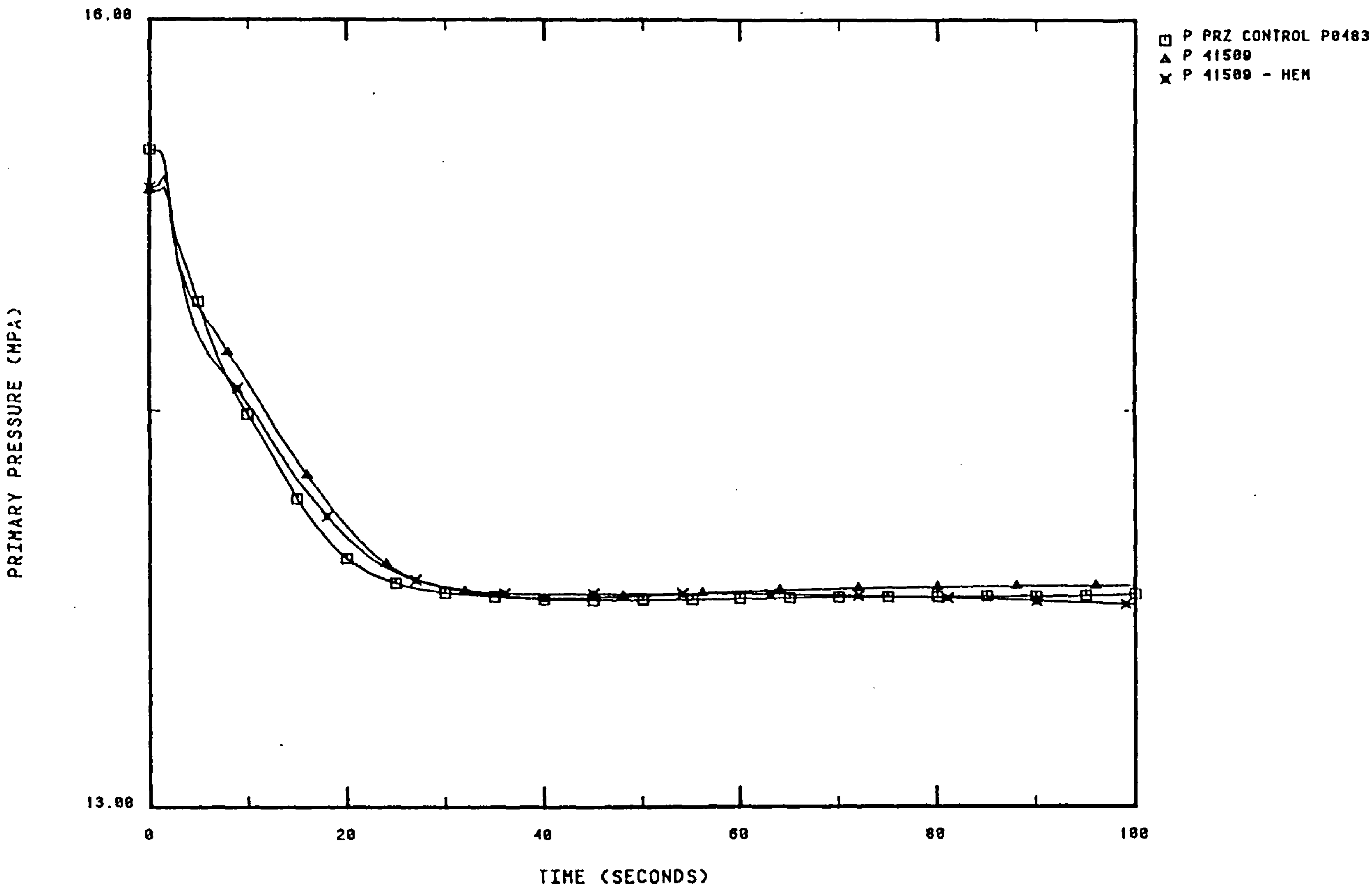

FIGURE 19 . 2ND. ADDITIONAL STUDY : PRESSURIZER PRESSURE .

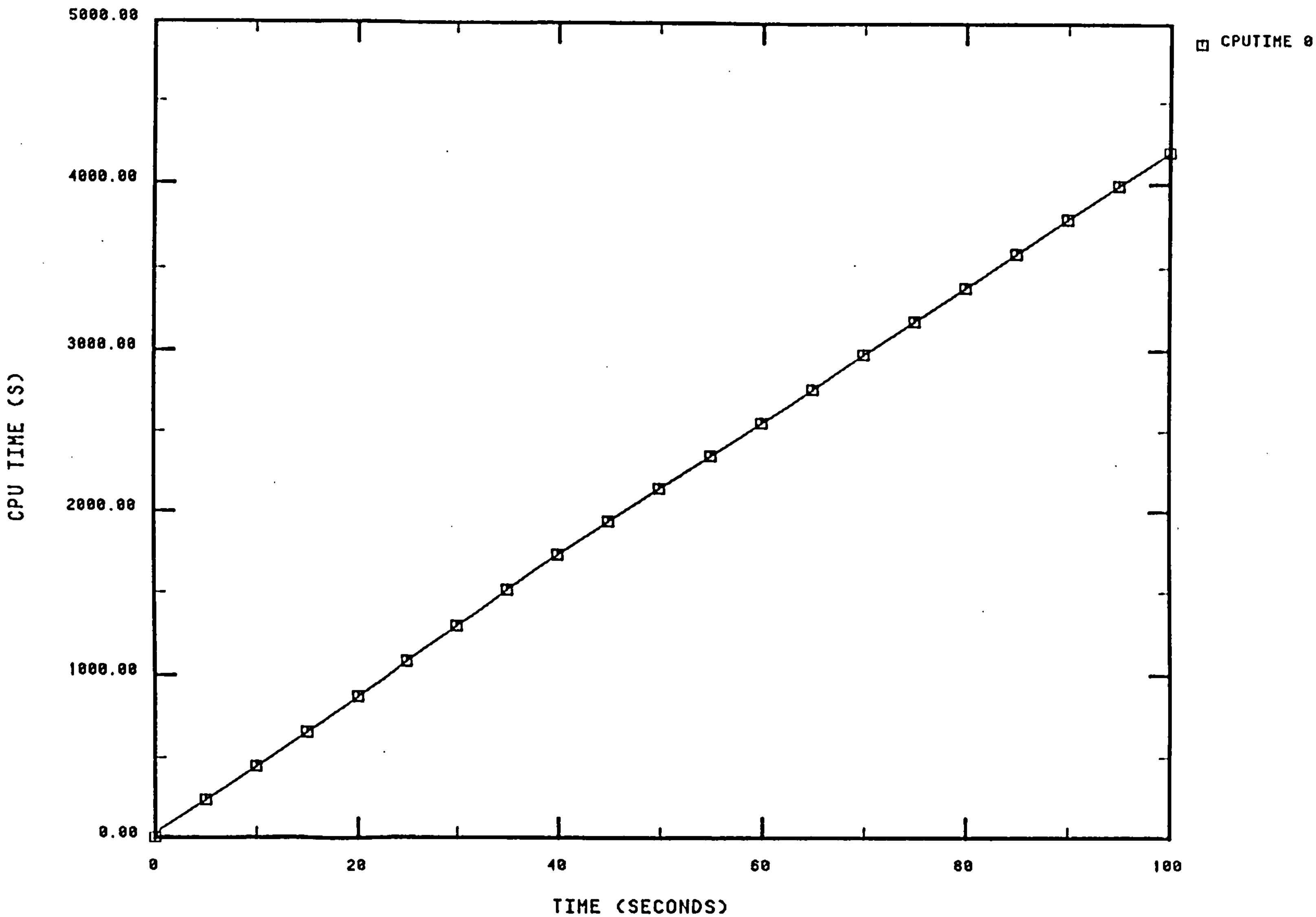

FIGURE 20 . BASE CASE : CPU TIME .

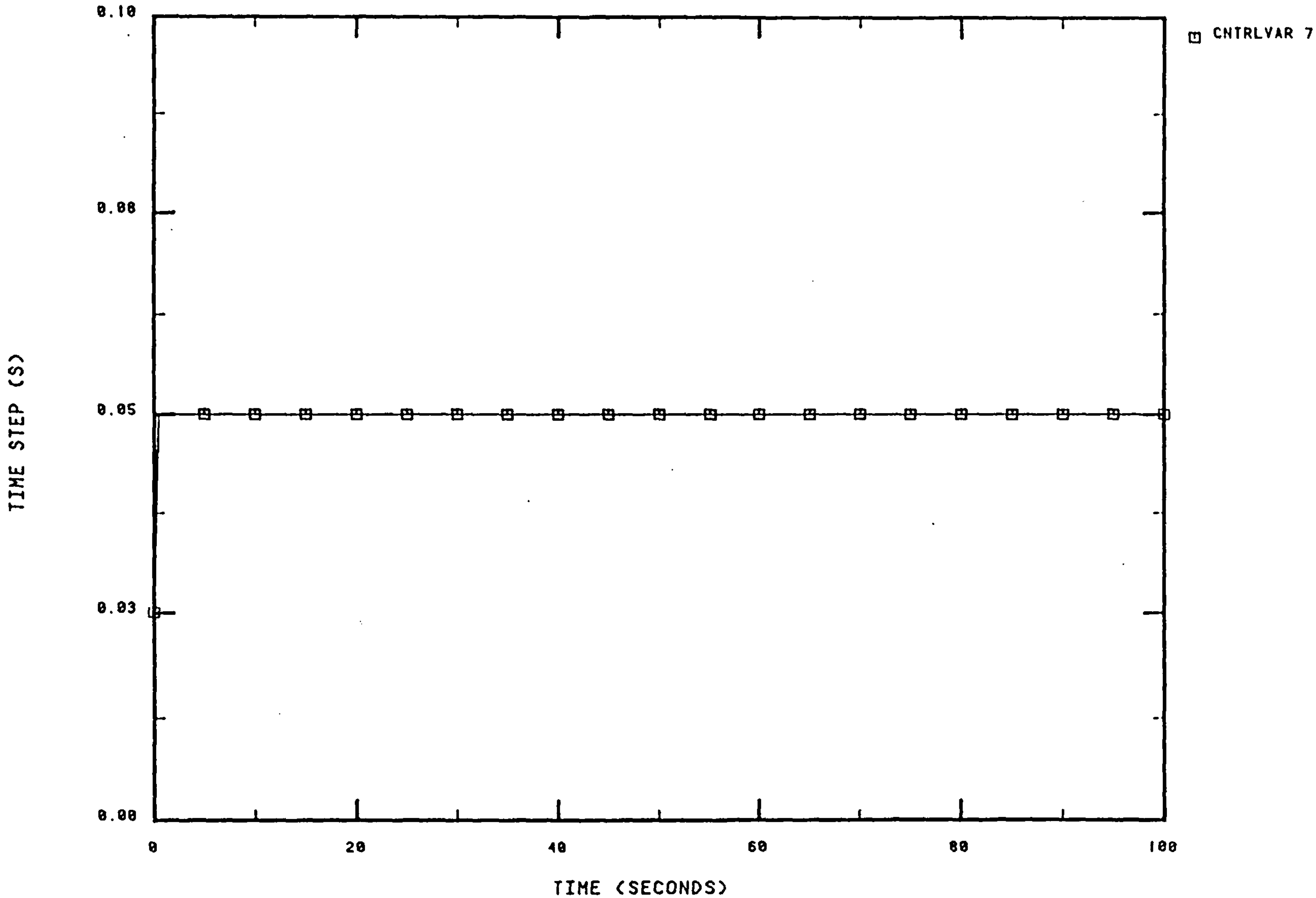

FIGURE 21 . BASE CASE : TIME STEP .

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11. ABSTRACT (200 words or less)

An assessment of RELAP5/MOD2 cycle 36.04 against a turbine trip from 100% power in Vandellós II NPP (Spain) is presented. The work is inscribed in the framework of the Spanish contribution to ICAP Project.

The model used in the simulation consists of a single loop, a steam generator and a steam line up to the steam header all of them enlarged on a scale of 3:1; and full-scaled reactor vessel and pressurizer.

The results of the calculations have been in reasonable agreement with plant measurements. An additional study has been perfomed, to check the ability of a model in which all the plant components are full-scaled to reproduce the transient. A second study has been performed using the Homogeneous Equilibrium Model in the pressurizer trying to elucidate the influence of the velocity slip in the primary depressurization rate.

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