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International Agreement Report

An Analysis of Semiscale Mod-2C S-FS-1 Steam Line Break Test Using RELAP5/MOD2

Prepared by
J. M. Rogers

United Kingdom Atomic Energy Authority
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Barnwood, Gloucester GL4 7RS
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Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

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Prepared as part of
The Agreement on Research Participation and Technical Exchange
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AN ANALYSIS OF SEMISCALE MOD-2C S-FS-1 STEAM LINE BREAK TEST USING RELAP5/MOD2.

J.M.Rogers

SUMMARY

An analysis has been performed of Semiscale Steam Line Break Test, to support the validation of RELAP5/MOD2.

Previous analyses of steam line breaks in the UK have made conservative assumptions about the lack of water carryover in the break discharge. This analysis utilises more sophisticated steam generator models attempting to follow the complex two phase phenomena that occur in this transient to obtain a more realistic assessment of its consequences.

Modelling, particularly of the phase separation process, is outlined. Problems with initial calculations are explained, and their solutions detailed. The main conclusion drawn is that although the calculations were acceptable overall, the carryover of water during the first seconds of the transient was too great. In addition the heat transfer degraded too quickly, resulting in a smaller than observed primary cool-down, which would in a real plant result in an underestimate of the potential reactivity insertion. These deficiencies lead to the recommendation that the implementation of interphase drag, and steam generator heat transfer warrant further study.

The work reported in this document was carried out for CEGB GDCD Barnwood underContract Number N/F 5176

AEE Winfrith

March 1989

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1. INTRODUCTION

RELAP5/MOD2 is being used by CEGB to assist in an independent assessment of the Sizewell B POSR. As part of the process of validation of the code for that assessment, calculations are planned in which the performance of the code will be examined by applying it to the results of various experiments performed in test facilities. These experiments include steam line break tests in Semiscale (ref.1), MB-2 (ref.2) and LOBI (ref.3).

Most full plant analyses of steam line breaks to date have used licensing type models of the steam generator which result in potentially unduly pessimistic calculations. This view is supported by the growing amount of experimental evidence.

To assess the conservatisms in the licencing models it is desirable to utilise rather more sophisticated steam generator models to attempt to follow the complex two phase phenomena that occur in this transient to obtain a more realistic assessment of its consequences. Unfortunately, difficulties were encountered in previous UK attempts, using RETRAN-02, such that the code ran into severe run time problems, or resulted in calculations which are too optimistic (ref.3).

This report presents RELAP5/Mod2 calculations of the Semiscale steam line break test S-FS-1. The performance of the code is assessed by examining several broad parameters such as steam generator pressure, with concentration in some detail on primary to secondary heat transfer. This is the thermal hydraulic phenomenon of greatest interest in plant faults such as steam line break, where excessive cooling of the primary circuit can lead to a return to power. Modelling, particularly of the separation process, is outlined. Problems with initial calculations are explained, and their solutions detailed. Conclusions are drawn from the final calculations, and recommendations are given for future analyses of steam line break experiments using RELAP5/MOD2, and in general.

2. THE SEMISCALE MOD-2C FACILITY.

Semiscale is an integral PWR simulator sited at the Idaho National Engineering Laboratory (INEL).

An outline of the main feature of Semiscale is given below. Full details of the facility can be found in Reference 1.

The Semiscale system has a 2/3411 core power relationship with its reference four loop PWR plant (figure 1). Elevation, dynamic pressure heads, power/volume ratio, and liquid distribution have been maintained as much as possible. The "broken loop", in which the steam line break occurs represents a single loop of the reference plant, the other three loops being represented by a single "intact loop". Additional heating is applied around the primary circuit, in an attempt to counteract heat loss.

The Semiscale facility has been altered many times to take account of lessons learned from previous test series. The system for the S-FS-1 test incorporated a new design of steam generator into the broken loop (figure 2). This "build" of Semiscale is called "Semiscale Mod-2C". This has better instrumentation than was available previously, an external downcomer, and a steam dome with separator. The separator is discussed later, but it should be noted here that it is NOT typical of any PWR plant.

3. THE S-FS-1 TEST.

3.1. Conduct of test S-FS-1

The sequence of events is given in Table 1. Points to notice about the test are:

[1] It simulated a double ended offset shear of a steam line downstream of the flow restrictor.

[2] The intact loop steam generator blew down a separate break assembly until the secondary pressure reached a level at which the main steam isolation valves would have operated at the reference plant (on a low steam generator pressure signal). This is the Safety Injection Signal or SIS time.

[3] A loss of onsite power was assumed to occur at the time of SIS delaying HPIS and auxiliary feed, and causing the pumps to trip.

[4] Initial Conditions represented "hot standby" on the Zion reactor, with augmentation to account for heat losses.

[5] The test specification included additional phases, investigating recovery of the plant. These are not investigated in this report.

3.2. Thermal Hydraulic Phenomena

Many different thermal hydraulic phenomena can potentially occur during a steam line break transient. The key ones are listed below.

- Performance of separators (carry over of liquid from the break).
- Changes in heat transfer from the primary to the faulted steam generator.
- Cooldown in the primary circuit and thermal asymmetry.

- Pressuriser response as the primary fluid contracts.
- Pressuriser response as the primary fluid expands. (eg during HPIS operation)
- Voiding in the primary circuit (eg. upper head).
- Reverse heat transfer from unaffected steam generator.

The last two phenomena were not observed in test S-FS-1. The evolution of the transient is described chronologically with respect to the calculations later.

4. PRELIMINARY CALCULATIONS.

Calculations were made initially to assess nodalisation of the broken loop separator and to identify any features of the transient that might require a more detailed investigation.

4.1. RELAP5/MOD2 Input Deck.

A RELAP5/MOD2 input deck of Semiscale Mod-2C was obtained from INEL. This was identical in most respects to one that had already been supplied to the UK (CEGB) for analysis of the LH small break series. The deck is a development of that documented in reference 4, to take account of the new features in the Mod-2C design. The model includes 185 volumes, 170 junctions and 256 heat structures (figure 3). The broken loop steam generator has six nodes in the boiler region. A control system is included to help to obtain an initial steady state. The deck included conditions for the feedline break tests. Those tests were scaled to Combustion Engineering Plant, whereas S-FS-1 was scaled to Westinghouse. Therefore conditions such as the pump coastdown behaviour required alteration. Additionally the feedwater injection position had to be changed to be at the top for the broken loop steam generator, and at the bottom for the intact loop. (In fact no feedwater was actually injected into the broken loop steam generator during the test, although it had been included in the specification). Naturally the deck required representation of the steam line break itself.

4.2. Separator nodalisation.

The primary separator in the broken loop steam dome in Semiscale consists of a rigid cone, situated over the outlet from the boiler region (figure 4). Water hits the cone, and is deflected outwards and downwards into the external downcomer. Steam rises around the cone to be dried in a secondary separator, with further drain lines. This is in contrast to real plant with "swirl vane" separators.

Two separate nodalisations of the Semiscale broken loop steam dome had been included in the model as supplied by INEL. One explicitly modelled the secondary separator with its drain lines, the other simply representing the steam dome as one volume. Neither of these were considered to be suitable for the purposes of this study since the first assumed the separation process to take place entirely at the secondary separator, and the second did not include possible bypass paths.

Two new different nodalisations were devised. The first, model "A", divided the separator node in the simple model outlined above to create a bypass route (figure 5). The second, model "B" changed the elevation of the top of the separator and bypass to be the top of the separator cone, to create a volume for potential gravity separation between the primary separator and the steam dome (figure 6) Calculations were performed using both models. Both these models result in separator nodalisation similar to then employed by GDCD in the Sizewell "B" input deck.

Consideration was made to using a more sophisticated separator component model along the lines suggested by reference 5, which is sometimes loosely known as the "Griffith"s" model. This is really more suited to a typical separator with swirl vanes and weirs, rather than the peculiar Semiscale design. It was decided not to use it for this work, but keep it in reserve for possible use in future steam line break analysis of the Westinghouse MB-2 facility, especially if this study suggests some general deficiency in the capability of modelling separator processes.

4.3. Problems.

The preliminary calculations will not be discussed in detail, since the actual physical behaviour predicted was much the same as the final calculations. However, some problems were initially encountered which needed to be overcome for a final calculation. These are outlined below.

4.3.1. Steady State Initialisation.

The initial conditions had to be altered to represent hot standby. This situation usually causes more trouble to initialise the steam generators, because they are almost stagnant. Any perturbation induced by incorrect initial specification of steady conditions in the deck therefore takes a long time to be rectified. An example of this is the steam generator pressure. If the gain on the steam generator valves is set at the full power value, they remain open for longer than necessary to correct the over pressure, resulting in under pressure, and the steam generator becoming too cool. The small heat transfer across the tubes takes a long time to reheat the steam generators. Obviously the solution here is to turn down the gain on the valves for steady state, to make them faster acting and to start with them closed.

Changes to the valves did not on their own yield a satisfactory steady state. In fact the steam generators converged to a reverse circulation state. This was due to the controlling mechanism for steam generator mass. When excess mass is required to be removed from a steam generator in the model, water is extracted via the feedwater volume if the steam valve is closed. If mass needs to be added, feedwater is injected, but at a much lower temperature than the water in the steam generator. The small corrections to the steam generator mass were enough to affect the density distribution to cause reverse circulation. This was cured easily by turning off the mass controller early in the initialisation, without having too much of an effect on the steam generator mass. At this time an error was detected in the input description of the control system for determining the broken loop steam generator mass. This seemed to refer to an earlier, and coarser nodalisation of the boiler region no longer present in the model. A similar error was later found in the control system for calculating broken loop primary to secondary heat transfer.

After these alterations a satisfactory steady state was obtained. A comparison of calculated against experimental values is given in Table 1. The main condition which could not be simulated was the loop-to-loop temperature difference.

4.3.2. Pressuriser Behaviour.

Two anomalies arose concerning the behaviour of the pressuriser in the preliminary calculations. One was traced to a feature of the design of the model for steady state initialisation, as set up by INEL, which resulted in the pressure being maintained in the pressuriser at the initial level for 5s after the steam line break.

The other concerned the initial pressuriser level. Suspicions had been first aroused by a statement in the Quick Look Report (ref.1) that the pressuriser emptied at about 20s. This could not have been possible if the "collapsed level" had been at a level of 1.67m as stated in the Quick Look Report (ref.1)) taking into account the rate of primary depressurisation drop. This was supported by the comparison of the measured pressuriser differential pressure with the value from the preliminary calculation (figure 7). Consultation with INEL revealed a difference in terminology was the cause of this discrepancy, and the initial value should be set to 0.76m, called the "interfacial level" in the Quick Look Report (ref.1)

4.3.3. Intact Loop Behaviour.

The main interest of the analysis was the behaviour of the broken loop steam generator. The intact loop steam generator was of secondary importance. However, because of the long isolation time of over 20 seconds from the initiation of the steam line break any error in the calculation of the intact loop would have a large distorting effect on the whole calculated transient. This is increased because of the relative weighting effect of the intact loop compared to the broken loop. Preliminary calculations did suffer from this problem.

Figure 8 shows the intact loop steam generator steam dome pressure from initialisation of the steam line break to the SIS point. The pressure decreased until the SIS point was reached, after which the pressure increased until the temperatures of the primary and secondary fluid had re-equilibriated. The trend was well predicted, but the depressurisation was overdone. Although the initial calculation up to about 3 seconds is good, the depressurisation is then much greater than observed in the experiment for the next 5 seconds. This causes a subsequent offset in the secondary pressure of about 0.8MPa. When this feeds into the primary circuit via heat transfer, it leads to an overcooling of the primary side and a large drop in primary pressure. This could not be cured by adjusting parameters controlling the break flow such as discharge coefficient and flow resistance within reasonable physical limits. The root of this problem was not clear to identify. An initial thought was that it might be an effect of not modelling the experimental break assembly in the input deck. Possibly these lines may have initially contained subcooled water which could affect the initial break flow. An investigation in modelling this area in greater detail resulted in large run times due to Courant limiting and mass error in the break assembly, with no significant change in the intact loop steam generator depressurisation rate.

This problem was bypassed by forcing the correct intact loop steam generator depressurisation by a boundary condition on the volume into which the break was discharging. This does not form a perfect boundary condition, but proved to be adequate. A more obvious site for the response to be enforced, inside the steam generator was not possible due to the restriction on the number of junctions that can be connected to time dependent volumes in RELAP5/MOD2. (Limit is currently one).

Re-examination of this problem after the rest of the study had been finished uncovered the most probable cause of the rapid depressurisation. In the experiment, the intact loop steam generator was steaming, ie. there was both a feedwater flow inwards and a steam flow outwards. The broken loop steam generator was not steaming. The RELAP5/MOD2 steady state calculation however had neither steam generator steaming. The effect on the intact loop steam generator was to introduce thermal stratification in the downcomer which had not been there in the experiment (figure 9). The presence of subcooled liquid in the bottom of the steam generator is enough to increase the depressurisation rate in the calculation.

4.3.4. Pump Behaviour.

On examining the experimental data it was found that the pump coastdown behaviour was not stated in the test specification document (ref. 6). The instrument for measuring the pump speed in the intact loop appeared to have not performed reliably. However, additional evidence was provided by the intact loop flow meter. A revised coastdown curve was devised from the experimental evidence.

4.4. Summary.

Preliminary calculations had run into difficulty with the steady state initialisation, pressuriser behaviour and intact loop steam generator pressure response. The first two were largely resolved. The last was bypassed by constructing a calculation with the intact loop driven by a pressure boundary condition. Differences in behaviour between the experimental and specified pump coastdown were noted.

5. FINAL CALCULATIONS.

Applying the lessons learned performing the preliminary calculations, three "final" calculations were run. They were:

[1] Model B separator, intact loop steam generator pressure "constrained" by a boundary condition

[2] Model B separator, pressure "unconstrained" intact loop steam generator (break modelled explicitly)

[3] Model A separator, intact loop steam generator pressure "constrained" by a boundary condition

The first is the "best estimate", in the sense that the above experience suggests that it should provide a prediction closest to the experiment The others were performed mainly to check the above assumption, and to provide a final sensitivity study of separator nodalisation.

The transient predicted by all the calculations was qualitatively the same. This is described below using the "best estimate" calculation as a reference. This calculation is then discussed, including comparison with the experiment and alternative calculations.

Selected parameters from the "best estimate" calculation are plotted in figures 9 to 19 including test data where available. An indication of the primary to secondary heat transfer for the experiment has been taken from the Quick Look Report (ref.1). This is a quantity derived from the enthalpy changes in the primary fluid before and after entering the U-tubes, and must be viewed with caution.

5.1. Outline of the Predicted transient

After the steam line break the secondary pressure responds immediately (figure 10). Level swell in the steam generators rapidly overwhelms the separator and a two phase mixture is discharged from the breaks (figure 11). The heat transfer increases greatly to around 200kW across the broken loop U-tubes (figure 12) A constant cooldown rate is established in the primary circuit (figure 13), resulting in a shrinkage in the fluid (figure 14), and emptying of the pressuriser (figure 15). About the same time the broken loop steam generator reaches a pressure of 4.14MPa, the setpoint for activation of the SIS. Shortly afterwards flow through the intact loop steam generator break terminates. The heat transfer across the intact loop steam generator tubes falls by 75% in the first 10 seconds after the SIS. After a further 50 seconds, heat transfer is virtually constant, at a rate very similar to the initial conditions prior to the steam line break (figure 16).

The broken loop steam generator continues to depressurise, with the separator beginning to resume its function by 40 seconds. The broken loop heat transfer reduces in "steps" as the progressive tube bundle uncovery is simulated by sequential dry out of the calculational nodes until 50 s (figure 12). For the subsequent 100 seconds the heat transfer varies around a mean value of about 50kW. By the end of 150 seconds, the steam generator has depressurised to 0.5MPa (figure 10).

The continued heat transfer to the broken loop steam generator maintains the temperature drop in the broken loop cold leg at a rate of 0.15K/s. The change in heat transfer to the intact loop steam generator causes the intact loop cold leg temperature to stop falling almost immediately (figure 17). It takes about 15 seconds, the transit time, for this to manifest itself in the hot leg temperatures (figure 18). The primary pressure initially falls rapidly (figure 19), with the pressuriser now empty (figure 15). This fall is arrested by the fall in primary to secondary heat transfer outlined above and the operation of the HPIS, which is initiated 25 seconds after the SIS point. No flashing in the upper head is observed, and the pressure remains well above accumulator setpoint levels. The primary circuit subsequently slowly repressurises, as the constant core power setting of 30+15kW is now greater than the total primary to secondary heat transfer.

5.2. Comparison of best estimate with experiment

The best estimate calculation at a superficial glance appears to give a very good prediction of the test, especially with regard to primary and broken loop steam generator pressure. However, at a more detailed level there are some important differences, mainly in the primary to secondary heat transfer, and hence in the broken loop cold leg temperature. Intact loop secondary conditions will not be considered in any great detail in this section, as they are largely defined by the input of the pressure boundary constraint outlined in the section on the preliminary calculations.

The broken loop steam generator depressurisation matches the experiment almost exactly for the short period for which single phase steam is being discharged from the break (figure 10). Although the experimental measurement of break density is not as good as one might like, it is possible to infer that the flow calculated after the first 3 seconds was of too high a density (figure 11). This suggests that the carryover was greater than the experiment. This accounts for the depressurisation being too slow for this part of the prediction. The carryover corrects itself by about 15s, with the subsequent depressurisation being too rapid.

The trend of the heat transfer between primary and secondary is modelled well in broad outline. However, the correlation is less good once the tubes start to dry out (figure 20). There is a clear "step" effect as each node progressively changes heat transfer mode. It should be pointed out that the model is finely noded in the U-tubes region. This does not seem to have helped in any real degree to counter the "step" effect, as several successive nodes appear to change heat transfer regime within a few second of another. The experimental data indicates a rapid drop in primary to secondary heat transfer at about 70 s, somewhat later than the calculation.

Later the heat transfer stays around 20 kW, with significant spikes. These are caused by the calculated flow conditions. For most of the time the liquid is relatively stagnant, at the bottom of the steam generator A sudden surge of liquid from one node to another causes a significant change in void fraction. This feeds into the heat transfer calculations causing a change in heat transfer mode. This is not shown by the derived value for the experiment, but it is unlikely that this phenomenon if physical would be observed by this method. However, this sudden change from basically counter-current flow to co-current flow will be strongly dependent on interphase terms These terms are known to be poorly calculated by RELAP5/MOD2 for the physical state the broken loop steam generator is in by 60 seconds, ie. low flow and pressure (<1.0MPa). Therefore this phenomenon may have been spuriously induced by deficiencies in RELAP5/MOD2. However it must be said that the overall effect on the transient is minor. It may be possible to reduce the size of the peaks by finer noding at the bottom of the steam generator boiler. Work currently in progress at Winfrith has shown that the treatment of interphase friction in RELAP5/MOD2 can produce anomalous results in counter-current flow situations.

The broken loop primary to secondary heat transfer has its main effect as expected on the broken loop cold leg temperature. The temperature fall on the intact side is largely arrested after the SIS since its blowdown valve is then shut. It continues to be indirectly affected via mixing in the vessel The early dry-out of the steam generator tubes outlined above leads to an underestimation of the broken loop cold leg temperature by about 20K (figure 13). This is, of course non conservative. The RELAP5/MOD2 results show an offset for some temperature comparisons as explained in the section on steady state initialisation.

There are other plausible reasons for the relatively poor prediction of primary temperature behaviour. These concern the modelling of environmental heat loss, and the system heat capacitance. These have not been investigated.

The primary pressure response is well modelled, noting in particular the correlation between the calculated and measured pressuriser differential pressure (figure 12). This is partly the result of the compensating effect of over prediction of intact loop heat transfer, and under prediction of the broken loop heat transfer The pressure drop does not show such a marked change in gradient observed when the pressuriser empties (figure 19). This may possibly be due to the lower predicted heat transfer or more fundamentally to limitations introduced by finite difference solution methods. The drop is terminated by the fluid re-expanding and the operation of the HPIS.

5.3. Comparison of best estimate with other calculations.

Only a brief comparison will be made, relating to points brought out above.

5.3.1.

The "unconstrained" intact loop steam generator depressurisation is rather quicker than the "constrained" case (figure 21). Therefore the initial cooldown of primary fluid on the intact side is greater (figure 22). This apparently increases the broken loop cooldown also through mixing in the vessel (figure 23). The failure to match the intact loop steam generator depressurisation therefore distorts the comparison for the broken loop. The rest of the transient is broadly similar to the "best estimate" calculation.

5.3.2. Model 'A' separator noding.

The change in separator noding decreases the initial broken loop steam generator depressurisation (figure 24). Therefore it takes longer to activate the SIS. This indicates that the initial carryover, already shown above to be over predicted above is even greater for the simpler nodalisation scheme of Model "A".

The broken loop heat transfer does not show the later erratic peaks as in the "best estimate" calculation (figure 25). This agrees with the hypothesis advanced above that these are artificial, sensitive to small differences in hydrodynamic state, and may or may not be encountered in a particular calculation. In addition the heat transfer degrades about 15s later for each steam generator node. This greater depressurisation accounts for the slightly lower primary temperatures (figure 26). This suggests a lower carryover for latter phases of the transient. This may be due to the larger volume of the separator node in model "A" compared to model "B". Thus it requires the node to contain more water before the carryover is activated by exceeding the void fraction limit for perfect separation. This would not have an effect initially as the separator nodes in both models fill rapidly in the initial surge of water after the steam line break. Then the presence of the extra node in model "B" may provide a small amount of extra gravity separation.

5.3.3. Code Statistics.

The CPU time taken for the 150 seconds of the best estimate calculation transient was 386 seconds on the Cray2 computer at Harwell. The maximum CPU to real time ratio was 7.5, encountered during the first few seconds of transient. CPU time for the other calculations was broadly similar.

The version of RELAP5/MOD2 used throughout was RELAP5/MOD2 Cycle 36.05, including Cray conversion errors corrected at Winfrith.

6. OVERALL SUMMARY AND CONCLUSIONS.

[1] A series of calculations for the Semiscale experiment S-FS-1 have been performed with RELAP5/MOD2.

[2] Final calculations were acceptable overall, and obtained with reasonable computer effort.

[3] Separation processes were modelled adequately during most parts of the transient, apart from the initial phase where the carryover of water through the break was too great. The modelling of separation processes (interphase drag) in RELAP5/MOD2 therefore merits further study. Until this is done it is maybe not sensible to attempt to implement proposed techniques for modelling the separator.

[4] The other area of the calculation that still requires further study is primary to secondary heat transfer. The calculations predicted a premature degrading of the heat sink capabilities of the broken loop steam generator, and hence a smaller than observed primary cooldown. This is partially caused by the initial greater than observed carryover.

[5] When broken loop steam generator pressure fell below about 1 MPa, the hydrodynamic and heat transfer behaviour became erratic. This is probably due to known problems in the RELAP5/MOD2 interphase relationships in these conditions.

7. RECOMMENDATIONS.

[1] The phase separation and heat transfer aspects should be analysed further, and in more detail. This may require code modifications and investigation of boiler region noding schemes.

[2] Modelling of the separator itself may be contributing to the discrepancies observed in the initial part of the test. There may be value in developing a more sophisticated component model, although the atypicality of the Semiscale separator has already been noted. Planned future studies of a similar test in MB-2 (which has a separator more typical of Sizewell "B") will be of value in developing any requirement in this area.

8. ACKNOWLEDGEMENTS.

The author wishes to acknowledge INEL for making available their model of the Semiscale plant, and for answering queries concerning the conduct of test S-FS-1.

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Table 1: SEQUENCE OF EVENTS FOR TEST S-FS-1

Event	Time(seconds)
Transient Initialisation	0.0
Blowdown valves fully open	1.0
Intact Steam Generator steam valve fully closed	0.0
Broken Loop Steam Generator steam valve fully closed	2.0
Broken Loop Steam Generator pressure=4.14MPa (SIS)	21.0
Broken Loop Steam Generator feedwater valve fully closed	0.0
Intact Steam Generator feedwater valve fully closed	22.0
Pumps begin coastdown	24.0
Intact Steam Generator blowdown valve fully closed	25.0
HPIS started	47.0
Intact Steam Generator Aux. feed started	69.0
Power to pumps tripped	69.0

Table 2: MEASURED AND CALCULATED INITIAL CONDITIONS.

Parameter	Measured	RELAP5/MOD2
Pressuriser Pressure	15.44 MPa	15.44 MPa
Core Power	44.9 kW	45.9 kW
Core Δ T	0.7 K	0.78 K
Pressuriser Liquid Level	76 cm	76 cm
Intact Steam Generator Secondary Pressure	6.79 MPa	6.79 MPa
Broken Loop Steam Generator Secondary Pressure	6.76 MPa	6.75 MPa
Intact Steam Generator Secondary Mass	138.9 kg	138.9 kg
Broken Loop Steam Generator Secondary Mass	39.6 kg	40.17 kg
Intact Loop Cold Leg Fluid Temperature	560.0 K	557.78 K
Broken Loop Cold Leg Fluid Temperature	558.0 K	557.50 K
Intact Loop Cold Leg Flow Rate	9.87 l/s	9.85 l/s
Broken Loop Cold Leg Flow Rate	3.30 l/s	3.20l/s

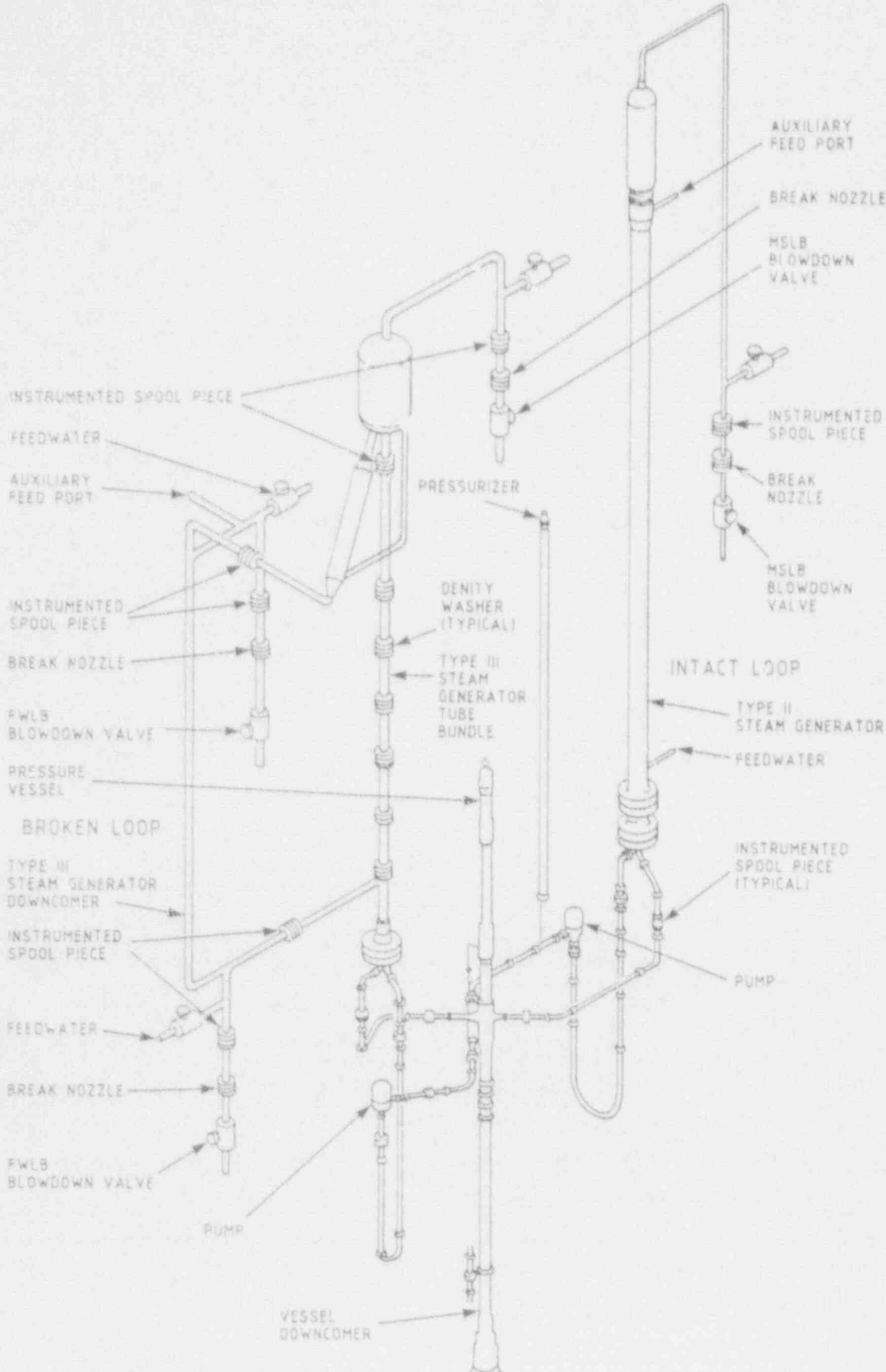


FIG.1 SEMISCALE MOD-2C SYSTEM AS CONFIGURED FOR THE FS TEST SERIES.

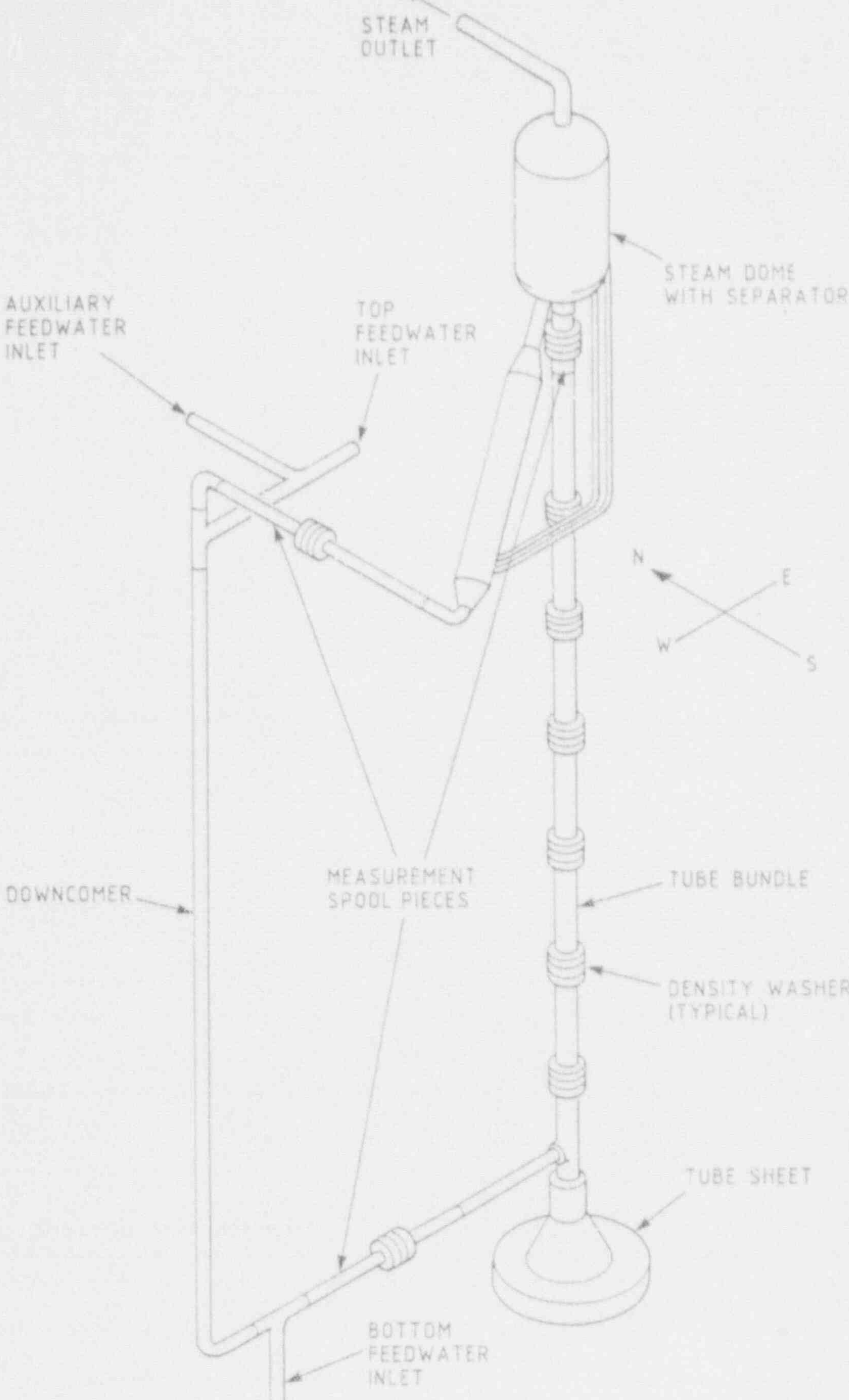


FIG.2 SEMISCALE TYPE III BROKEN LOOP STEAM GENERATOR CONFIGURATION.

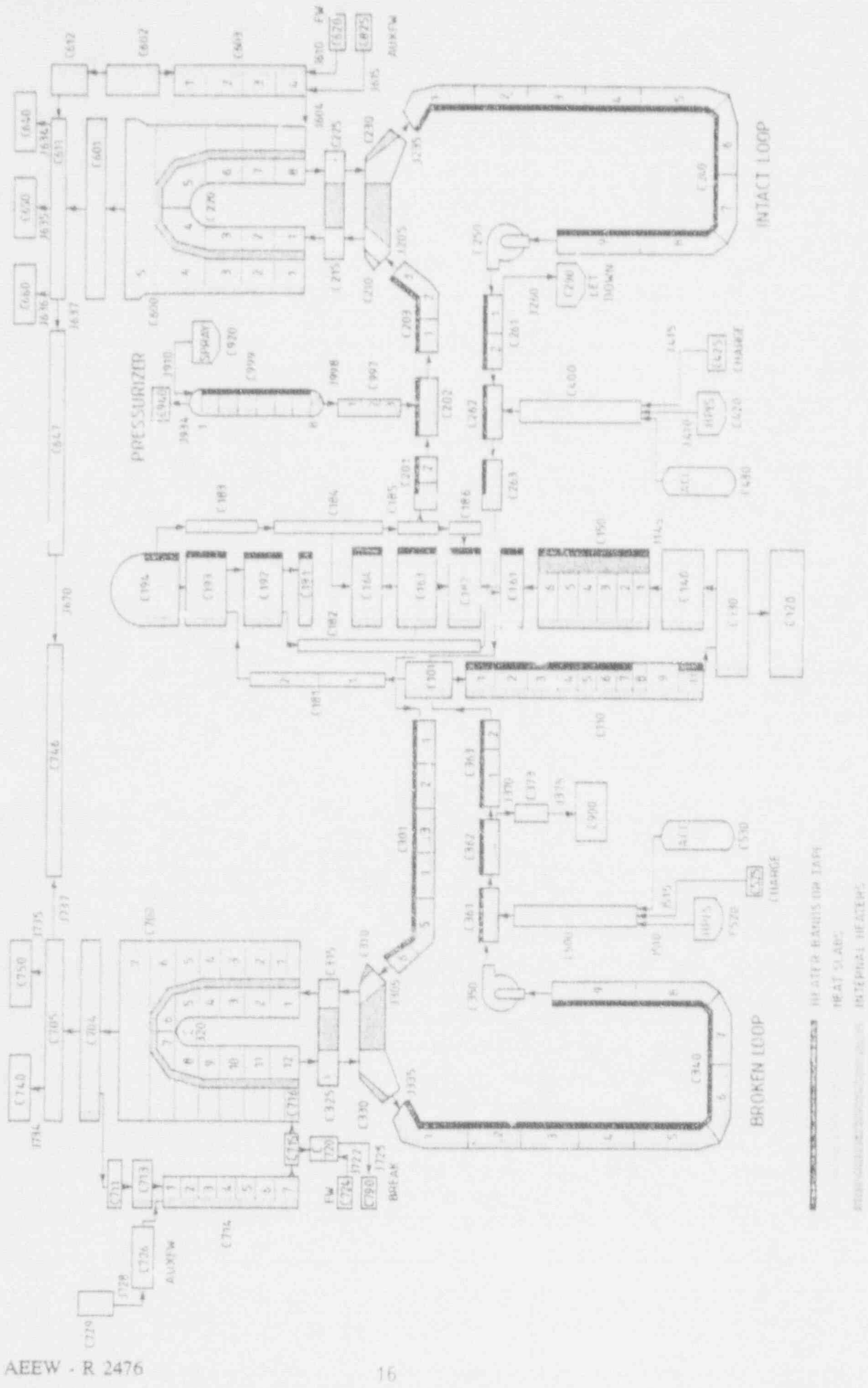


FIGURE 3 SEMISCALE MOD2-C RELAP5/MOD2 NODALISATION

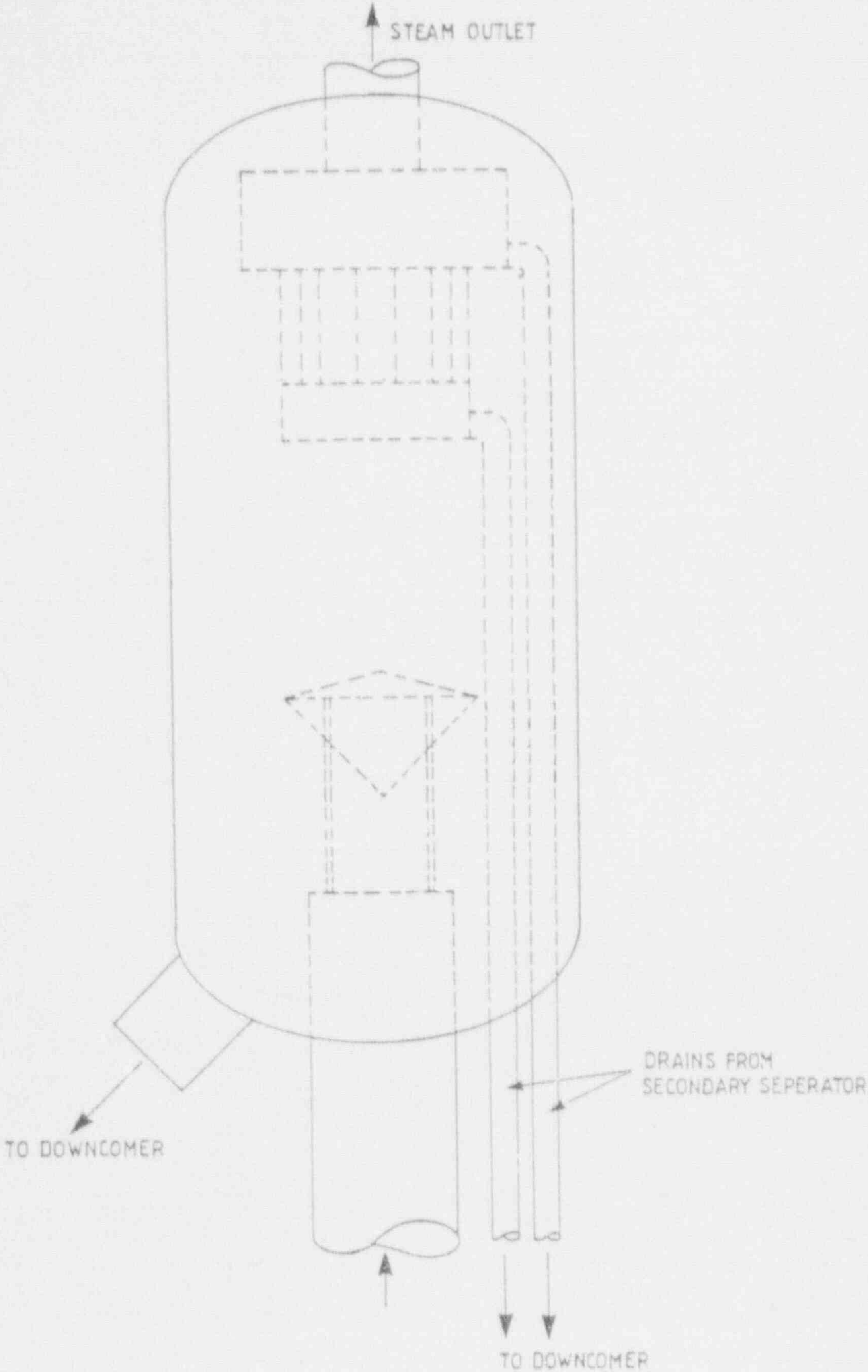


FIG.4 SEMISCALE STEAM DOME AND SEPARATOR.

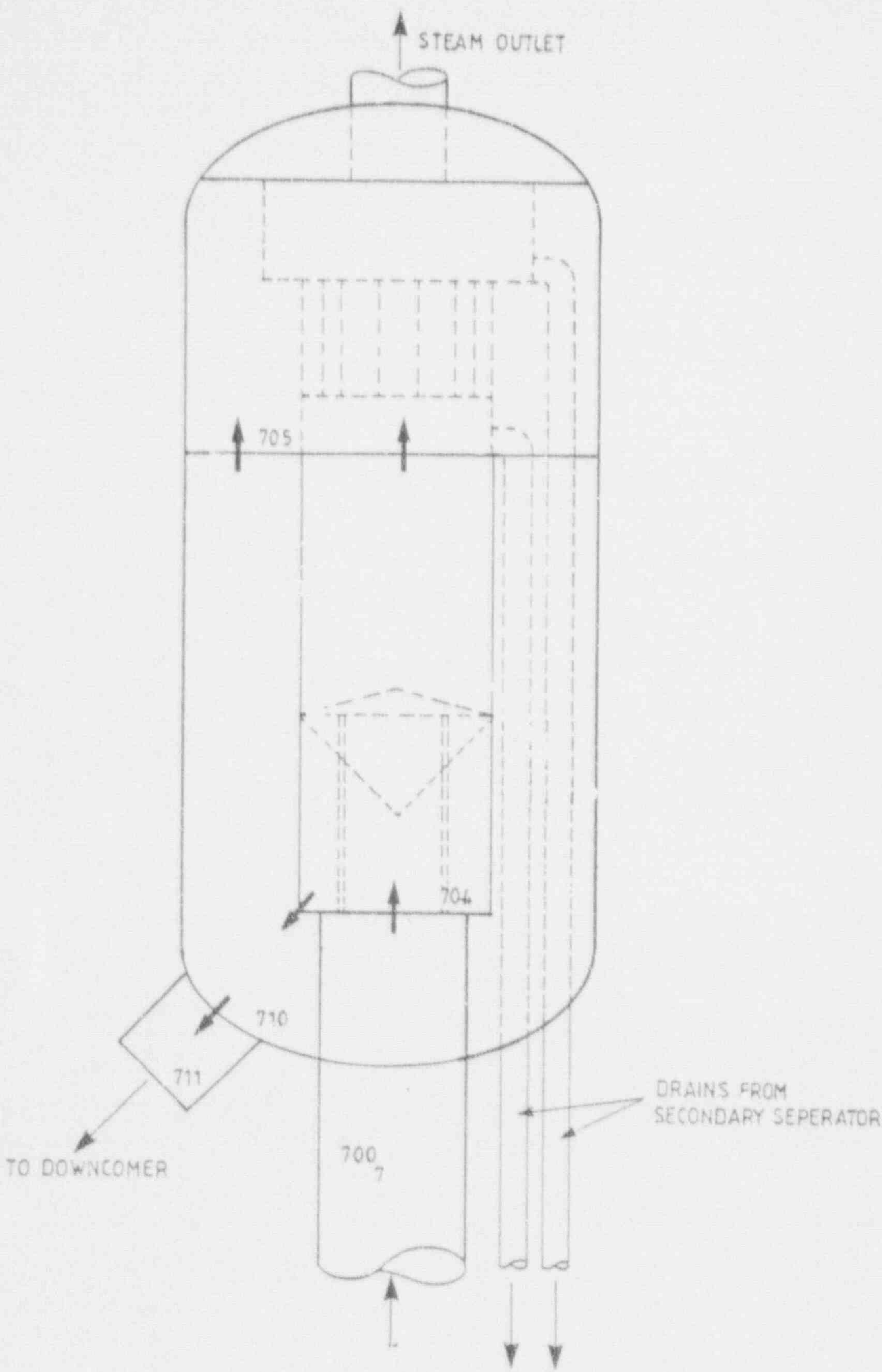


FIG.5 SEMISCALE STEAM DOME AND SEPARATOR. MODEL "A".

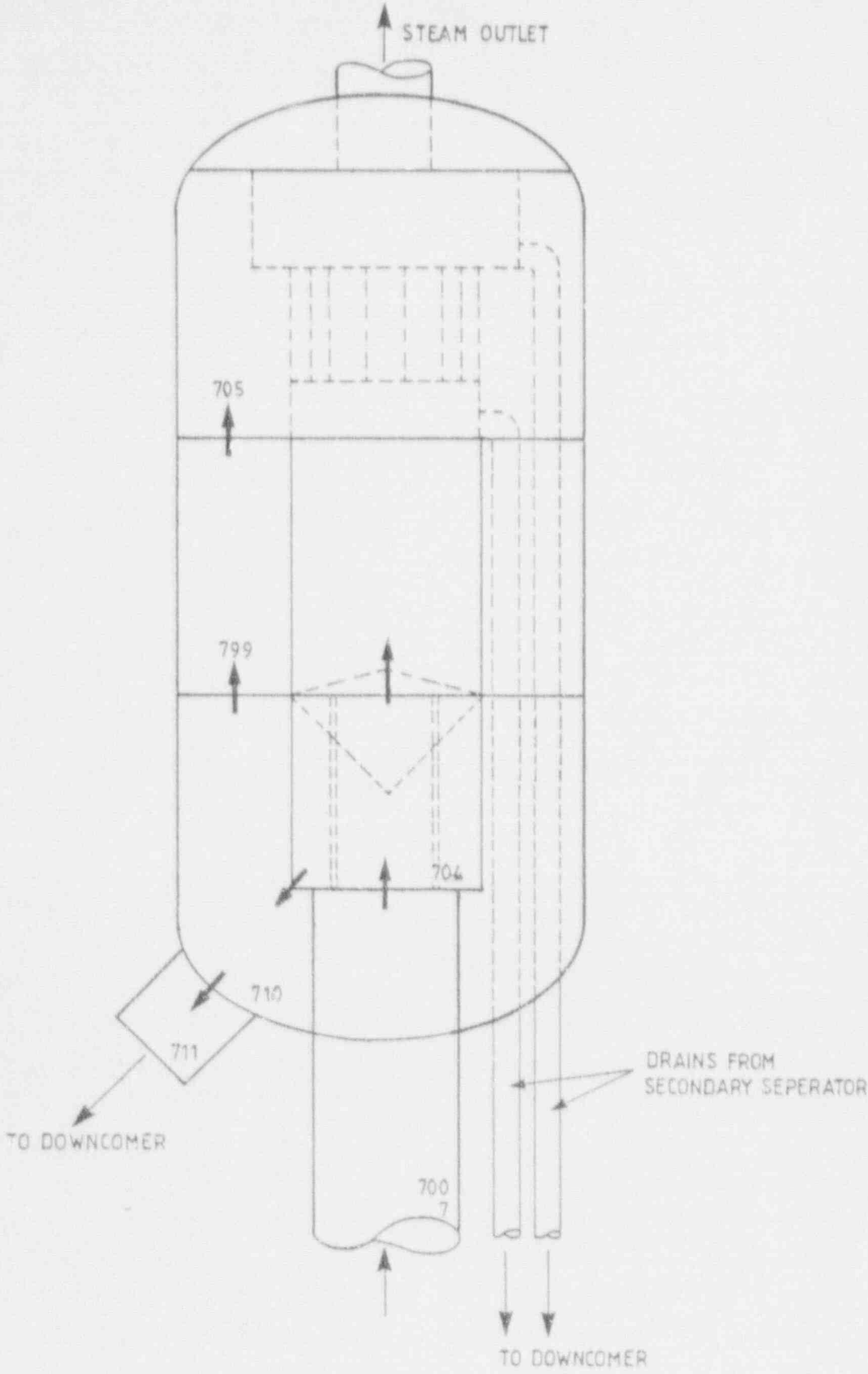
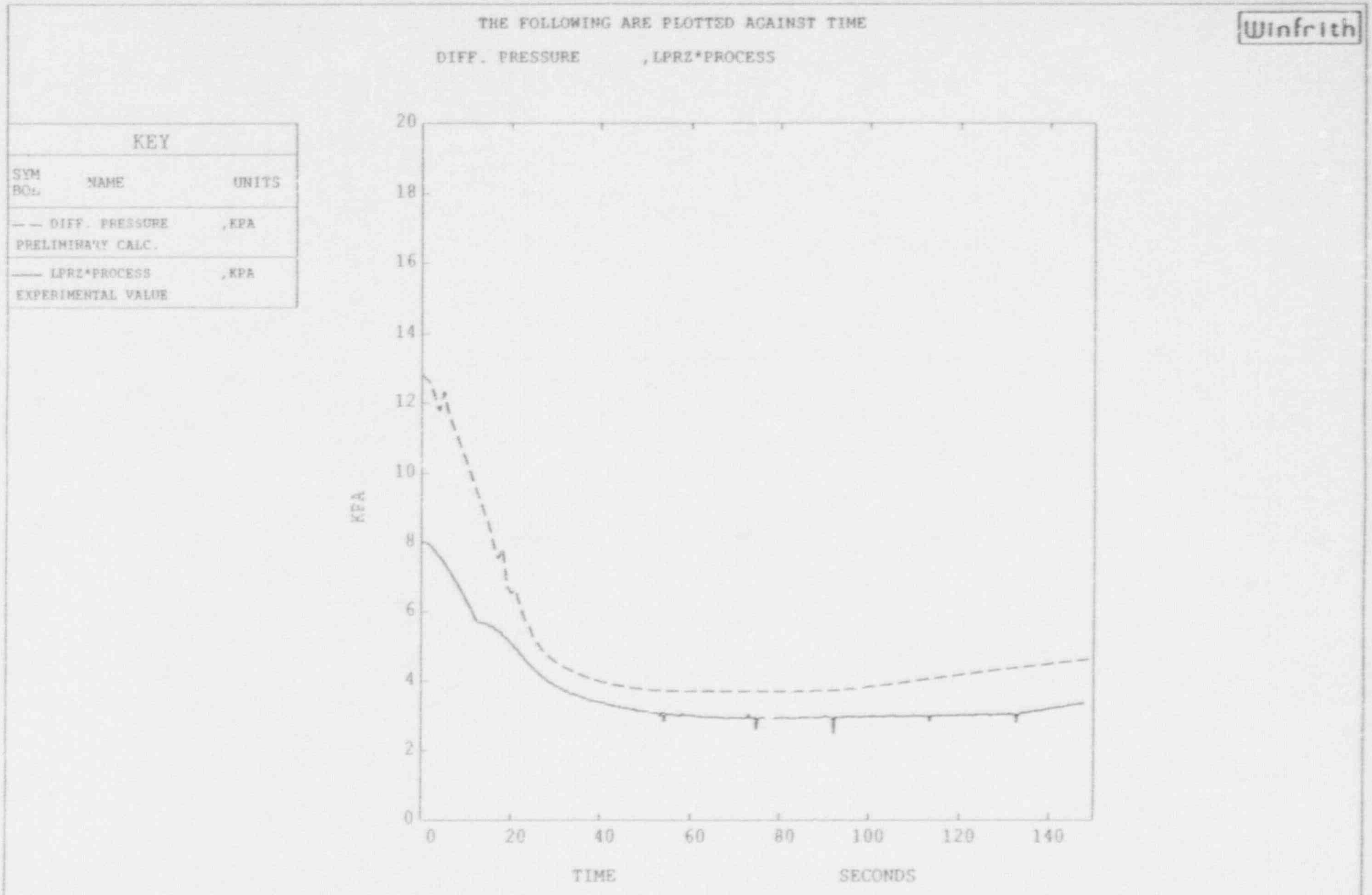
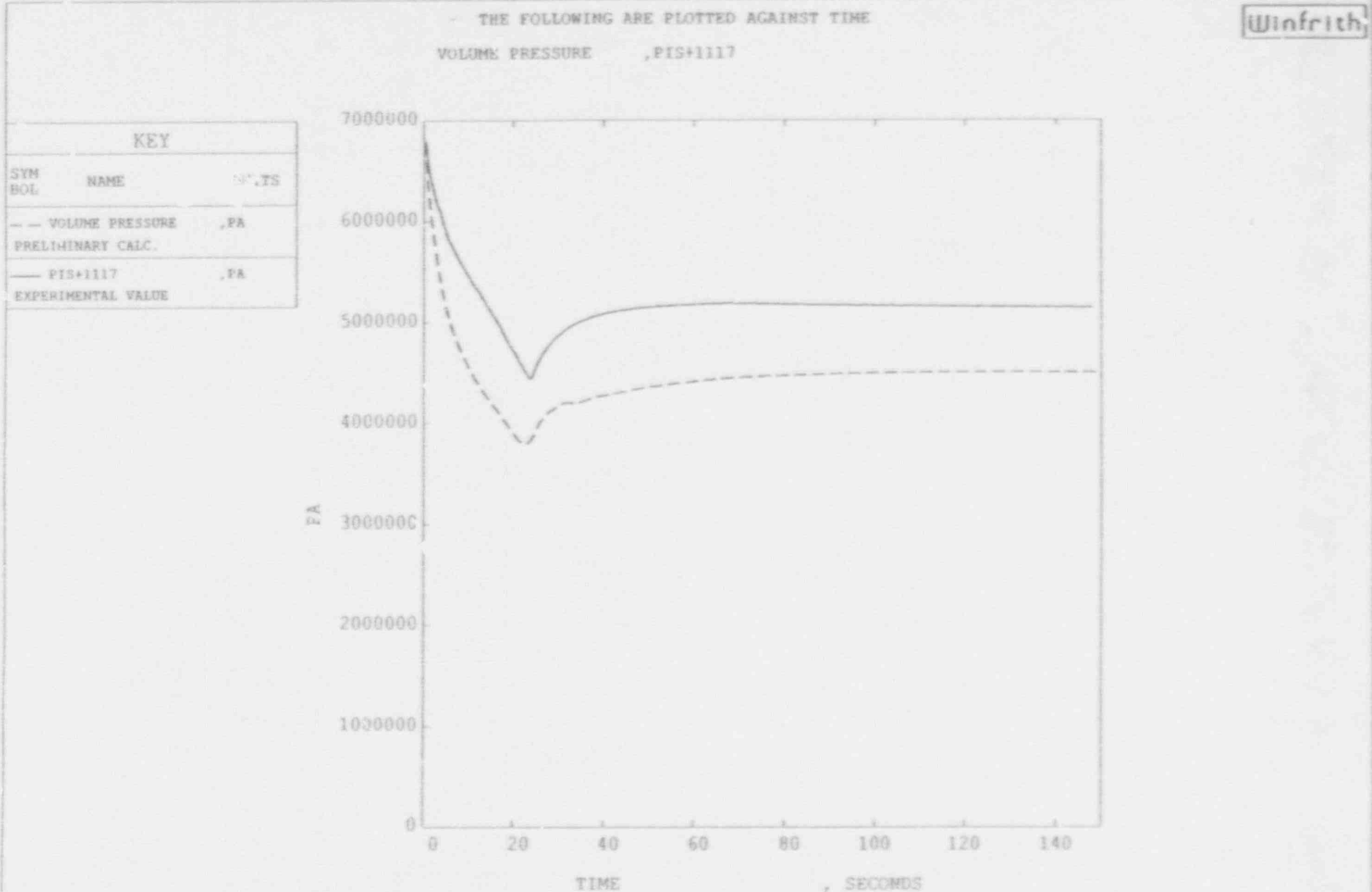


FIG.6 SEMISCALE STEAM DOME AND SEPARATOR. MODEL "B".



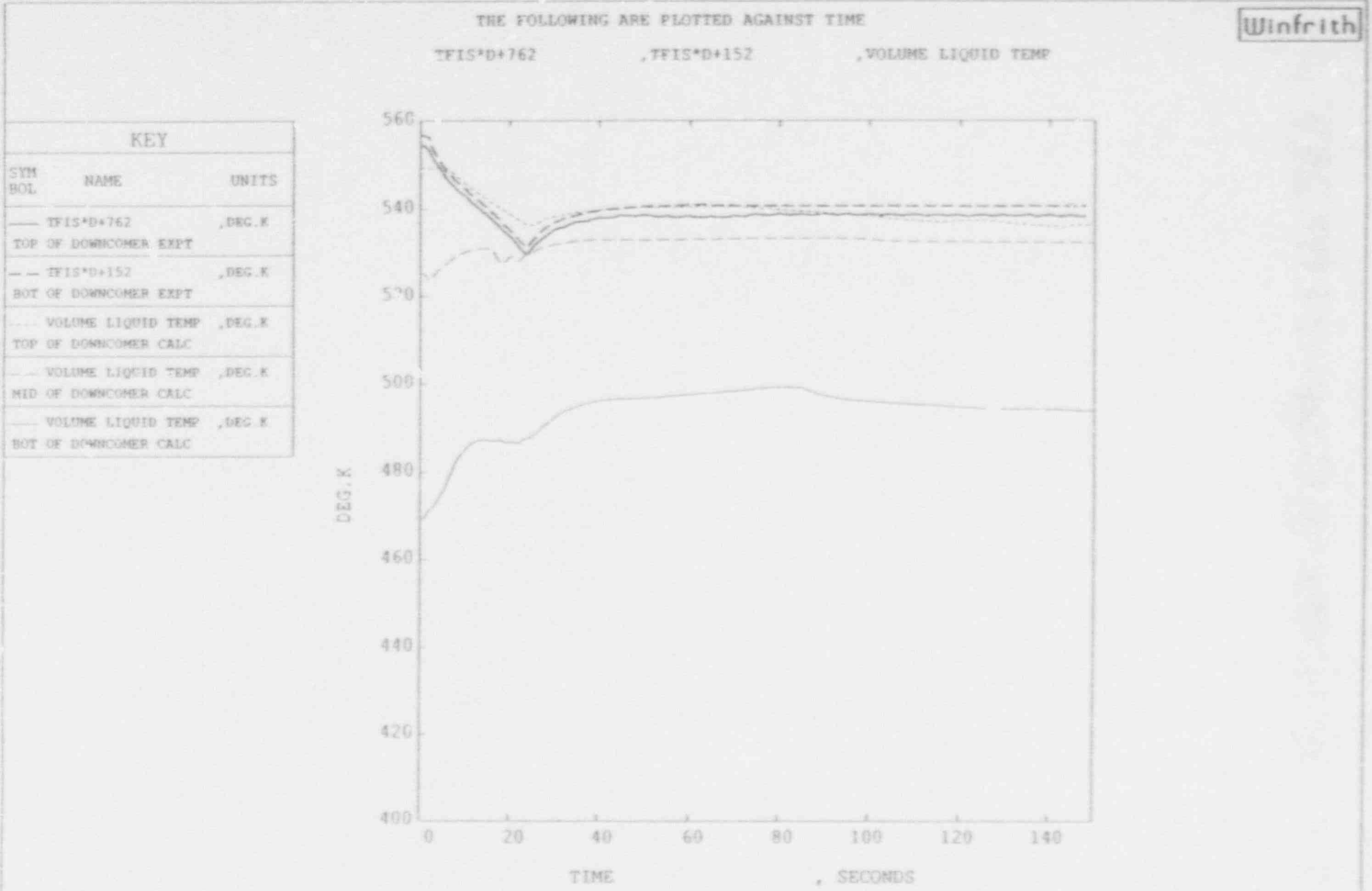
PRELIMINARY CALCULATIONS

FIGURE 7:-PRESSURISER DIFFERENTIAL PRESSURE



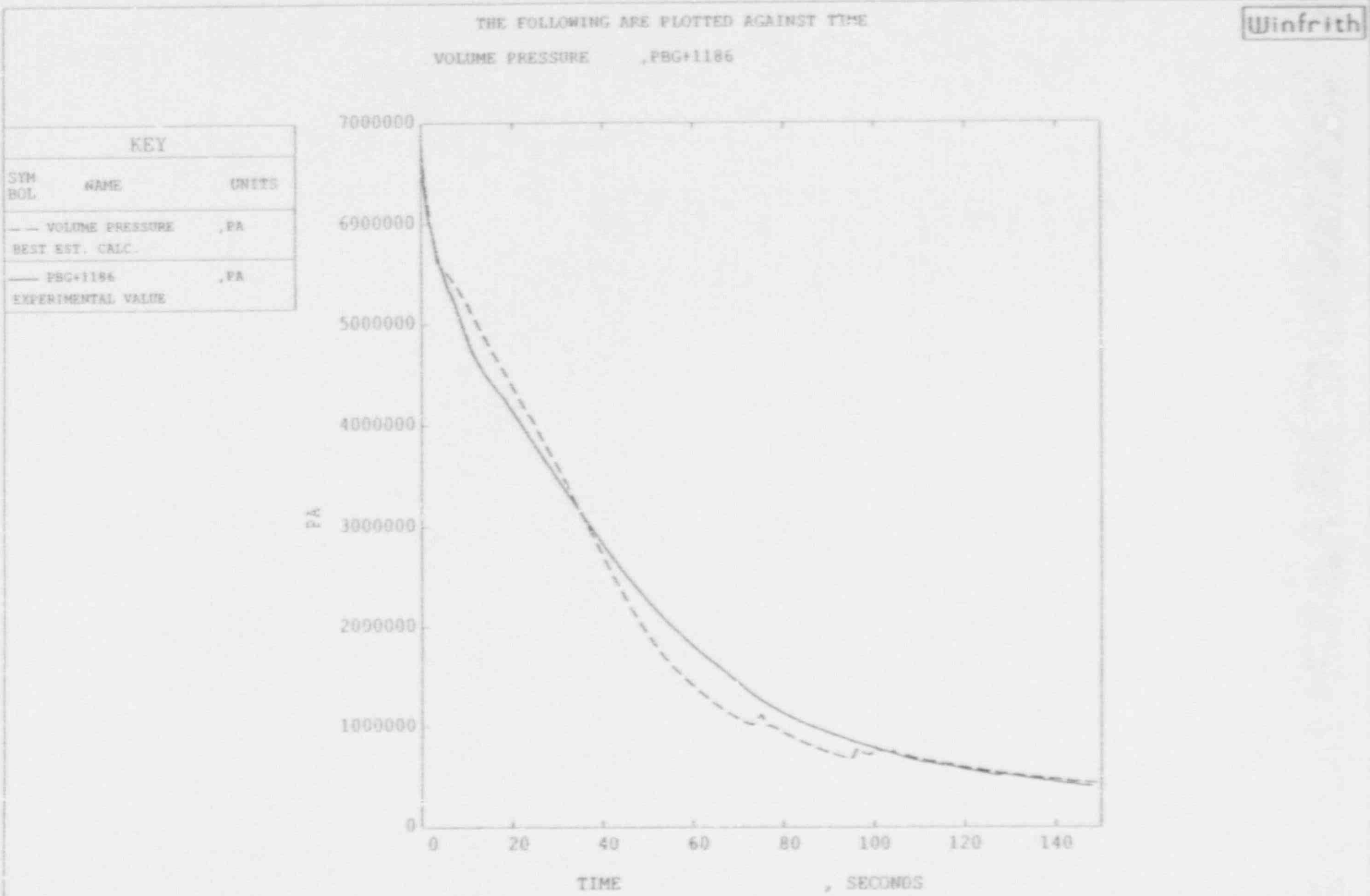
PRELIMINARY CALCULATIONS

FIGURE 8:-INTACT LOOP STEAM GENERATOR PRESSURE

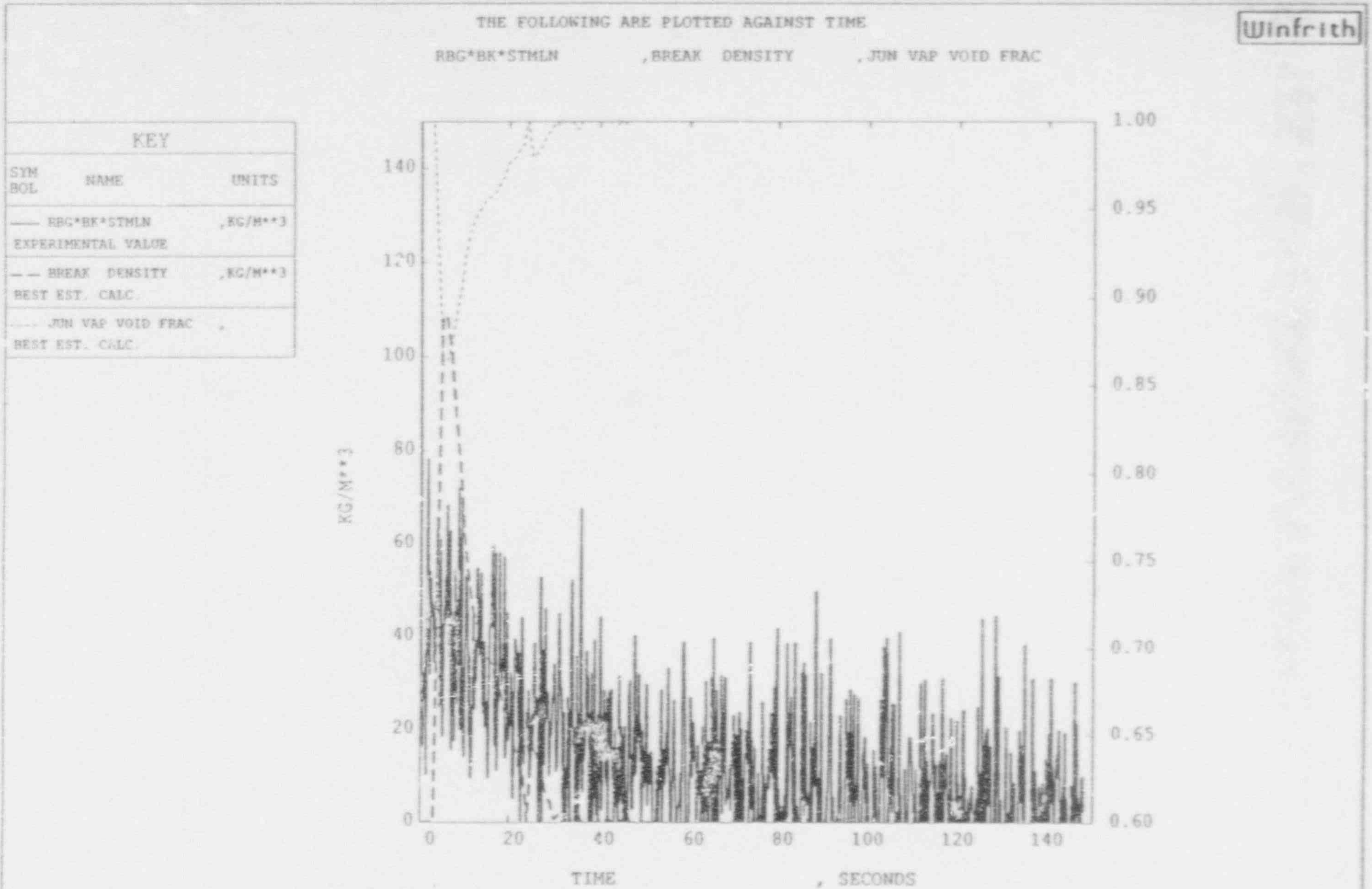


PRELIMINARY CALCULATIONS

FIGURE 9:-TEMPERATURE IN ILSG DOWNCOMER

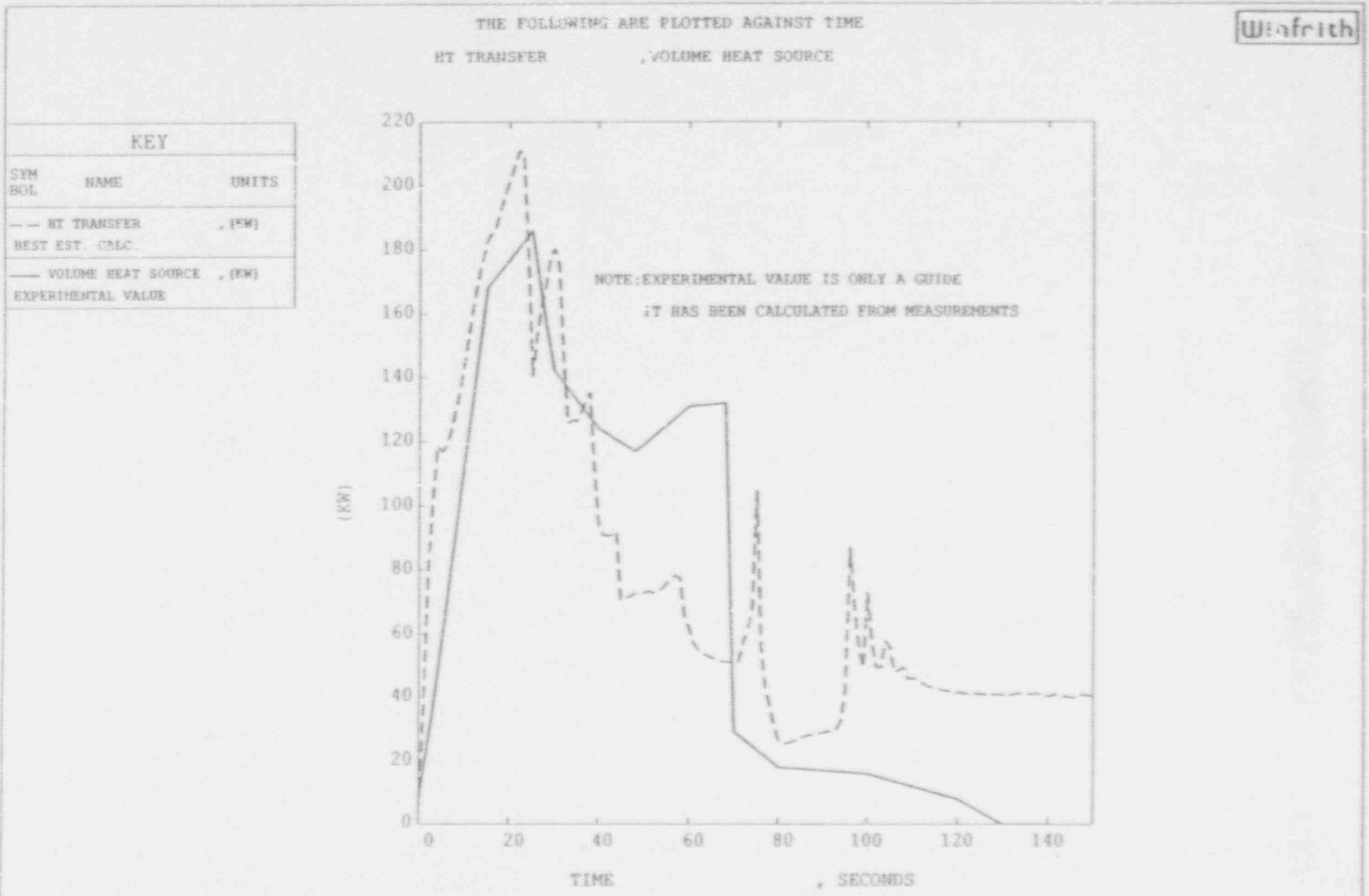


FINAL CALCULATIONS
FIGURE 10-BROKEN LOOP STEAM GENERATOR PRESSURE

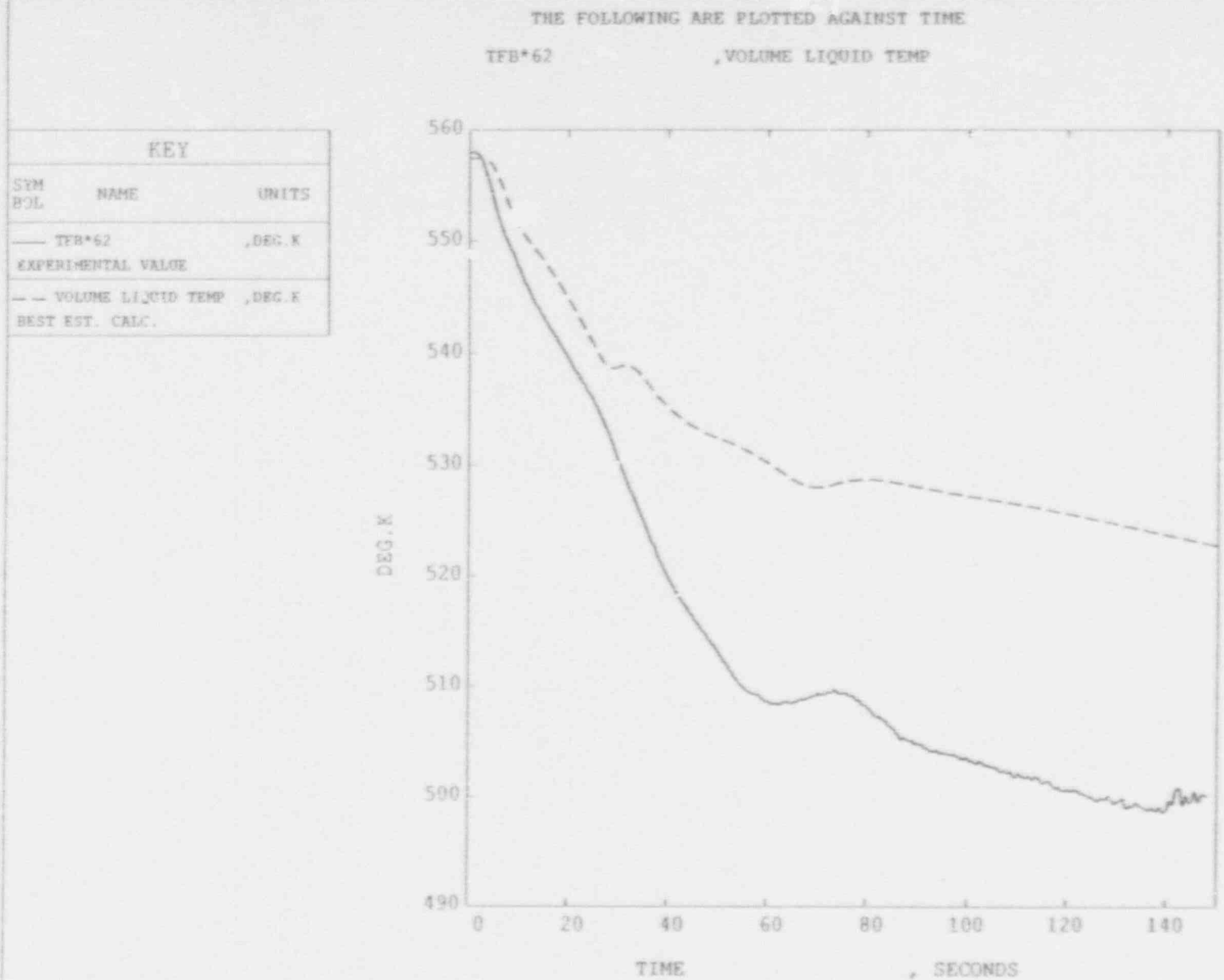


FINAL CALCULATIONS

FIGURE 11:-BROKEN LOOP BREAK DENSITY AND VOID FRACTION

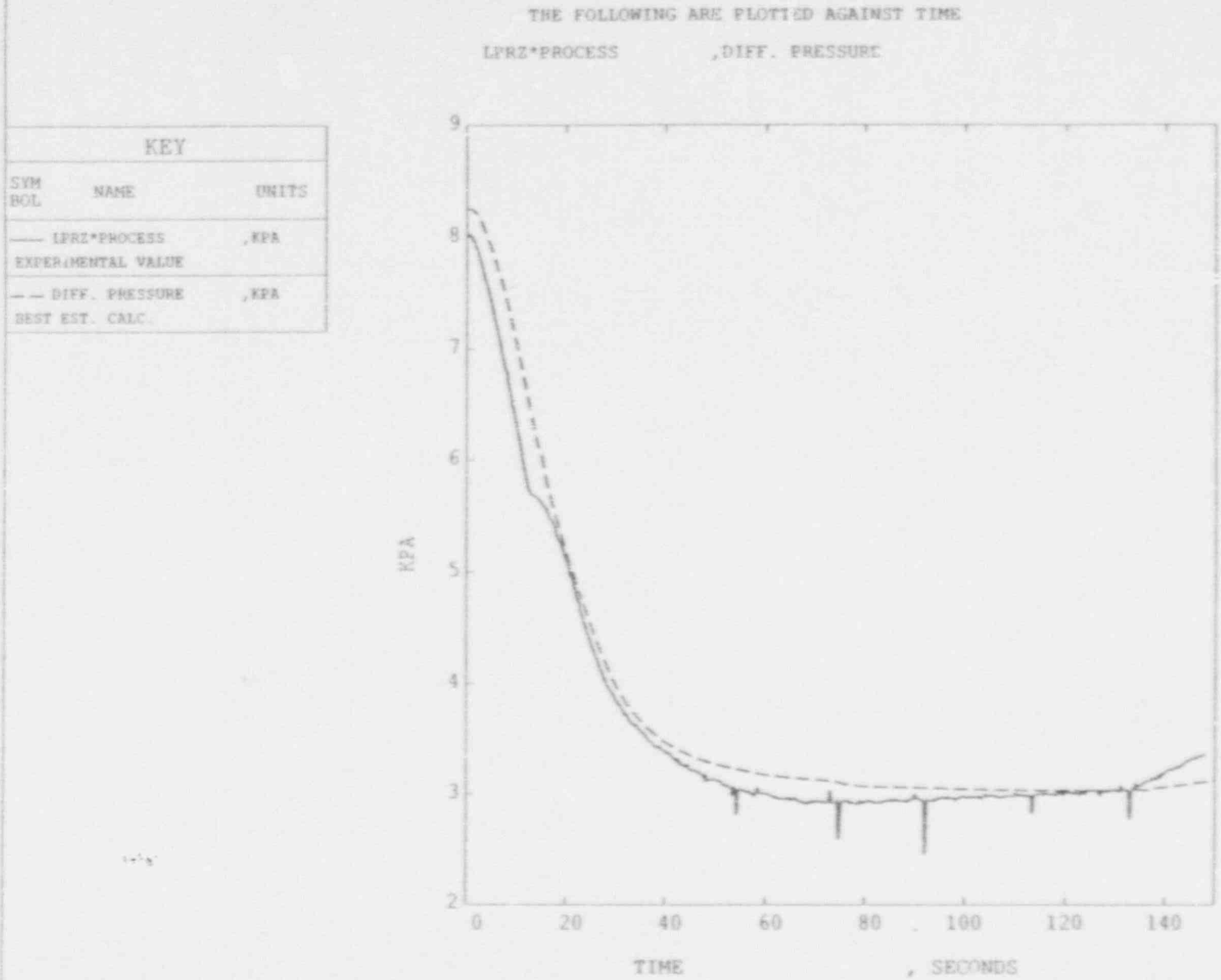


FINAL CALCULATIONS
FIGURE 12-BROKEN LOOP HEAT TRANSFER



FINAL CALCULATIONS
FIGURE 13:-BROKEN LOOP COLD LEG TEMPERATURE

Winfrith



FINAL CALCULATIONS

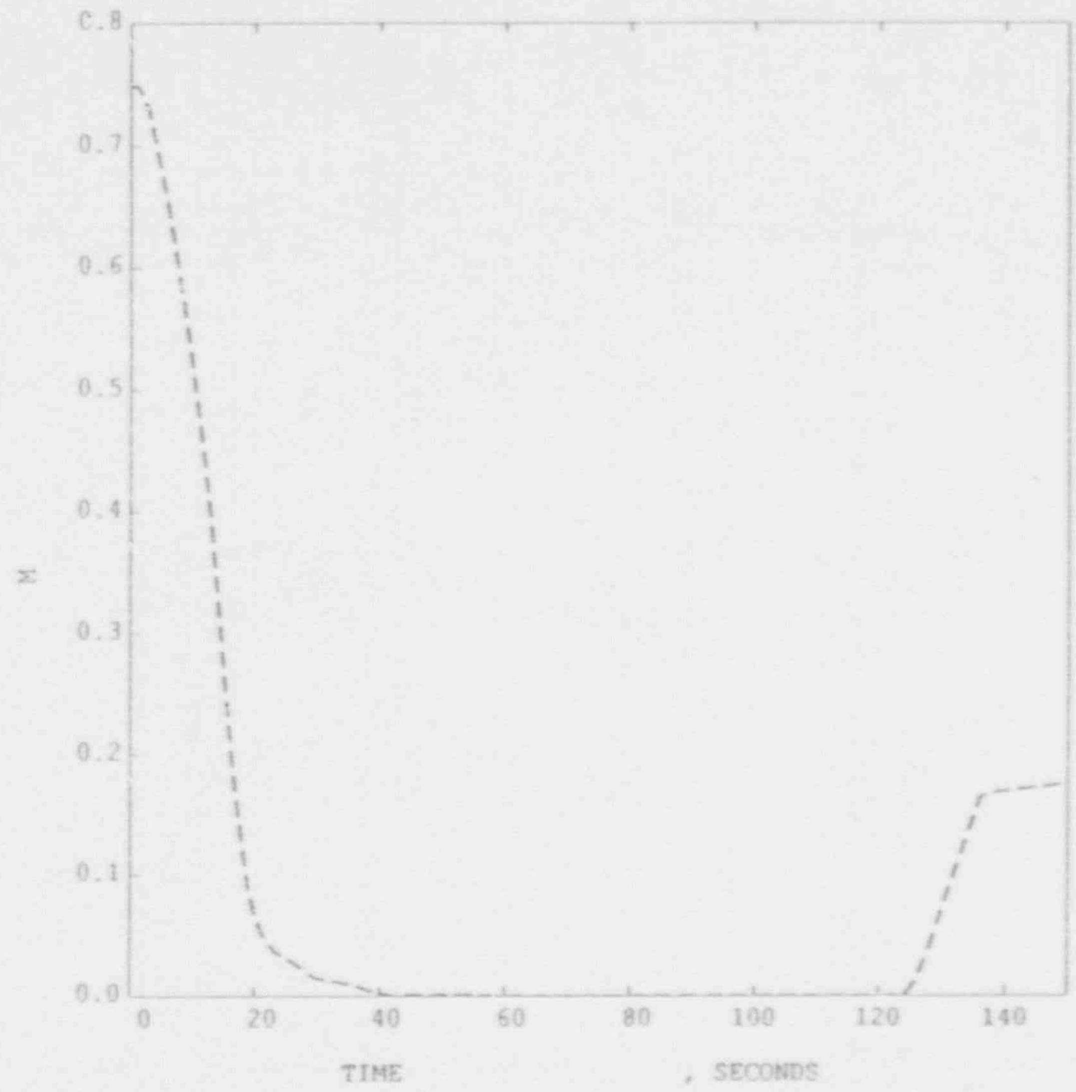
FIGURE 14:-PRESSURISER DIFFERENTIAL PRESSURE

THE FOLLOWING ARE PLOTTED AGAINST TIME

PRESSURISER LEVEL

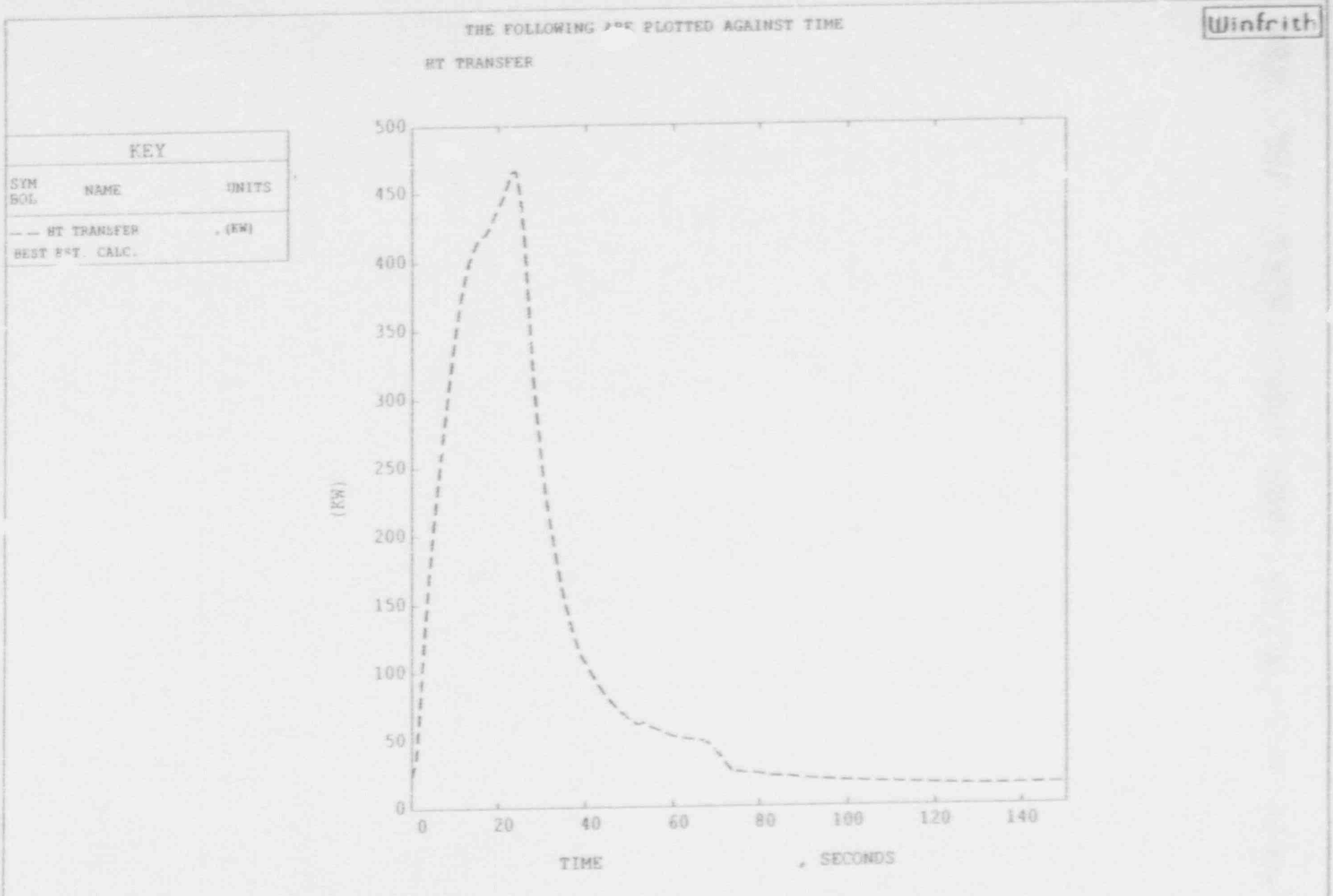
Winfrith

KEY		
SYMBOL	NAME	UNITS
— —	PRESSURISER LEVEL BEST EST. CALC.	,M



FINAL CALCULATIONS

FIGURE 15:-PRESSURISER LEVEL



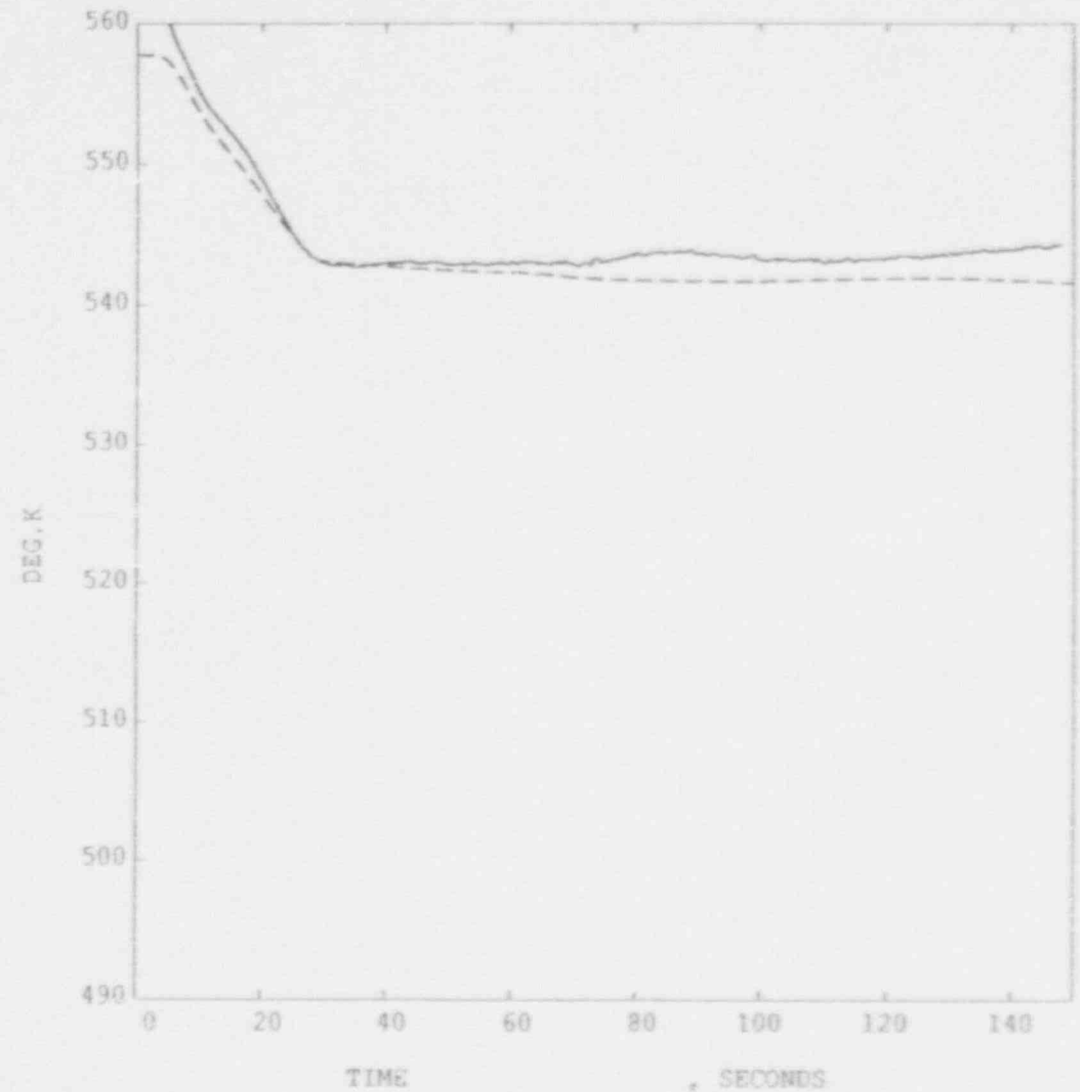
FINAL CALCULATIONS

FIGURE 16:-INTACT LOOP HEAT TRANSFER

THE FOLLOWING ARE PLOTTED AGAINST TIME

VOLUME LIQUID TEMP ,TFI*23CM

KEY		
SYM BOL	NAME	UNITS
— —	VOLUME LIQUID TEMP BEST EST. CALC.	,DEG.K
——	TFI*23CM EXPERIMENTAL VALUE	,DEG.K



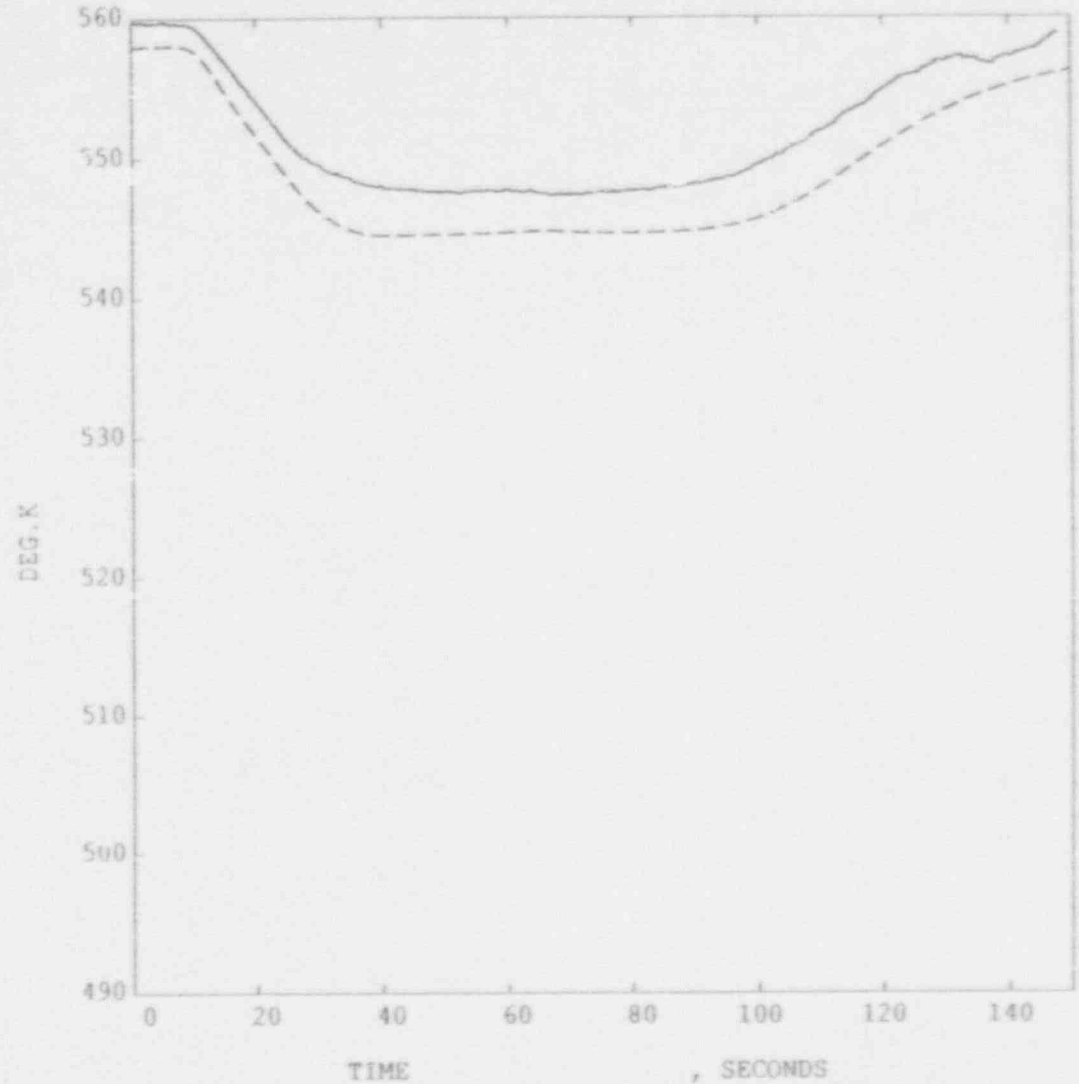
FINAL CALCULATIONS

FIGURE 17-INTACT LOOP COLD LEG TEMPERATURE

THE FOLLOWING ARE PLOTTED AGAINST TIME

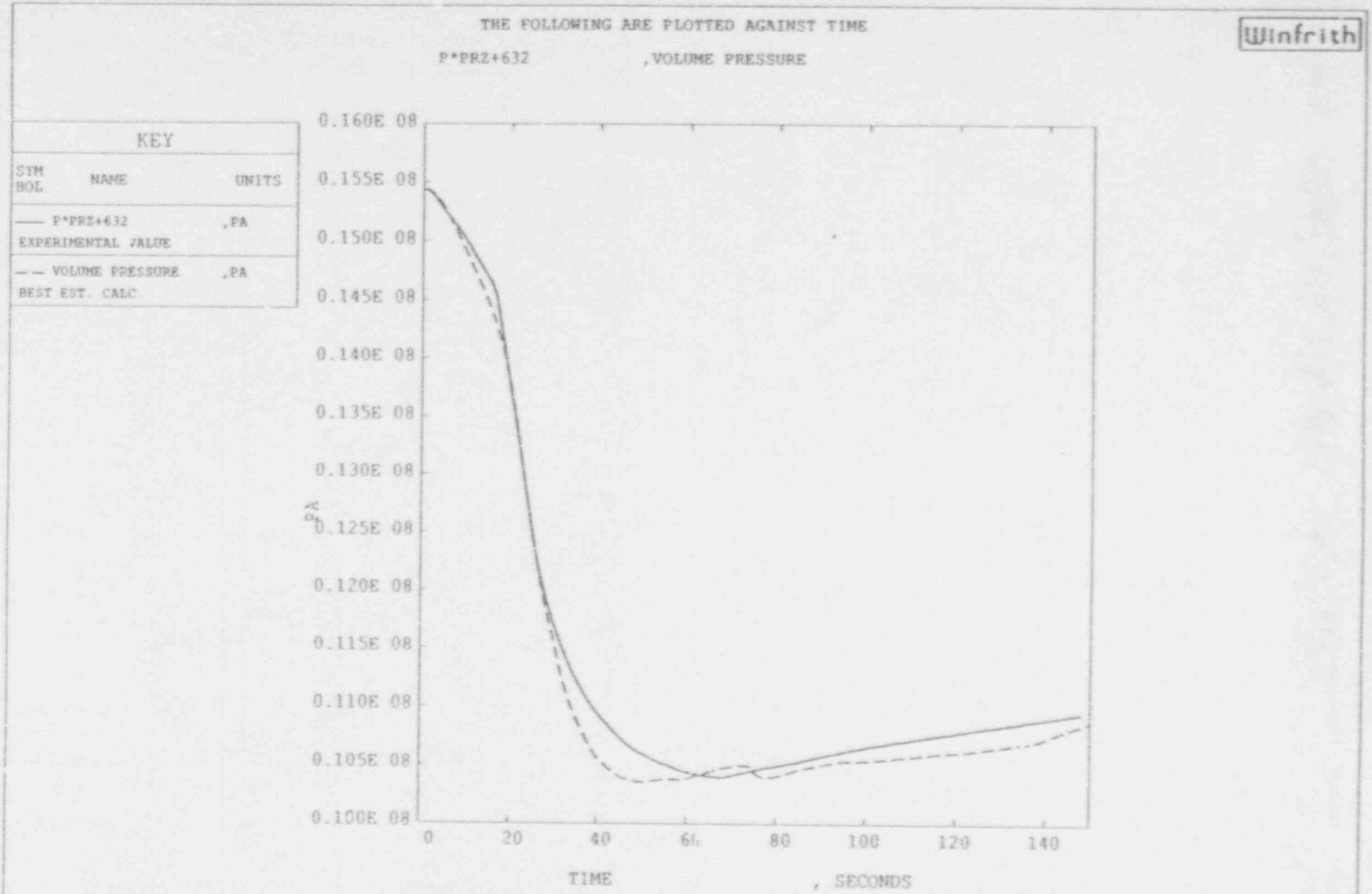
VOLUME LIQUID TEMP ,TFI*1A

SYM BOL	NAME	UNITS
– –	VOLUME LIQUID TEMP BEST EST. CALC.	,DEG.K
——	TFI*1A EXPERIMENTAL VALUE	,DEG.K



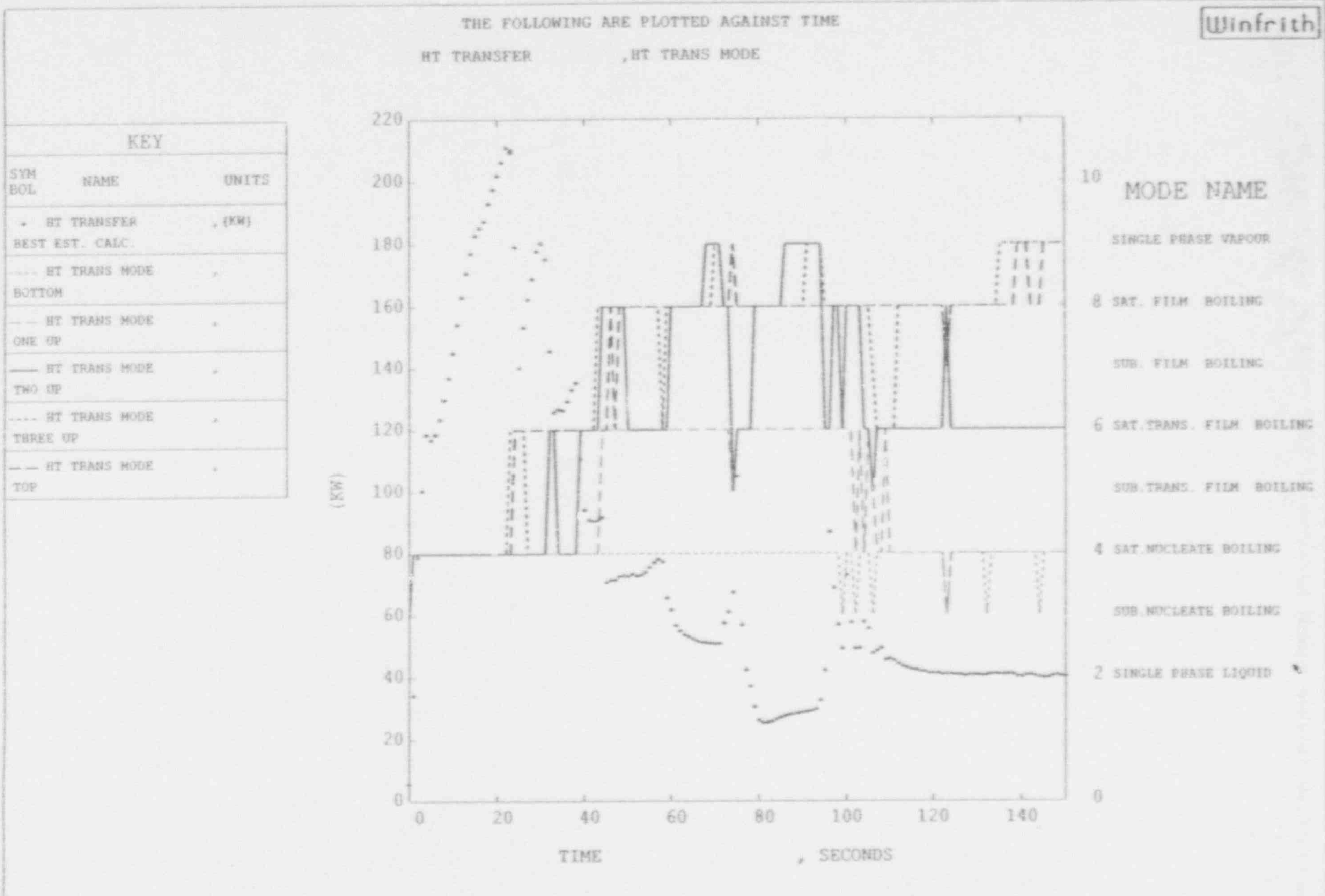
FINAL CALCULATIONS

FIGURE 18:-INTACT LOOP HOT LEG TEMPERATURE



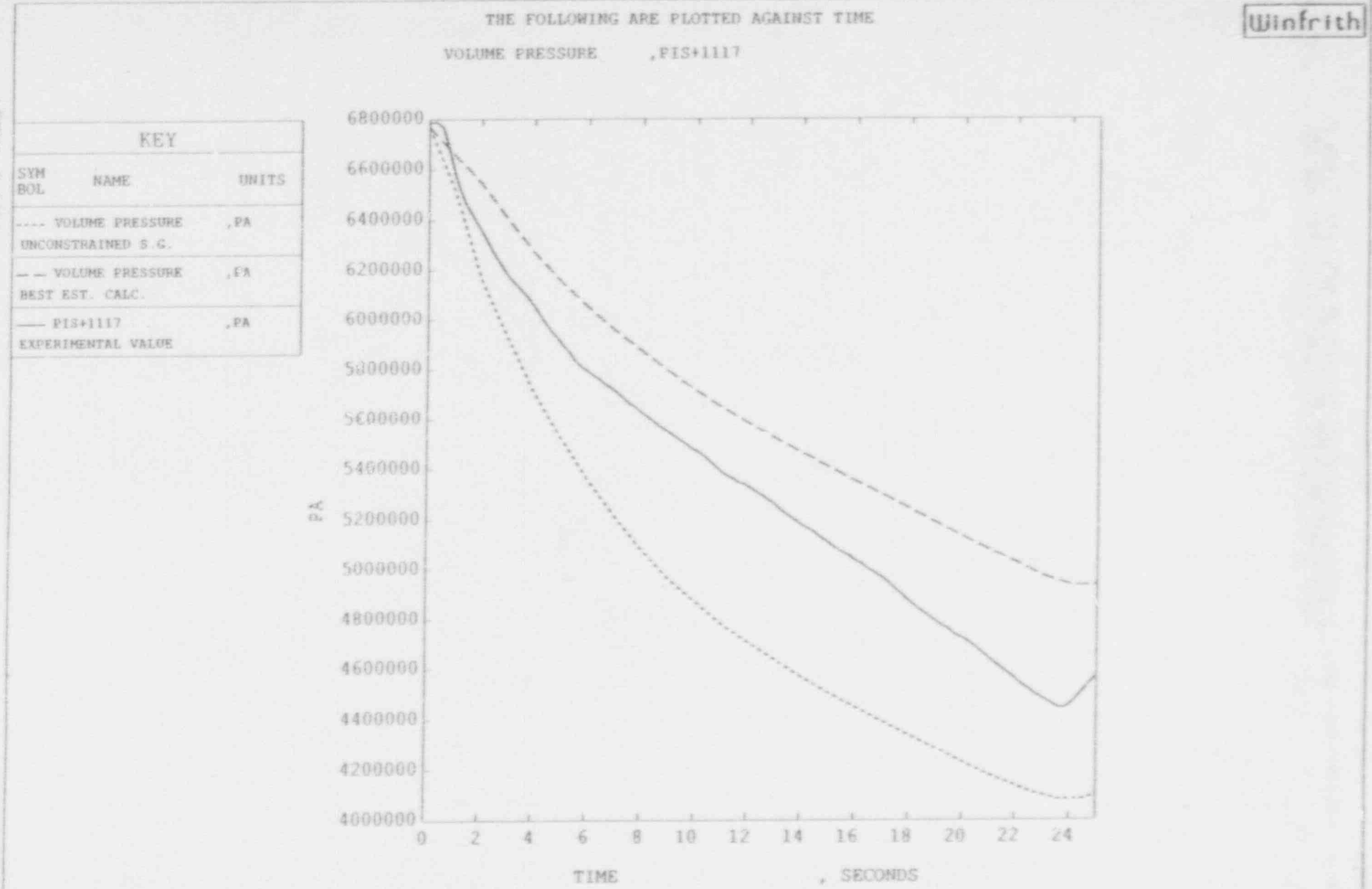
FINAL CALCULATIONS

FIGURE 19:-PRESSURISER PRESSURE



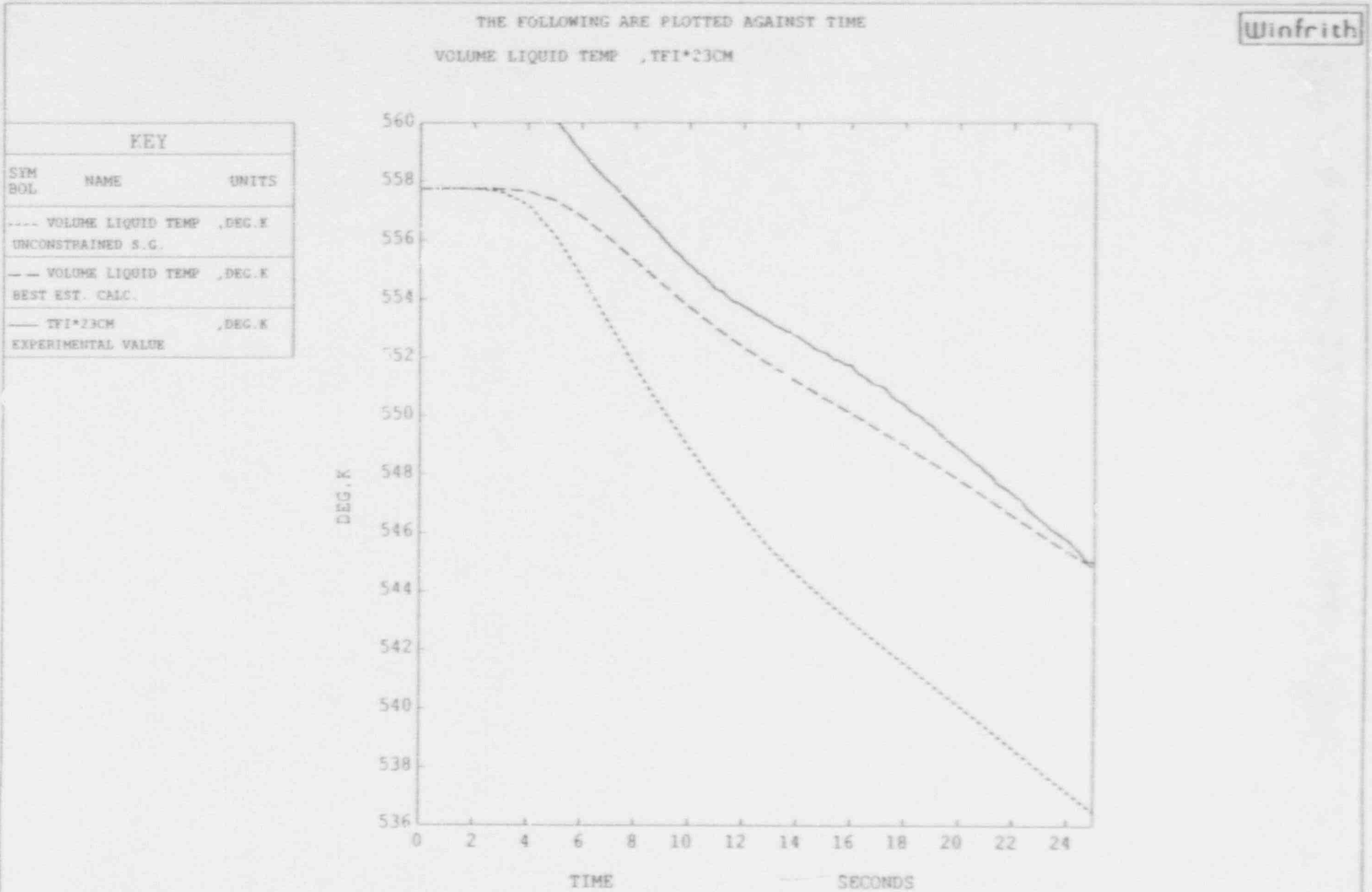
FINAL CALCULATIONS

FIGURE 20:BROKEN LOOP STEAM GENERATOR HEAT TRANSFER MODES



FINAL CALCULATIONS UNCONSTRAINED CASE

FIGURE 21-INTACT LOOP STEAM GENERATOR PRESSURE

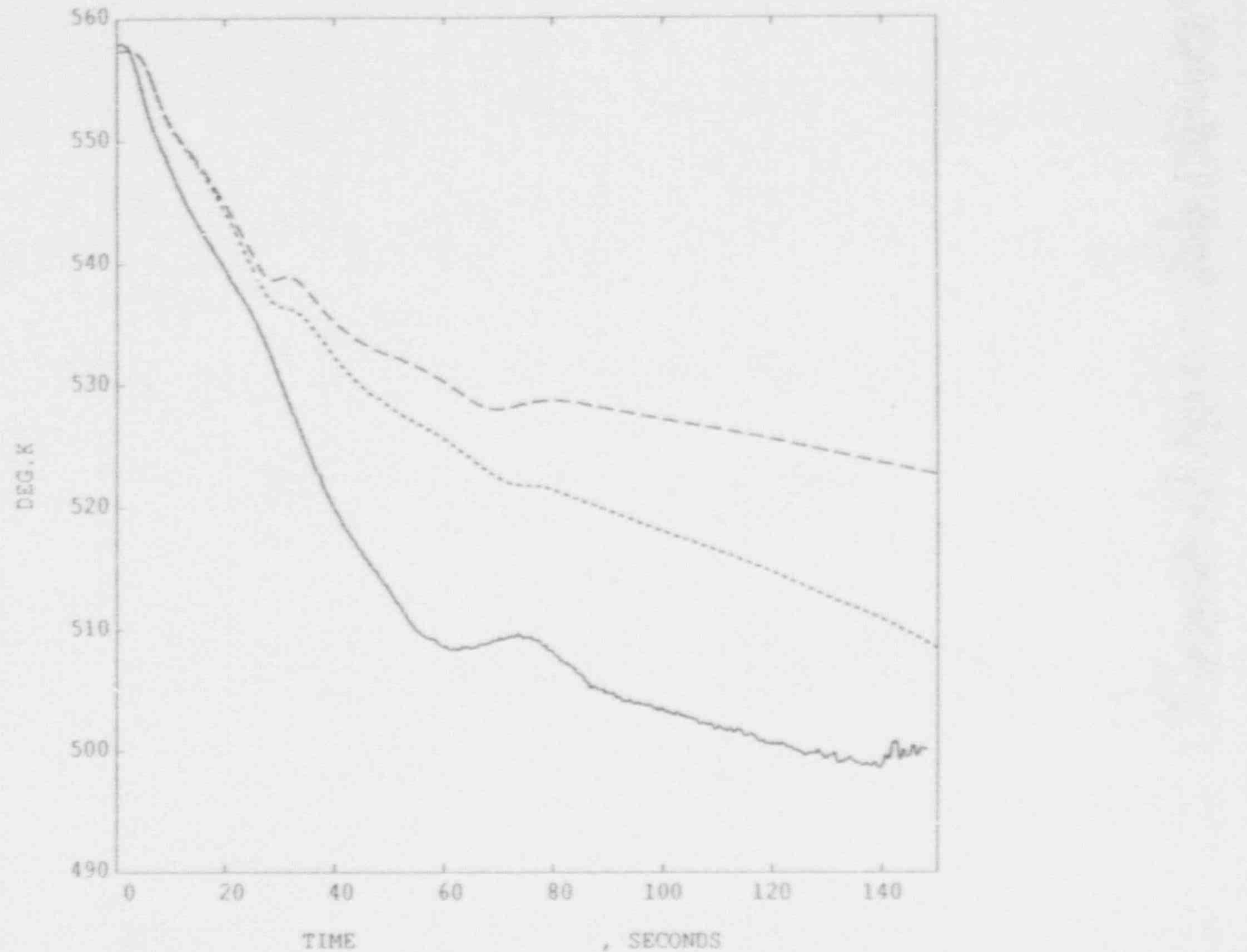


FINAL CALCULATIONS UNCONSTRAINED CASE
FIGURE 22:-INTACT LOOP COLD LEG TEMPERATURE

THE FOLLOWING ARE PLOTTED AGAINST TIME

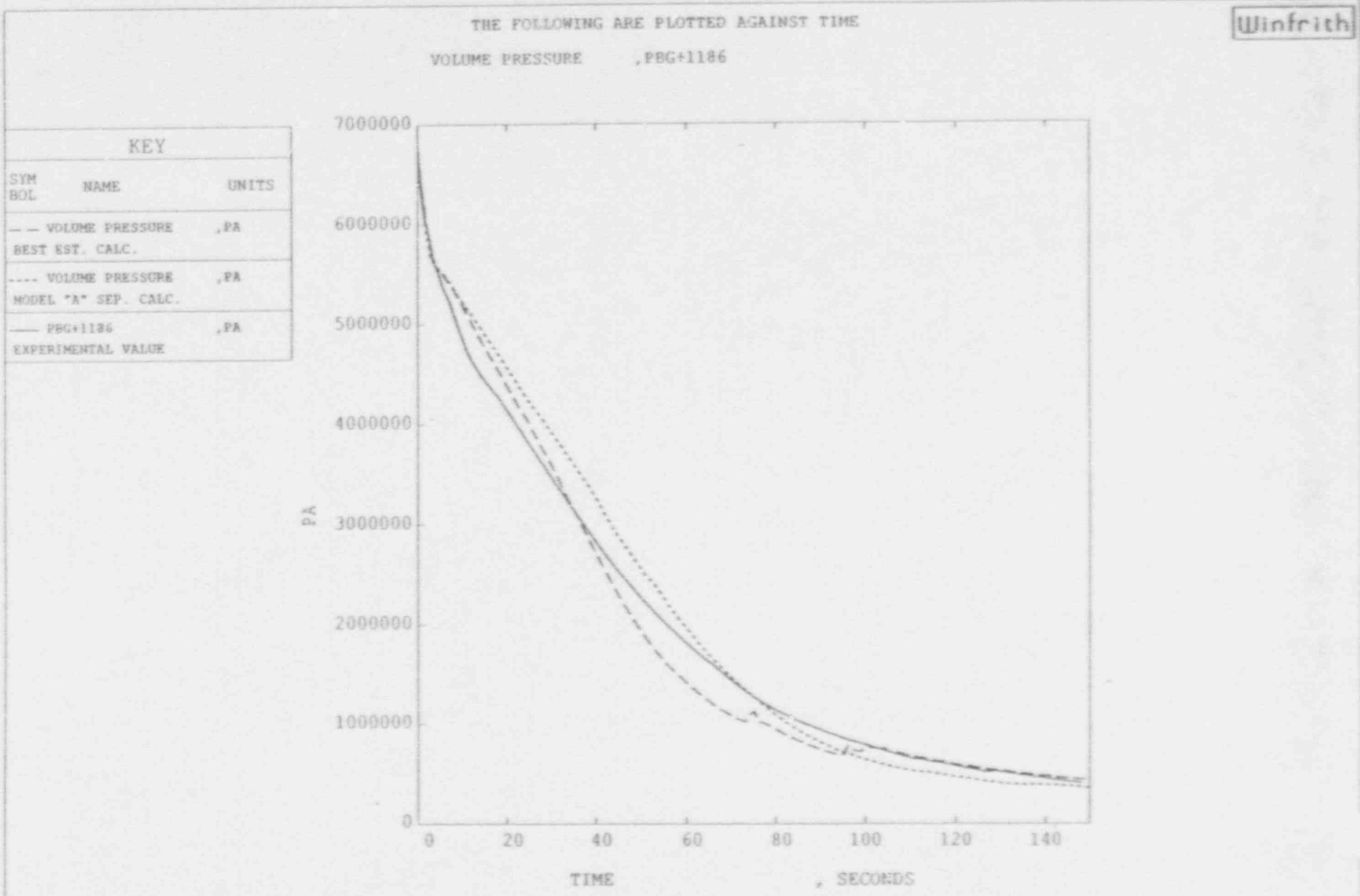
TFB*62 ,VOLUME LIQUID TEMP

KEY		
SYM BOL	NAME	UNITS
——	TFB*62 EXPERIMENTAL VALUE	,DEG.K
----	VOLUME LIQUID TEMP UNCONSTRAINED S.G.	,DEG.K
— —	VOLUME LIQUID TEMP BEST EST. CALC.	,DEG.K

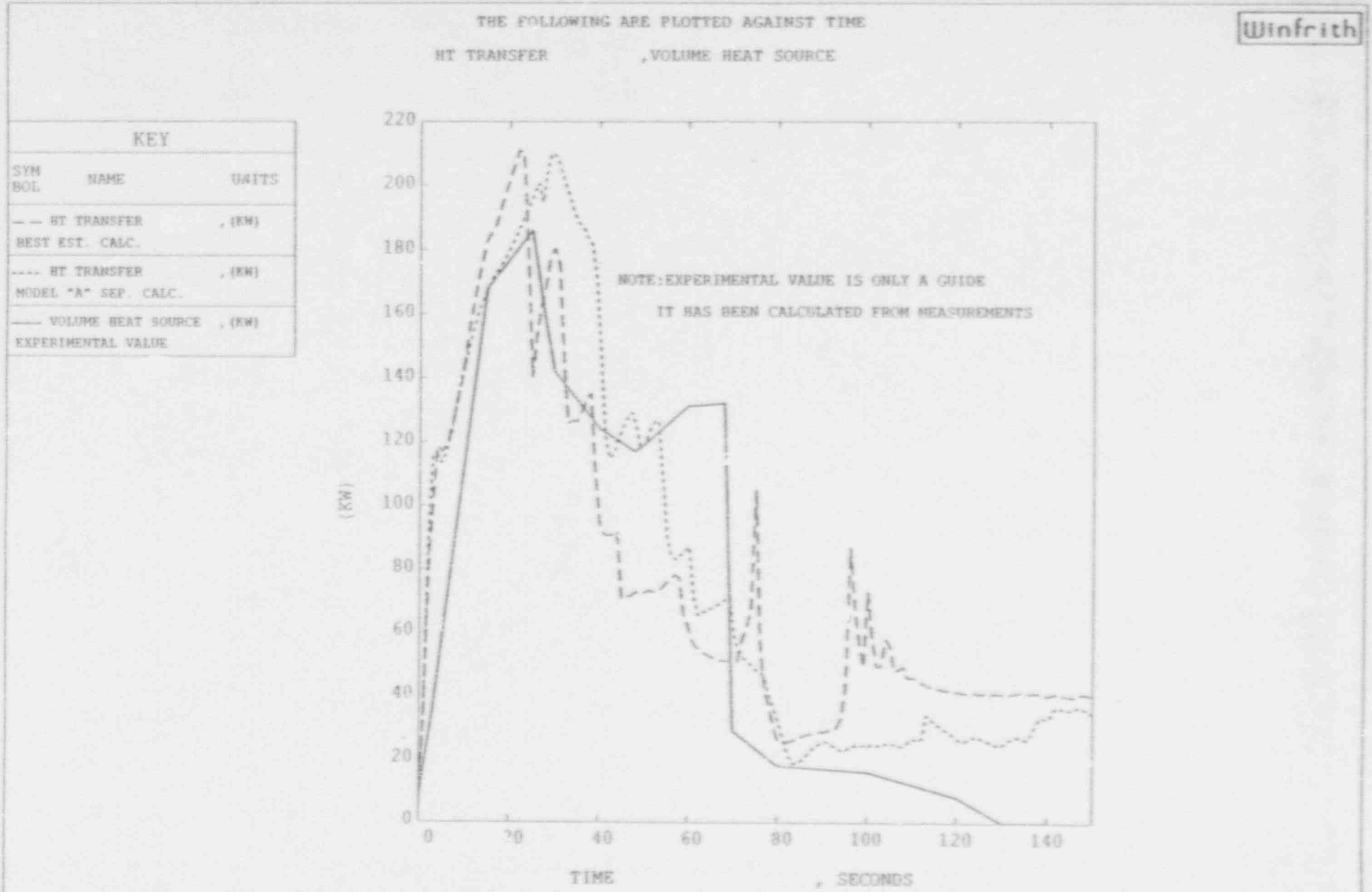


FINAL CALCULATIONS UNCONSTRAINED CASE

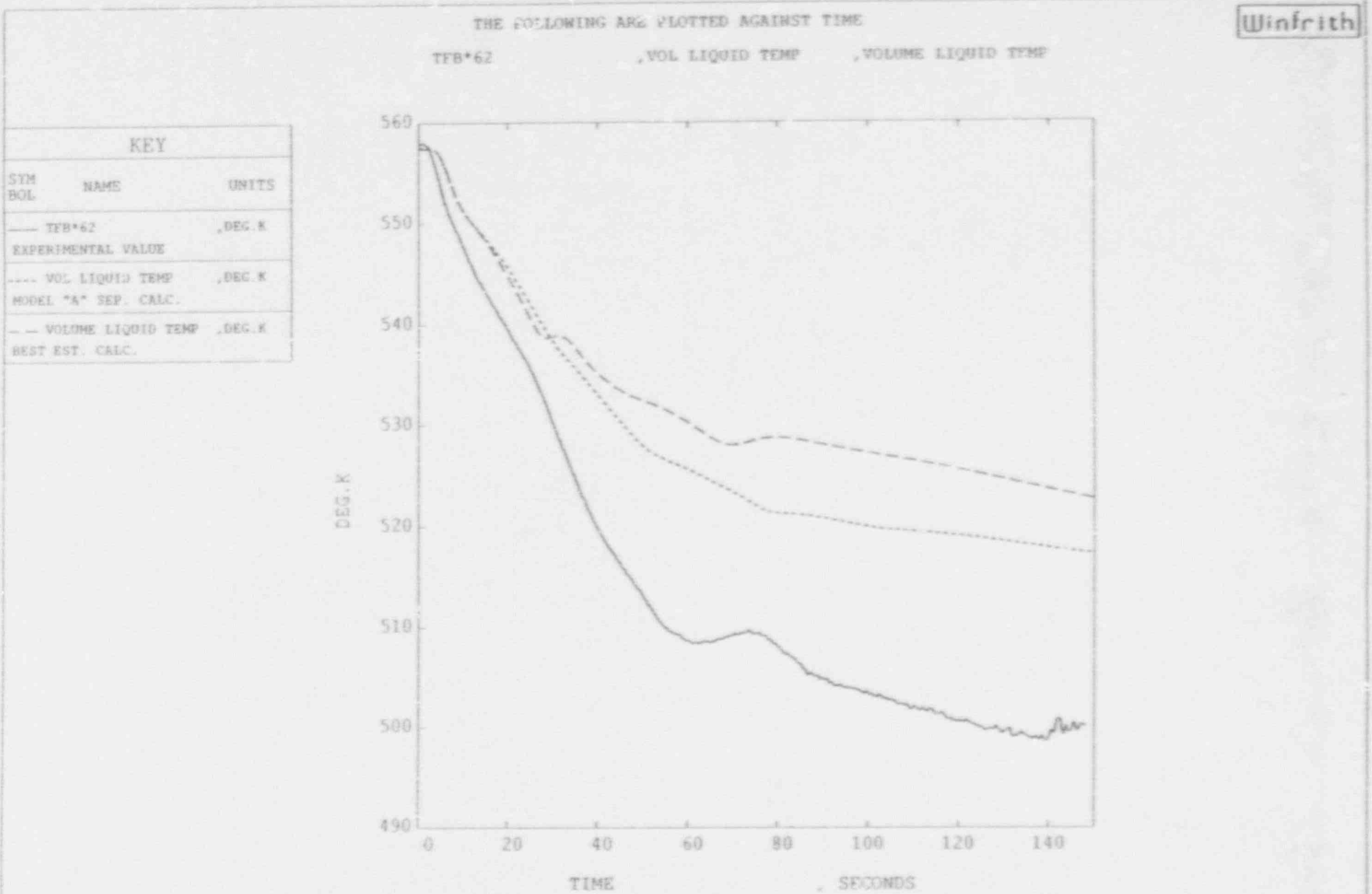
FIGURE 23:-BROKEN LOOP COLD LEG TEMPERATURE



FINAL CALCULATIONS:MODEL "A" SEPARATOR
FIGURE 24-BROKEN LOOP STEAM GENERATOR PRESSURE



FINAL CALCULATIONS:MODEL "A" SEPARATOR
FIGURE 25:-BROKEN LOOP HEAT TRANSFER



FINAL CALCULATIONS:MODEL "A" SEPARATOR

FIGURE 26:-BROKEN LOOP COLD LEG TEMPERATURE

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11. ABSTRACT (200 words or less)

RELAP5/MOD2 is being used by CEGB to assist in an independent assessment of the sizewell B POSR. As part of the process of validation of the code for that assessement performance of the code was verified by applying the results of Semiscale, MB-2 and LOBI.

This report presents the results of the code assessment of RELAP5/MOD2 using semiscale S-FS-1 steam line break test.

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