WCAP-10081-NP
Addendum 2

ADDENDUM TO THE WESTINGHOUSE SMALL BREAK ECCS EVALUATION MODEL USING THE NOTRUMP CODE: SAFETY INJECTION INTO THE BROKEN LOOP AND IMPROVED CONDENSATION MODEL

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1.0 INTRODUCTION

This topical report presents the Westinghouse methodology for modeling Safety Injection (SI) to the broken loop during a postulated small break LOCA in a Pressurized Water Reactor (PWR) analyzed using the NOTRUMP Westinghouse Small Break ECCS Evaluation Model (References 1, 2, & 3). The methodology described in this topical report was developed as a result of the Reference 4 report and followup discussions with the NRC.

Safety Injection, both pumped and accumulator, into the broken loop had previously not been modeled by Westinghouse in performance of small break LOCA analyses since it was assumed that the additional SI was a benefit. This assumption was based on older models which employed a homogenous equilibrium assumption for the mixing of different phases and generally calculated that break sizes larger than an SI line resulted in the highest Peak Cladding Temperature (PCT). The newer NOTRUMP model, developed in response to concerns raised by the Three Mile Island accident, uses non-equilibrium models and flow models which allow for slip between the liquid and steam phases. The assumptions regarding SI to the broken loop were carried over to the NOTRUMP model (Reference 2, pg 5-2). However, results using NOTRUMP show that smaller break sizes are now more limiting, and the response to broken loop SI can now result in an increase in the calculated PCT. Use of a more realistic model for condensation of steam by pumped SI is shown in this topical report to provide a benefit larger than any penalty seen for SI in the broken loop. Additionally, the most limiting broken loop injection scenario for small break LOCAs' has been identified, alleviating the need to examine multiple cases with or without broken loop SI for licensing analyses. This topical report presents the basis for these conclusions. The models described in the report will be applied to all new analyses prior to NRC review and approval. Once the models described in this topical have been reviewed and approved by the NRC, it is expected that all Westinghouse plants analyzed with the NOTRUMP small break evaluation model will demonstrate increased margins to the 10 CFR 50.46 PCT limit.

2.0 BACKGROUND

The small break model described in Reference 2 incorporated models for Safety Injection and Accumulator injection to the cold legs which accounted for non-equilibrium effects. Additionally, ECCS performance has always been affected by assumptions concerning the backpressure on the spilling branch line. Analysis procedure at Westinghouse has always accounted for the assumed back pressure in the ECCS branch line associated with the faulted loop and the resulting affect on pumped ECCS performance. These models and assumptions were incorporated assuming that the Safety Injection water in the branch line associated with the faulted loop (broken loop) did not actually enter the Reactor Coolant System (RCS) and therefore did not interact with the RCS inventory or the blowdown associated with a LOCA. Reference 2 Section 5 provided the basis for assuming that no SI water actually entered the RCS through the broken loop. To fully understand the significance of the assumption made for the spilling line back pressure on small break LOCA calculations, an understanding of the typical Westinghouse ECCS design is helpful.

While a complete description of the various ECCS designs on all Westinghouse designed plants is not possible for this topical report, the general design aspect of interest for SI in the broken loop is very common among the various designs. Typically, the Westinghouse ECCS systems is composed of high and low pressure centrifugal pumps, each connected to a dedicated header which splits into branch lines, one for each RCS cold leg. The dedicated headers of each pump type are joined by a cross tie line which is usually open (typical of 4 loop designs), such that one pump is capable of injecting to all RCS cold legs simultaneously (Figure 1 shows a typical arrangement). This feature allows one train of ECCS to inject to all locations such that a single failure can not preclude injection or result in asymmetric injection such that a large fraction of the SI would be assumed to go to the faulted (broken) loop. This design of headers and branch lines, results in two assumptions for the backpressure on the SI branch line(s) connected to the faulted loop depending upon the size of the postulated break.

If the postulated break is larger (diameter) than an SI branch line diameter, then that branch line is also postulated to be affected by the fault and SI in that branch line is assumed to spill to the containment floor. SI flow performance for injection to the intact RCS cold legs is based upon the faulted branch line spilling against containment backpressure. Spill to containment backpressure results in a lower flow being delivered to the intact SI branch lines, due to the higher pressure drop across the broken branch line giving a high flow in this branch line, which reduces flow to the intact branch lines. This assumption translates into higher Peak Cladding Temperatures (PCT) due to the reduced delivery to the intact loops.

If the postulated break is smaller in size (diameter) than an SI branch line, then that branch line is assumed to remain connected to the RCS but may contain the break such that SI flow performance is based on spill against the RCS pressure but the SI still spills to the containment floor. Spill to RCS backpressure results in the highest SI flow in the intact branch lines which translates into a reduction in PCT.

Both of the above situations shared the assumption that spilling the ECCS flow in the faulted loop branch line to the containment floor was conservative. Further, the NOTRUMP Small Break Evaluation Model (Ref:1,2,&3) has tended to predict that smaller break sizes resulted in the most limiting PCT, and therefore, credit for SI spilling against RCS back pressure, in terms of the effect on SI delivery to the intact loops, has been taken in numerous analysis. However, other effects of SI in the broken loop had not been fully considered, since it was assumed that if the SI did not spill to the containment floor, the additional SI delivery to the RCS through the faulted loop would aid in core cooling (Ref 2, pg 5-2). The remaining sections of this topical report will deal with the effects of SI entry into the faulted (broken) loop on postulated small break LOCA calculations and the modifications to the Westinghouse Small Break LOCA Evaluation Model.

3.0 SI IN THE BROKEN LOOP/SAFETY INJECTION PHENOMENA

The principal issues associated with broken loop safety injection are:

1) the additional subcooling of the broken loop inventory due to mixing with the highly subcooled SI during the period of subcooled break flow,

2) effect of condensation efficiency on the balance between the loss of RCS inventory due to break flow, and makeup of inventory from SI entering the broken loop during the two-phase/single phase steam break flow period,

3) comparison of the condensation efficiencies of the existing and proposed models, and

4) determination of appropriate SI delivery to the intact loops due to changes in assumptions.

3.1 Subcooled Break Flow Period

Small break LOCA transients are characterized by a critically limited blowdown that begins with a period of subcooled liquid break flow prior to loop seal clearing and then a transition to two-phase critically limited break flow. The presence of Safety Injection (SI) in the loop containing the break will affect local conditions used in determining the flow rate and energy release out of the postulated break. How these conditions are affected by the presence of the subcooled SI will change the transient response of the RCS to the postulated break, when compared to the case without SI to the broken loop.

The time from inception of the postulated break to just before the loop seal clears is a period of liquid break flow which is generally subcooled. During this period, both the intact and broken loop cold legs remain water solid while the systems is drained by the break until uncovery of the loop seal. During this time, since steam is not yet present in the cold legs, the effects of condensation models on local conditions are non-existent, and therefore, the choice of a condensation model is not relevant to this period of the transient. However, when SI is allowed to mix with the contents of the broken RCS cold leg, the result is that the highly subcooled SI will further subcool the fluid in the cold leg. Since subcooled break flow rates increase with increasing subcooling, an increase in break flow is observed. This increase is sometimes dramatic in that an injection rate of 10 lbm/sec to the broken loop can result in an increase of the break flow by up to 100 lbm/sec, depending upon the extent of SI subcooling. The increase in break flow during the early subcooled portion of the small break LOCA transient results in an earlier drain down of the RCS to the level needed for loop seal uncovery. However, the increased blowdown of the RCS prior to loop seal blowing also results in less system inventory at the beginning of the two-phase break flow period, resulting in the potential for an extended and deeper core uncovery than seen for a case without SI to the broken loop.

3.2 Two-Phase and Single Phase Steam Break Flow Period

Once the loop seal has cleared, steam begins to enter the RCS cold legs and the break flow changes over to two-phase. RCS flow to the broken loop is predominately all steam. During this period the presence of SI in the broken loop will result in condensation leading to a pronounced effect on break flow and system pressure. Therefore, during this period, the choice of a condensation model will be important to the prediction of the course of the transient.

To illustrate the importance of condensation efficiency in the broken loop, the following comparison is provided. The following conditions were taken from a 3-inch diameter cold leg break analysis performed for a 3-loop 2775 MWt plant.

System Pressure = 1016 psia,	T-Saturation = 546°F,
h_g = 1190 BTU/lbm,	h_f = 544 BTU/lbm
Break Flow = 106 lbm/sec	Flow quality = 96%
4 lbm/sec saturated liquid,	
102 lbm/sec saturated vapor	

First, assume that the broken loop SI cannot condense any of the broken loop steam flow. In this case, the SI would tend to partially plug the break resulting in a smaller effective break size for relieving the steam created as a result of the decay heat load. The RCS pressure and mass inventory transient then looks like a slightly smaller break size during this period. If pumped SI in the broken loop were modeled, then approximately 18 lbm/sec at 110°F would be delivered to the broken loop. If this SI was assumed to not interact with the broken loop two phase mixture, then the break flow would consist of a mixture of subcooled liquid, saturated liquid, and saturated vapor. This composition is a nonequilibrium mixture for which calculation of the break flow or reservoir pressure is difficult. However, assumptions can be made which would allow an estimate of the new system pressure to be made based on preserving the break mass flow rate. If the 18 lbm/sec of subcooled SI were assumed to be saturated when leaving the break, then the new break flow composition would be 22 lbm/sec of saturated liquid, and 102 lbm/sec of saturated vapor, as a result of assuming no condensation. The new quality would be 82% for an enthalpy of 1076 BTU/lbm (@ 1016 psia). Given these conditions, a system pressure of 1060 psia would be needed to support the break flow given the addition of the SI. If the subcooled SI were assumed to remain subcooled then an estimate of the system pressure needed to support the break flow can be made by partitioning the break area between subcooled liquid and saturated components. This results in a system pressure of approximately 1033 psia. In either case the system pressure had to increase to accommodate the additional break flow brought about by the introduction of the pumped SI to the broken loop.

The opposite assumption would be to assume homogeneous condensation (100% efficiency) in that all the SI were raised to saturation through condensation of the broken loop steam flow. If complete thermal equilibrium were assumed with condensation permitted, the SI would condense about 13 lbm/sec of saturated steam to saturated liquid. Now, the break flow would consist of 35 lbm/sec of saturated liquid and 89 lbm/sec of saturated vapor for a total break flow of 124 lbm/sec with a homogeneous quality of 72%. A system pressure of 965 psia would be required to support the new break conditions. Since the system pressure decreased in this example, the effect of SI in the broken loop is dependent upon the condensation effectiveness of the SI. Accounting for accumulator injection, which may or may not come on prior to calculating the Peak Cladding Temperatures, would enhance any condensation effects and aid in reducing system pressure.

Thus, the presence of SI in the broken loop will affect the effluent leaving the break and depending upon condensation effectiveness of the SI, RCS pressure may either increase or decrease when compared to the case with no SI to the broken loop. This interaction between the SI in the broken loop, break flow and system pressure are the effects primarily responsible for determining if SI to the broken loop will result in a increase or decrease in PCT.

3.3 Comparison of Condensation Models

Safety Injection flow into the broken loop affects the overall amount of steam condensation which may occur within the Reactor Coolant System (RCS). The amount of steam condensation which can be accomplished by the safety injection flow into the broken loop is a function of the condensation efficiency.

3.3.1 Original NOTRUMP Condensation Model

The current NOTRUMP cold leg condensation model is described in Reference 2, Section 3-3, "Safety Injection Nonequilibrium Model Description." This model is known to underpredict condensation rates, and comparison of the current model to experimental results in Reference 5 found that for typical conditions, the model predicted a condensation efficiency on the order of only [ ]^{a,c}, where condensation efficiency is defined as the ratio of the heat absorbed by the SI to the heat required to raise all the SI to saturation. The current model was selected as a convenient model for providing low condensation rates, which was judged to be conservative for SBLOCA analyses based upon gross homogeneous thermal hydraulic phenomena in the RCS. Low condensation rates resulted in conservative predictions of SI influence on system performance and core cooling due to two main mechanisms: lower condensation induced depressurization rates, and less core level swell. The reduced core level swell was attributed to the fact that the SI water was heated less from cold leg condensation, and thus contributed to a net lower core inlet enthalpy, which resulted in less boiling and void displacement. However, due to this low efficiency, the effects of parametrically varying SI flow are greatly reduced and generated some of the questions related to the broken loop SI issue.

3.3.2 COSI Condensation Model

An improved condensation model is based on data obtained from the COSI test facility. The COSI test facility is a [ ]^{a,c} scale representation of the cold leg and SI injection ports in a Westinghouse designed PWR. The COSI tests covered a pressure range of [ ]^{a,c} psia, which is the range of typical interest for small break LOCA transients. Condensation at pressures below [ ]^{a,c} psia are not of interest since accumulator injection at these pressures will dominate a postulated small break LOCA, usually terminating the clad heatup. Additionally, review of the COSI test data shows that the condensation heat transfer was only weakly influenced by variations in pressure. The COSI tests covered various ECCS configurations for entry of the SI into the cold leg, a range of injection flows scaled against flows seen for the full scale ECCS, and the effect of the RCP weir on condensation. Thus, the tests are considered to be fully descriptive of various ECCS configurations found in Westinghouse designed PWRs. The significant finding of the tests was that the majority of the condensation [ ]^{a,c}. Thus, it was possible to derive a correlation for the condensation heat transfer coefficient based on [ ]^{a,c}. The test results indicated that condensation efficiency ranged from [ ]^{a,c}, except at very low SI flow conditions, where efficiency fell to around [ ]^{a,c}. The higher condensation efficiencies are considered typical for PWRs using a Westinghouse designed ECCS.

When the current NOTRUMP condensation model is replaced by a newer model (Reference 5) based on tests which modeled the configuration of the SI piping to the RCS cold leg, an increase in steam condensation rate is calculated. Improved condensation of steam in the intact loops results in lower RCS pressure and larger SI flow rates. Further, increased condensation of steam by the SI water in the intact cold legs results in additional warming of the SI water prior to reaching the core. Warmer water entering the core results in increased steaming in the core, increased mixture void fraction and increased mixture level. In some cases, the increased steaming tends to offset any pressure reduction expected as a result of increased condensation, however, the higher mixture level leads to a lower PCT. Additionally, improvements in condensation in the broken loop by the broken loop SI can further decrease RCS pressure and may partially or completely offset any "plugging" effect on the break. The increase in SI flow rates, due to lower RCS pressure, leads to lower calculated Peak Cladding Temperatures. Thus, the effects of SI into the broken loop on break flow can be offset by an improved SI condensation model.

The COSI model will be applied to pumped ECCS in both the intact and broken loops. Condensation due to ECCS Accumulator injection will continue to use the conservative condensation model discussed in Section 3.3.1.

3.4 SI Delivery Assumptions

While there is no direct effect of SI to the broken loop on SI delivery, some assumptions made in calculating the SI flows need some additional justification. Generally, SI flows are generated with a single backpressure assumption applied to all branch lines, and either RCS or containment back pressure is used. In the case of SI to the broken loop the RCS pressure in the broken loop may be different than the pressure in the intact loops which could change the flow balance between branch lines. [

]^{a,c}.

4.0 ANALYSIS OF TYPICAL PLANTS: RESULTS

In order to demonstrate the effect on NOTRUMP SBLOCA licensing analyses, break spectrums were analyzed for both a 3-loop and 4-loop Westinghouse designed PWR. The spectrum included sensitivities to the new COSI condensation model and SI to the broken loop. Thus, each break size had a minimum of 3 cases which were 1) original condensation model, 2) COSI condensation model in the intact loop, and 3) COSI condensation model in both the intact and broken loops with SI to the broken loop. In addition, for some breaks, a case(s) was run using the original condensation model with SI flow in both the intact and broken loops. In this manner single effects can be determined over the range of break sizes generally analyzed with the NOTRUMP SBLOCA Evaluation model for licensing applications.

4.1 3 Loop Plant

A 3 loop plant having a reactor core power rating of 2775 Mwt and an ECCS design typical of newer Westinghouse designs using 12 foot cores was chosen for use in performing the 3 loop plant studies. This same plant was used in developing the estimated effect on PCT reported in Reference 4. The ECCS design generally has two trains of SI each composed of a high pressure pump (Charging/SI) and a low pressure pump (RHR/LHSI). Each train of SI is headered to the 3 RCS cold legs with the Charging/SI headered to the RHR/LHSI upstream of the connection to the RCS cold legs. Therefore, breaks less than the RHR/LHSI line diameter (6 inch Schedule 160) would traditionally be assumed to spill against RCS back pressure. Each train of SI has a dedicated diesel generator for operation in the event that offsite power is lost.

Tables 1 and 2 present the results of the break spectrum. These results show that the 3-inch cold leg break was more limiting, after NOTRUMP was modified with the COSI condensation model and SI to the broken loop was considered. The most limiting break size, did not change relative to the analysis performed using NOTRUMP having the original condensation model and without SI to the broken loop (Table 5). However, the spread in PCT between the limiting break and the small break has increased, while the PCT spread between the limiting break and the larger break has decreased.

Tables 3 and 4 presents the sensitivity studies performed to determine the effect of the new condensation model (COSI) and SI in the broken loop on calculated PCT. Detailed results are presented only for the most limiting break, however, similar cases were run for both the 2 and 4 inch breaks. Table 5 presents the resulting PCT for the 2 and 4 inch break sensitivity cases. These sensitivity studies show a large penalty (200°F) for SI to the broken loop when the original condensation model is used and a benefit for the improved condensation model. These results are somewhat different than reported in Reference 4 which indicated that SI to the broken loop was a 150°F penalty. The change in the sensitivity for SI in the broken loop may be related to a more accurate programming of the COSI model into NOTRUMP than was used in the scoping analysis reported in Reference 4. In, particular, the presence of superheated steam was considered when COSI was reprogrammed into NOTRUMP.

Key parameters from the NOTRUMP transient for the 3 loop plant cases appear in Figures 2 through 10. For the 2 inch case, the improved condensation resulted in a lower system pressure (Figure 2) with a resultant increase in SI such that a net improvement in core mixture level (Figure 3) and PCT (Figure 4) was seen when compared to the NOTRUMP model using the original condensation model and no SI to the broken loop. This trend is noted for both the 3 and 4 inch transients, which were also aided by accumulator injection.

Since the effect of the COSI model on calculated PCT has been shown to be much greater than the effects of broken loop SI, all 3 loop plants currently licensed using the NOTRUMP SBLOCA Evaluation Model will remain below the 2200°F criteria. Margin will be available through performance of new analyses.

4.2 4 Loop Plant

A 4 loop plant having a reactor core power rating of 3250 Mwt and an ECCS design typical of newer Westinghouse designs using 12 foot cores was chosen for use in performing the 4 loop plant studies. The ECCS design generally has two trains of SI each composed of a high pressure pump (Charging/SI), an intermediate head pump (High Head SI), and a low pressure pump (RHR/LHSI). Each train of SI is headered to the 4 RCS cold legs with the HHSI headered to the RHR/LHSI which are headered to the accumulator lines. The Charging/SI has independent connections to the RCS cold legs. Therefore, breaks less than the RHR/LHSI line diameter (10 inch Schedule 140) would traditionally be assumed to spill the HHSI and LHSI against RCS back pressure. Since the Charging/SI have separate SI lines to the RCS cold legs (1.5inch schd 160) breaks sizes less than 1.5 inch are required to assume that the Charging/SI spills against RCS backpressure, thus the general FSAR analysis assumes spill against containment backpressure for the Charging/SI. Each train of SI has a dedicated diesel generator for operation in the event that offsite power is lost.

Tables 6 and 7 present the results of the break spectrum when the COSI correlation is used for SI condensation and SI is assumed to be injected to the broken loop. As in the 3 loop plant case, the most limiting break did not shift, but the spread in PCT between the limiting break and the smaller break has increased, while the spread between the limiting break and the larger break has decreased (see Table 10). Tables 8 through 9 present the sensitivity study for the 3 inch break with a result that SI to the broken loop is a penalty regardless of condensation model used in the calculation. Similar cases were run for both the 2 and 4 inch breaks which showed that broken loop SI was a penalty when the COSI condensation model was used in the calculation. The penalty ranged from [ ]^{a,c}°F for the 2, 3, and 4 inch break cases as can be seen from Table 10. Theses cases calculated penalties based on the effect seen during the subcooled break flow period.

Since the net benefit of the COSI model on calculated PCT has been shown to be much greater than the effect of broken loop SI, all 4 loop plants currently licensed using the NOTRUMP SBLOCA Evaluation Model will remain below the 2200°F criteria. Margin will be available through performance of new analyses.

4.3 Effect on Break Spectrum, Most Limiting Break

As can be seen from the plant studies performed, the most limiting break size did not shift as a result of the new COSI condensation model and broken loop SI. Since the COSI model reduces system pressure due to enhanced condensation, the effect of COSI is to make an existing transient behave like a larger break. SI to the broken loop, much like condensation effects in the intact loop, tends to result in system depressurization therefore an existing transient tends to behave like a large break. These effects, which are most pronounced for smaller breaks due to the greater dependency upon condensation effects, did not result in the most limiting break changing. Additionally, the COSI benefit and the effect of SI in the broken loop both varied with break size. For the 3 loop plant, these effects ranged from a [ ]^{a,c}°F benefit for the COSI model and a [ ]^{a,c}°F benefit for SI in the broken loop, as can be seen from Table 5. This range of variance over break size shows that for smaller breaks the effect of subcooling the broken loop liquid during the subcooled break flow period tends to dominate compared to the effects of SI to the broken loop during the two-phase/single phase steam period. Therefore, system changes which could cause larger breaks to become more limiting may be magnified by the assumption of SI to the broken loop. Westinghouse will consider such effects in future analysis and safety evaluations.

4.4 Relationship Between ECCS Spilling Assumptions and Break Location

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4.5 Effect on RCP Trip Criteria

The effect on RCP Trip criteria had previously been evaluated for SI to the broken loop. The conclusion was reported in Reference 4 and is repeated here for completeness. Studies performed in support of the Reference 4 for a typical 3 loop plant showed that SI in the broken loop did not change the sensitivity to RCPs running or the small break LOCA RCP trip criteria found in the Westinghouse Emergency Response Guidelines (ERGs).

5.0 Westinghouse Licensing Position

Westinghouse will incorporate the COSI condensation model into the NOTRUMP Evaluation Model and update input procedures to require that SI be injected into the broken loop. Since these changes will provide a net benefit for all plants, Westinghouse will track a 0°F effect on PCT for existing analyses. Any benefit in small break LOCA PCT will be obtained by new analysis when a plant is reanalyzed in support of a licensing amendment requiring small break LOCA reanalysis. This is a forward fit licensing position that does not result in compromising any safety requirement and satisfies 10CFR50.46 regulations.

Additionally, individual plant sensitivity studies will not be needed to determine if SI delivery to the broken loop or SI to spill to the containment is more limiting. The basis for this was provided in Section 2.0 and 4.5 with regard to the most limiting location within the RCS pipe for the break and physical orientation of the SI penetrations. Thus, [

]^{a,c}. New analyses performed after the submittal date of this topical report will include SI injection to the broken loop.

6.0 Conclusion

Reference 4 reported to the NRC a significant change in assumptions used in analyzing small break LOCA transients in Westinghouse designed PWRs or in some cases another vendors design which is utilizing fuel supplied by Westinghouse. Aspects of the Reference 4 report were clarified at a follow up presentation to the NRC (Reference 6) and this topical report satisfies agreements made at that meeting.

The results of work performed in this topical report have demonstrated that the NOTRUMP models of Reference 2 and 3 were underpredicting the condensation by the SI and were therefore overly conservative. The use of newer information (Reference 5), along with the correlation from Reference 5 has resulted in a large benefit in condensation and calculated PCT. Additionally, application of the Reference 5 correlation to SI in the broken loop piping, when SI is injected into the broken loop, has resulted in a much smaller effect due to SI in the broken loop than previously reported in Reference 4. Therefore, all analyses currently performed with the evaluation models of References 2 or 3 are conservative with respect to the changes reported in this topical report and continue to satisfy the requirements of 10 CFR 50.46 and Appendix K to 10 CFR 50.

SECTION 7

REFERENCES

1) WCAP-10079-P-A (PROPRIETARY) and WCAP-10080-A (NON-PROPRIETARY) "NOTRUMP: A Nodal Transient Small Break and General Network Code", August 1985.

2) WCAP-10054-P-A (PROPRIETARY) and WCAP-10081-NP-A (NON-PROPRIETARY), "Westinghouse Small Break LOCA ECCS Evaluation Model Using the NOTRUMP Code", August 1985.

3) WCAP-10054-P-A, (PROPRIETARY) Addendum 1 and WCAP-10081-NP-A (NON-PROPRIETARY) Addendum 1, "Addendum to the Westinghouse Small Break ECCS Evaluation Model using the NOTRUMP Code for the Combustion Engineering NSSS", March 1987.

4) W Letter ET-NRC-93-3971, N. J. Liparulo (W) to US NRC Document Control Desk, "Notification of a Significant Change to the Westinghouse Small Break LOCA ECCS Evaluation Model, Pursuant to 10CFR50.46 (a)(3)(ii): Safety Injection (SI) in the Broken Loop", September 21, 1993.

5) [

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6) W Letter NTD-NRC-94-4034, N. J. Liparulo (W) to US NRC Document Control Desk, "Slides from the January 12, 1994 NRC Meeting on Safety Injection in the Broken Loop and Westinghouse Topical Report WCAP-11767 (Proprietary) COSI/Steam Condensation Experiment Analysis, March 1988", Jaunary 11, 1994

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TABLE 1

3-Loop Plant SI in the Broken Loop
Cold Leg Break Studies
Using COSI Condensation Model

Time Sequence of Events

Item	2-Inch Diameter	3-Inch Diameter	4-Inch Diameter
Start	0	0	0
Reactor Trip Signal	127.25	37.27	22.56
SI Signal	143.61	51.22	32.74
Pumped SI Begins	170.61	74.46	60.39
Top of Core Uncovered	1549.95	578.12	234.21
Accum. Inj. Begins	N/A	1105.82	628.64
PCT Occurs	2751.64	1162.66	720.62
Top of Core Recovered	6078	3490	1015

Inputs

Reactor Trip Signal	1845 psia
SI Signal	1715 psia
Accum. Water Volume	1045 ft^3/ Tank

WESTINGHOUSE NON-PROPRIETARY CLASS 3

TABLE 2

3-Loop Plant SI in the Broken Loop
Cold Leg Break Studies
Using COSI Condensation Model

RESULTS

Results	Cold Leg 2-Inch	Cold Leg 3-Inch	Cold Leg 4-Inch
Peak Clad Temp. (°F)	1413.78	1772.3	1672.78
Peak Clad Temp. Elev. (Ft.)	11.50	11.50	11.25
Peak Clad Temp. Time (Sec)	2751.64	1162.66	720.62
Max Local Zr/H_2O Reaction (%)	0.6268	2.33	0.6348
Max Local Zr/H_2O Rxn Elev. (Ft.)	11.50	11.75	11.25
Total Zr/H_2O Reaction (%)	< 1.0	< 1.0	< 1.0
Hot Rod Burst Time (Sec)	NO BURST	NO BURST	NO BURST
Hot Rod Burst Elev. (Ft.)	N/A	N/A	N/A

Inputs

NSSS Power (1.02 % of)	2775
Peak Linear Power (1.02 % of)	FIGURE 2
Maximum Allowable Peaking Factor	2.45 @ 6.0 Feet
Enthalpy Rise Peaking Factor (F^N_{DH})	1.62

TABLE 3

3-Loop Plant 3-Inch Break
Sensitivities

a,c

TABLE 4

3-Loop Plant 3-Inch Break
Sensitivities

a,c

TABLE 5

3-Loop PCT For
Break Spectrum and Sensitivities

a,c

TABLE 6

4-Loop Plant SI in the Broken Loop
Cold Leg Break Studies
Using COSI Condensation Model

Time Sequence of Events

Item	2-Inch Diameter	3-Inch Diameter	4-Inch Diameter
Start	0	0	0
Reactor Trip Signal	56.49	23.17	13.45
SI Signal	56.49	23.17	13.45
Pumped SI Begins	96.49	63.17	53.45
Top of Core Uncovered	1962.0	717.0	371.0
Accum. Inj. Begins	N/A	1484.0	757.0
PCT Occurs	3240.0	1559.37	817.99
Top of Core Recovered	5424.0	2498.0	1019.0

Inputs

Reactor Trip Signal	1700.0 psia
SI Signal	1700.0 psia
Accum. Water Volume	853 ft^3/ Tank

TABLE 7

4-Loop Plant SI in the Broken Loop
Cold Leg Break Studies
Using COSI Condensation Model

RESULTS

Results	Cold Leg 2-Inch	Cold Leg 3-Inch	Cold Leg 4-Inch
Peak Clad Temp. (°F)	1546	1792	1526
Peak Clad Temp. Elev. (Ft.)	11.50	11.75	11.00
Peak Clad Temp. Time (Sec)	3240.0	1559.37	817.99
Max Local Zr/H_2O Reaction (%)	0.929	2.04	0.343
Max Local Zr/H_2O Rxn Elev. (Ft.)	11.50	11.50	11.00
Total Zr/H_2O Reaction (%)	< 1.0	< 1.0	< 1.0
Hot Rod Burst Time (Sec)	NO BURST	NO BURST	NO BURST
Hot Rod Burst Elev. (Ft.)	N/A	N/A	N/A

Inputs

NSSS Power (1.02 % of)	3250
Peak Linear Power (1.02 % of)	FIGURE 12
Maximum Allowable Peaking Factor	2.45 @ 6.0 Feet
Enthalpy Rise Peaking Factor (F^N_{DH})	1.65

TABLE 8

4-Loop Plant 3-Inch Break
Sensitivities

a,c

[ ]

TABLE 9

4-Loop Plant 3-Inch Break
Sensitivities

a,c

TABLE 10

4-Loop PCT For
Break Spectrum and Sensitivities

a,c

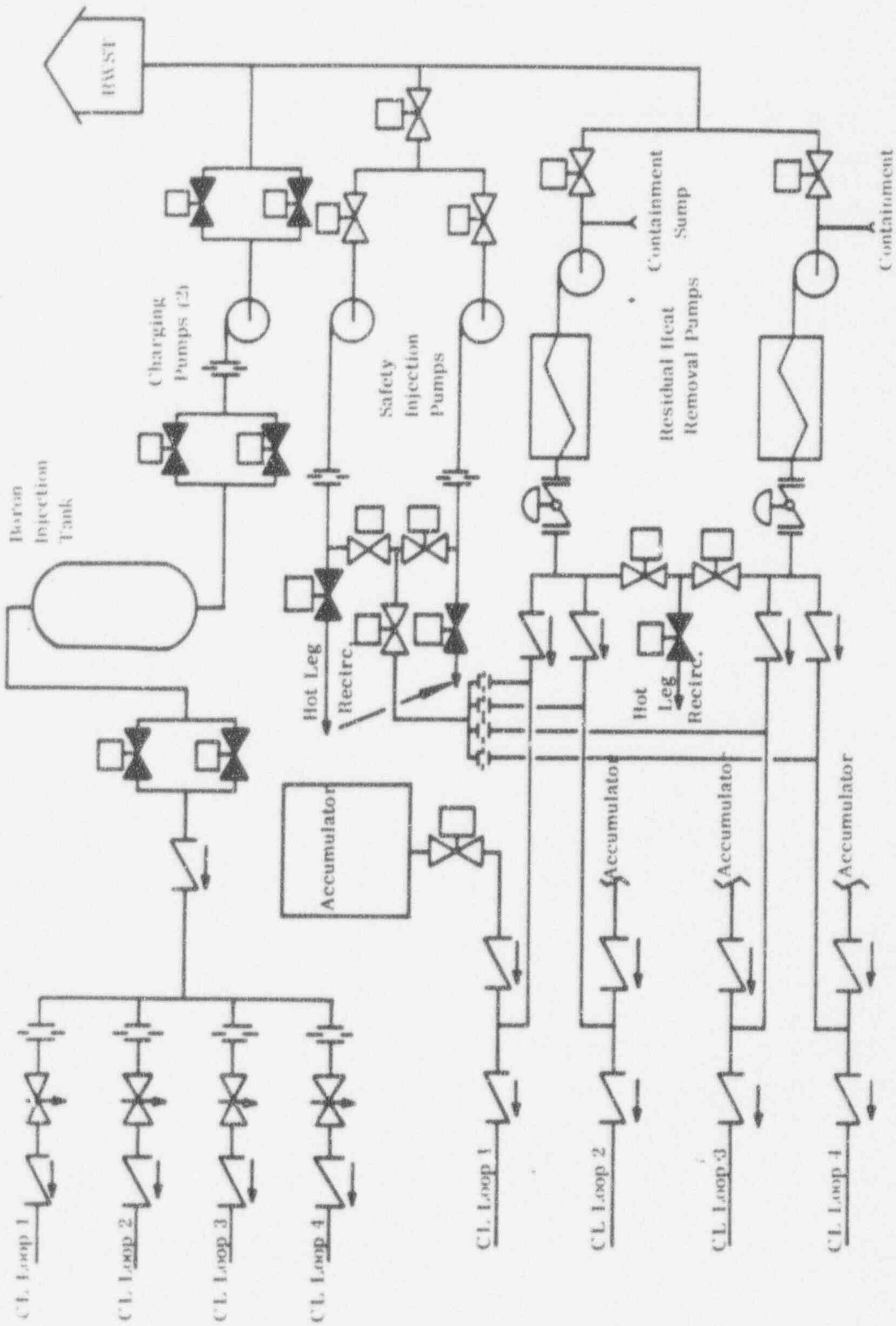

Figure 1 - Typical 4-loop Plant ECCS

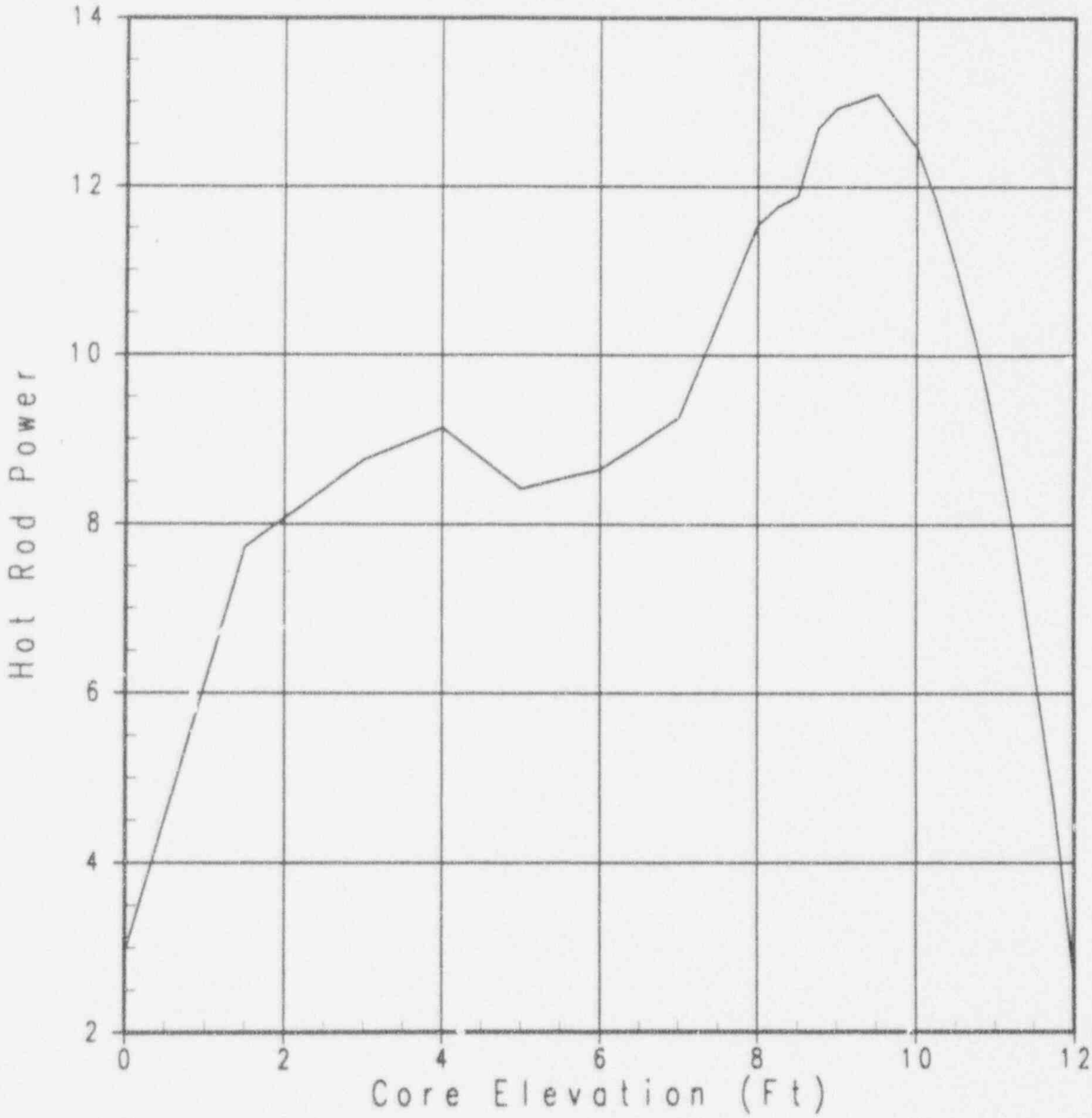

Figure 2 - 3 Loop Plant Power Shape (Kw/Ft)

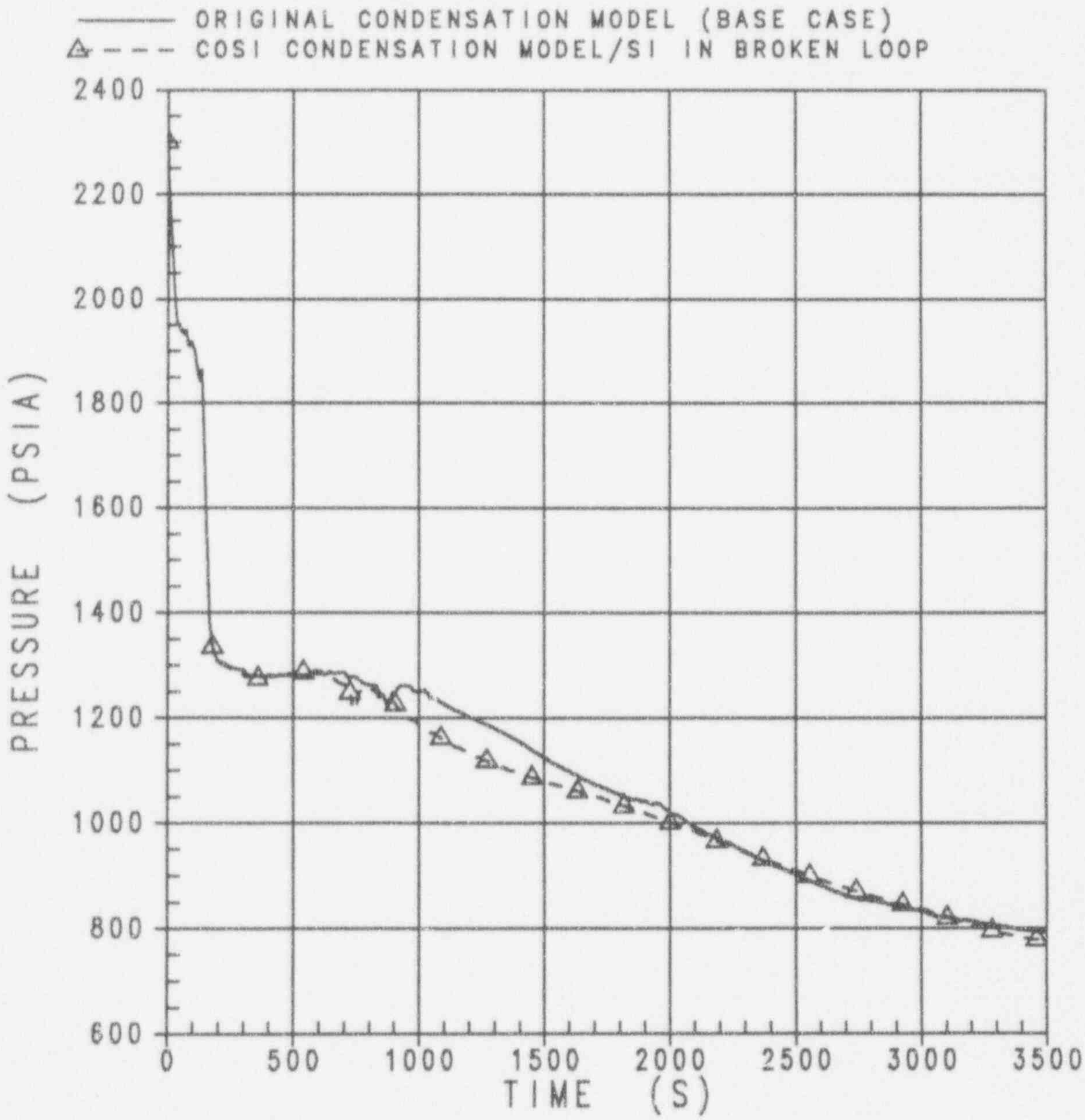

Figure 3
RCS Pressure
3 Loop Plant, 2 Inch Break

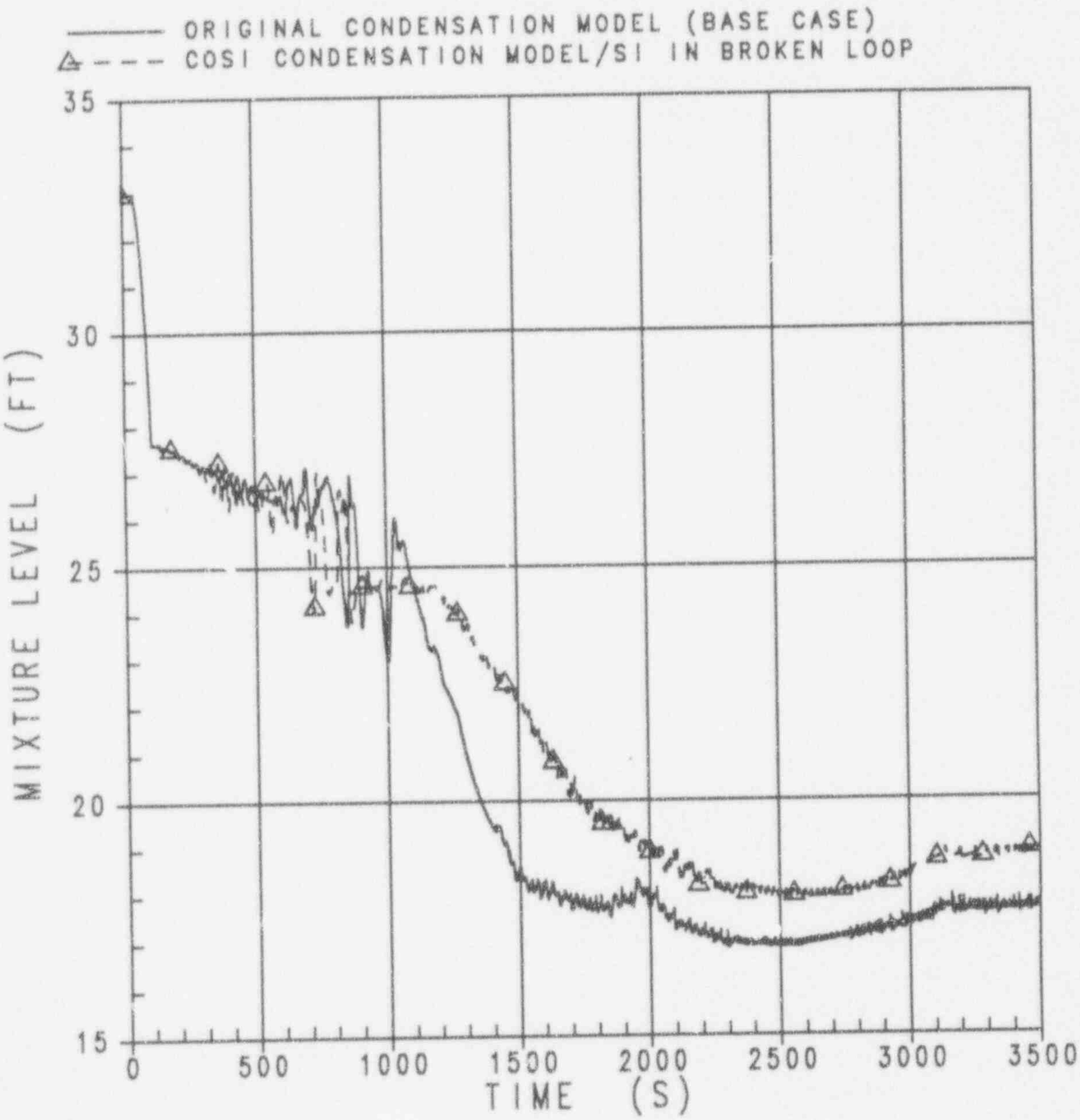

Figure 4
Core Mixture Level
3 Loop Plant, 2 Inch Break

[ ]a,c

Figure 5
Peak Clad Temperature
3 Loop Plant, 2 Inch Break

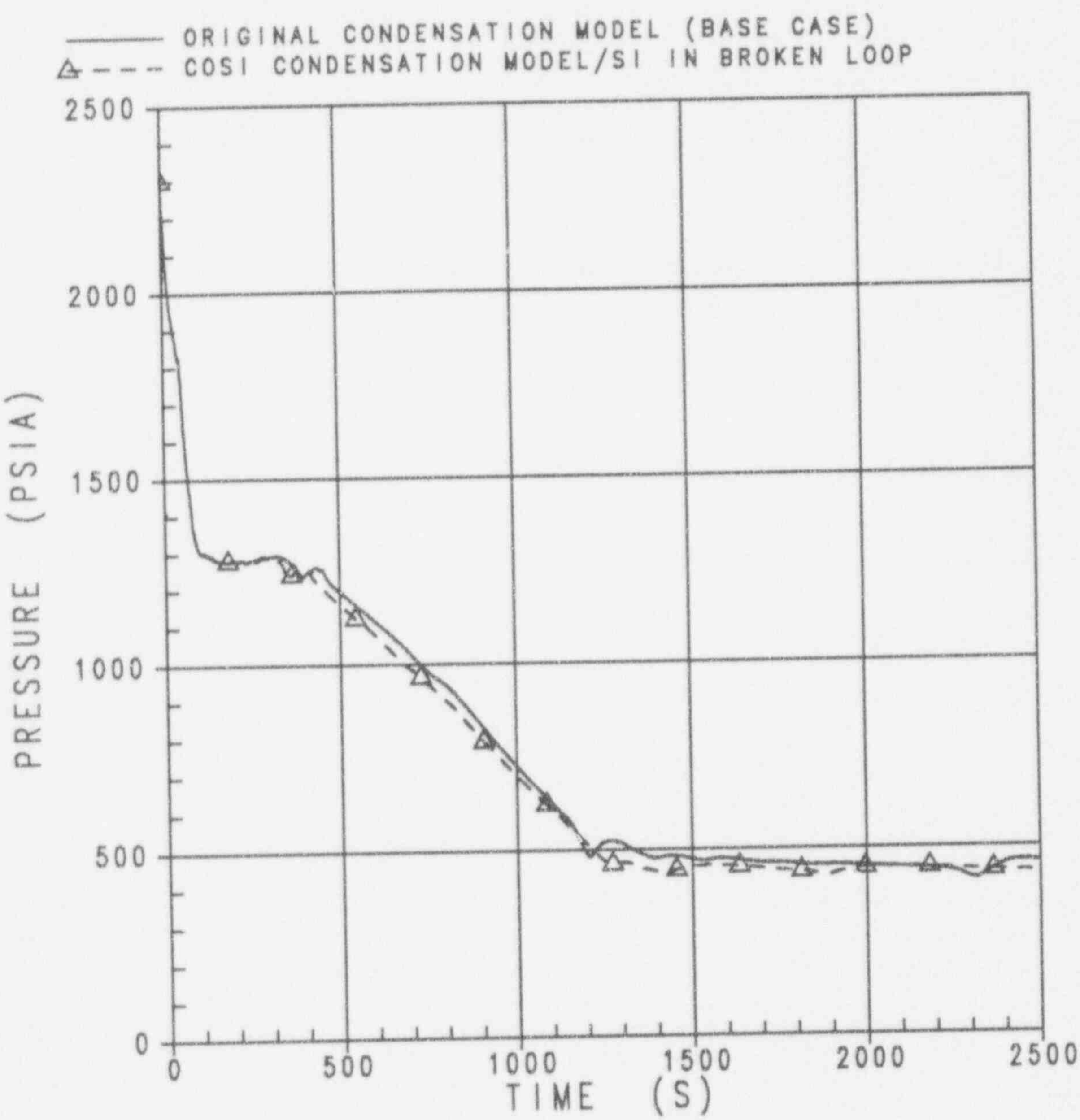

Figure 6
RCS Pressure
3 Loop Plant, 3 Inch Break

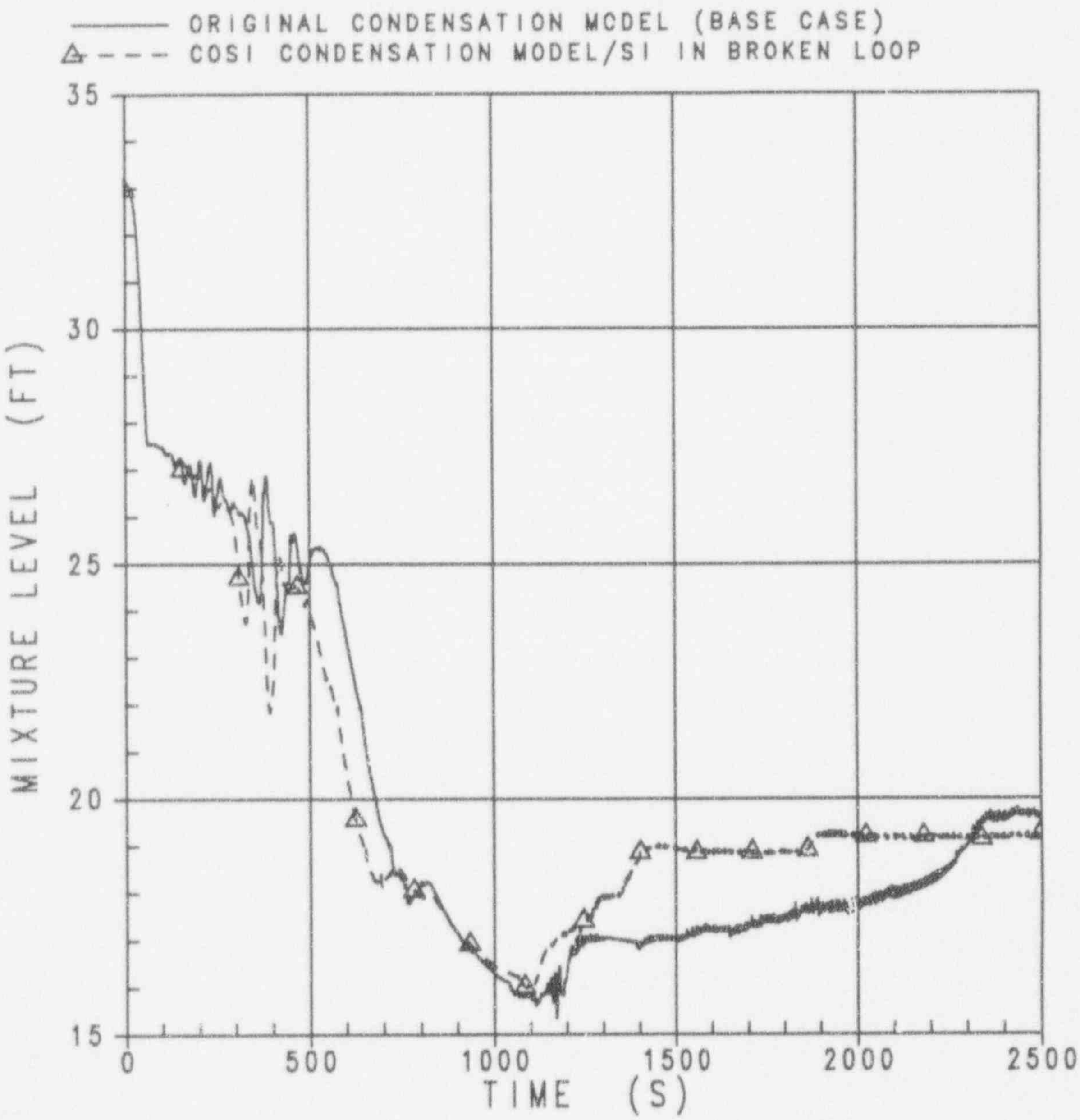

Figure 7
Core Mixture Level
3 Loop Plant, 3 Inch Break

a,c

Figure 8
Peak Clad Temperature
3 Loop Plant, 3 Inch Break

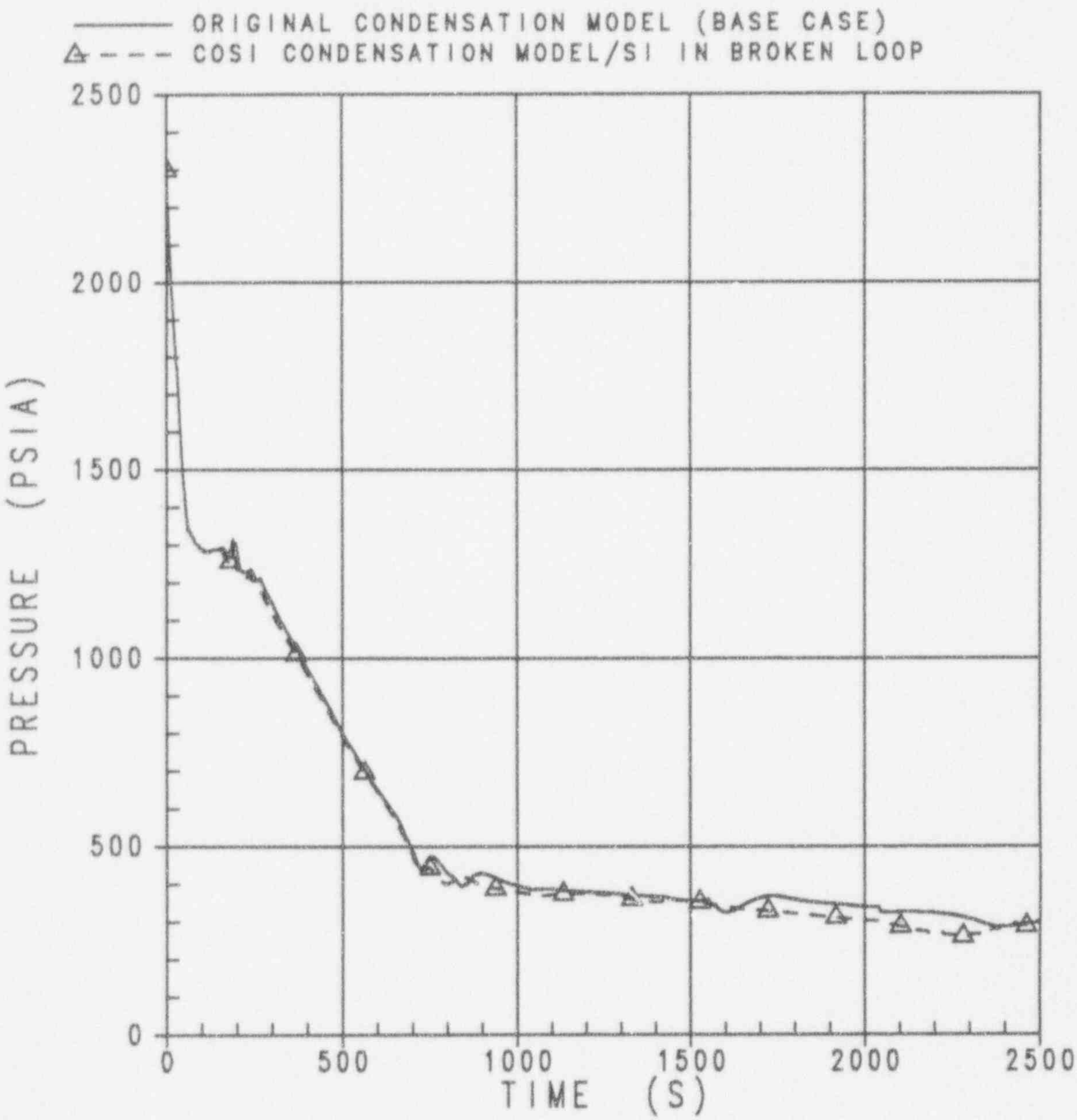

Figure 9
RCS Pressure
3 Loop Plant, 4 Inch Break

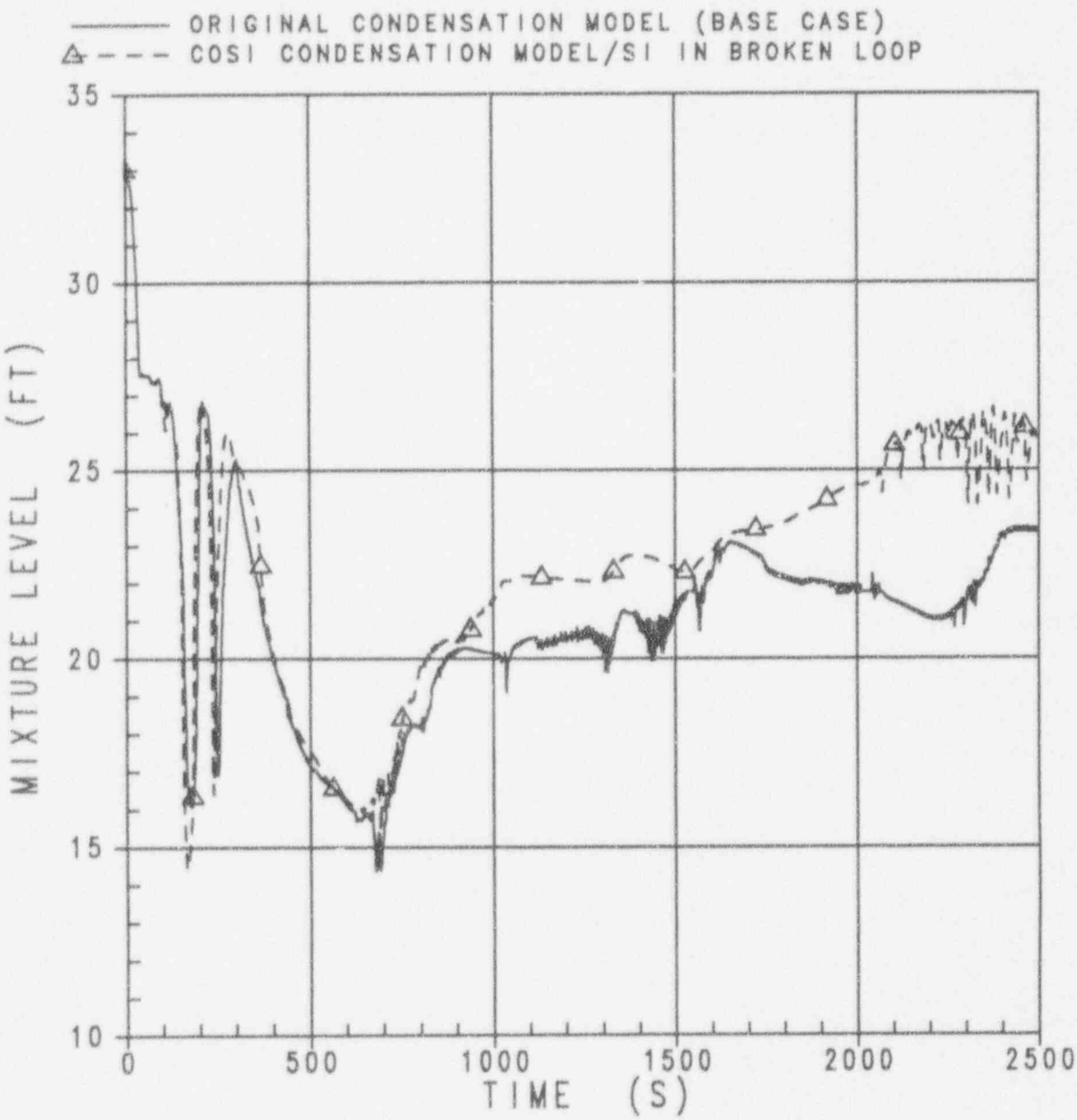

Figure 10
Core Mixture Level
3 Loop Plant, 4 Inch Break

[ ]a,c

Figure 11
Peak Clad Temperature
3 Loop Plant, 4 Inch Break

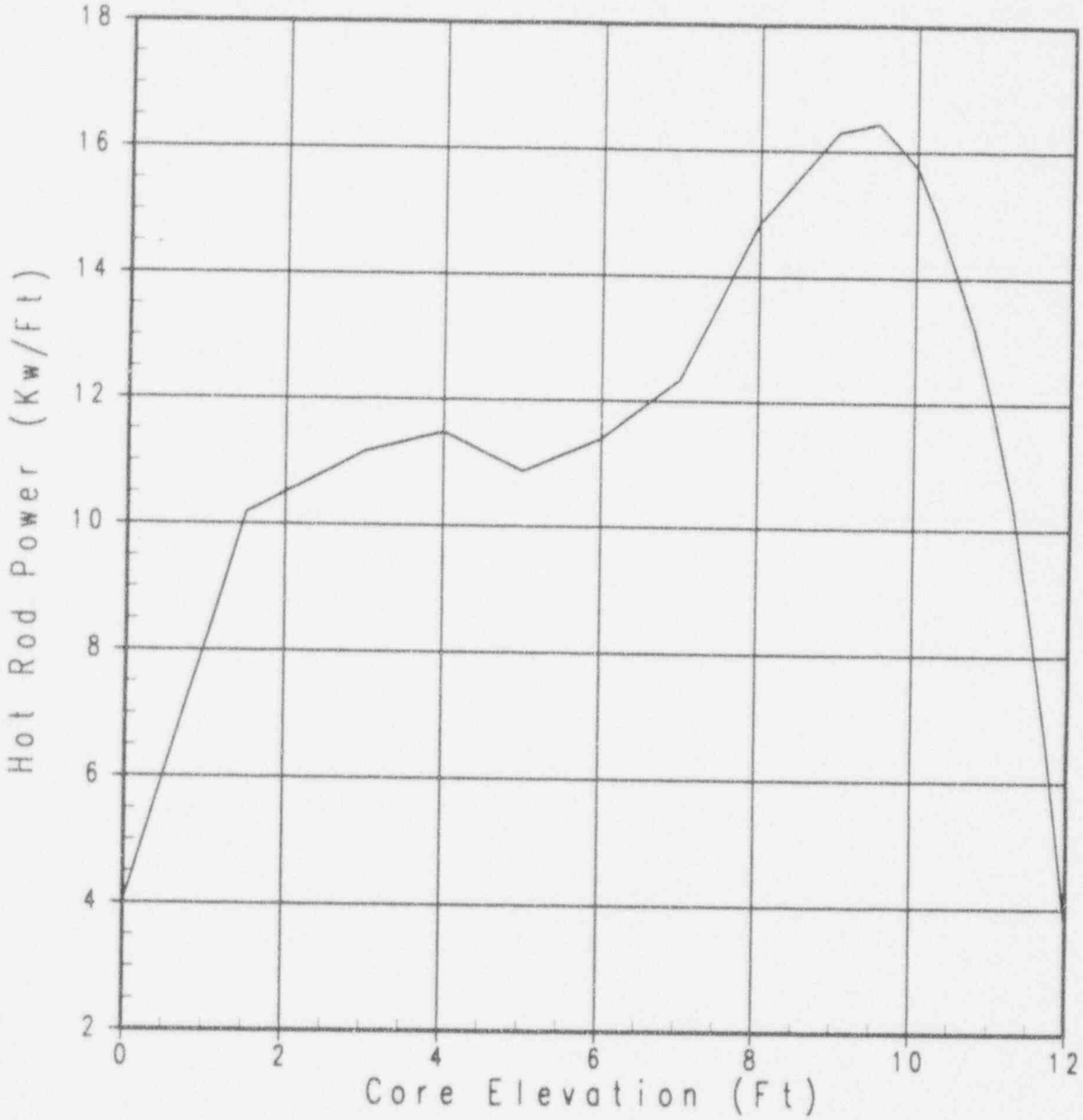

Figure 12 - 4 Loop Plant Power Shape (Kw/Ft)

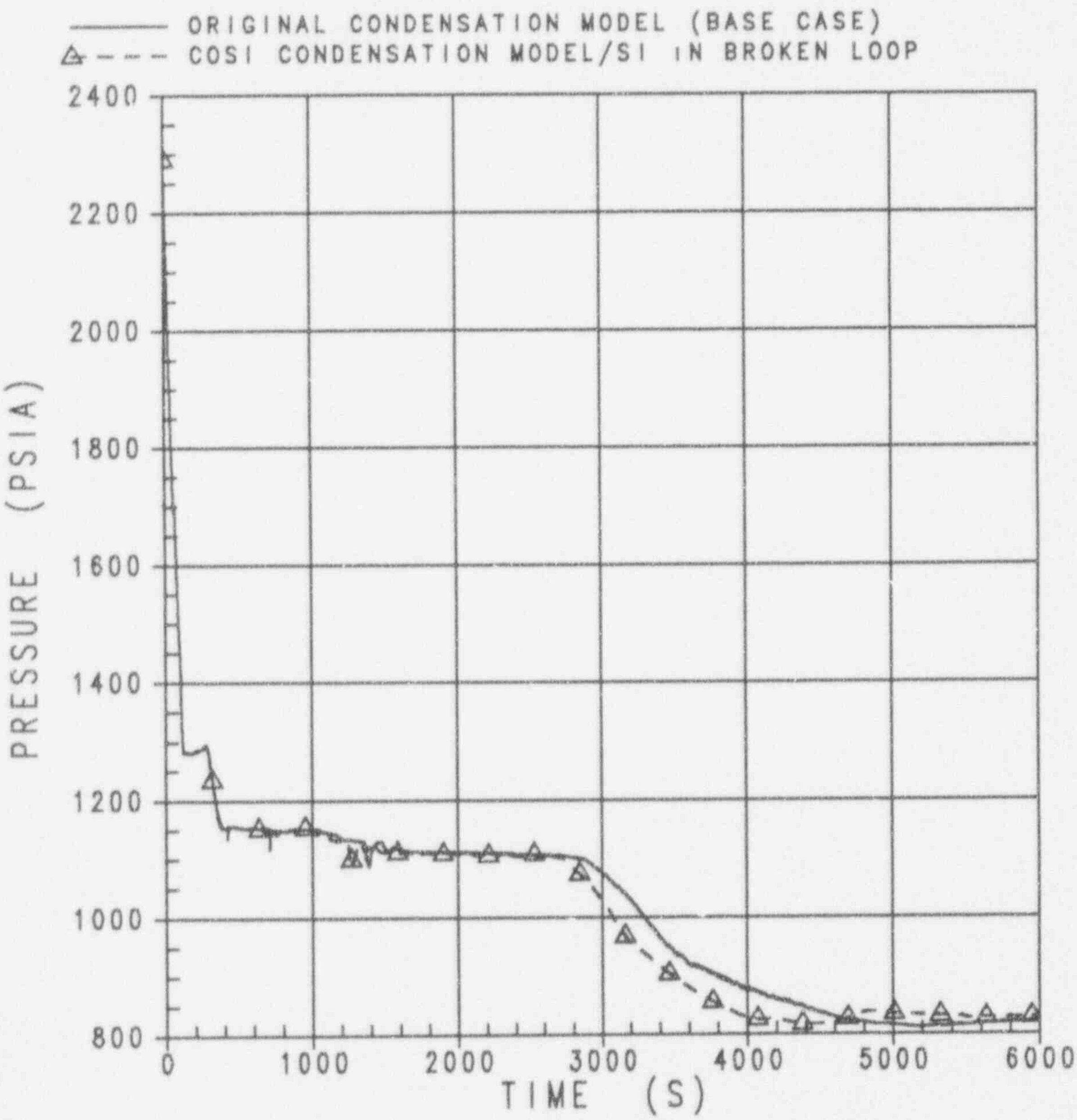

Figure 13
RCS Pressure
4 Loop Plant, 2 Inch Break

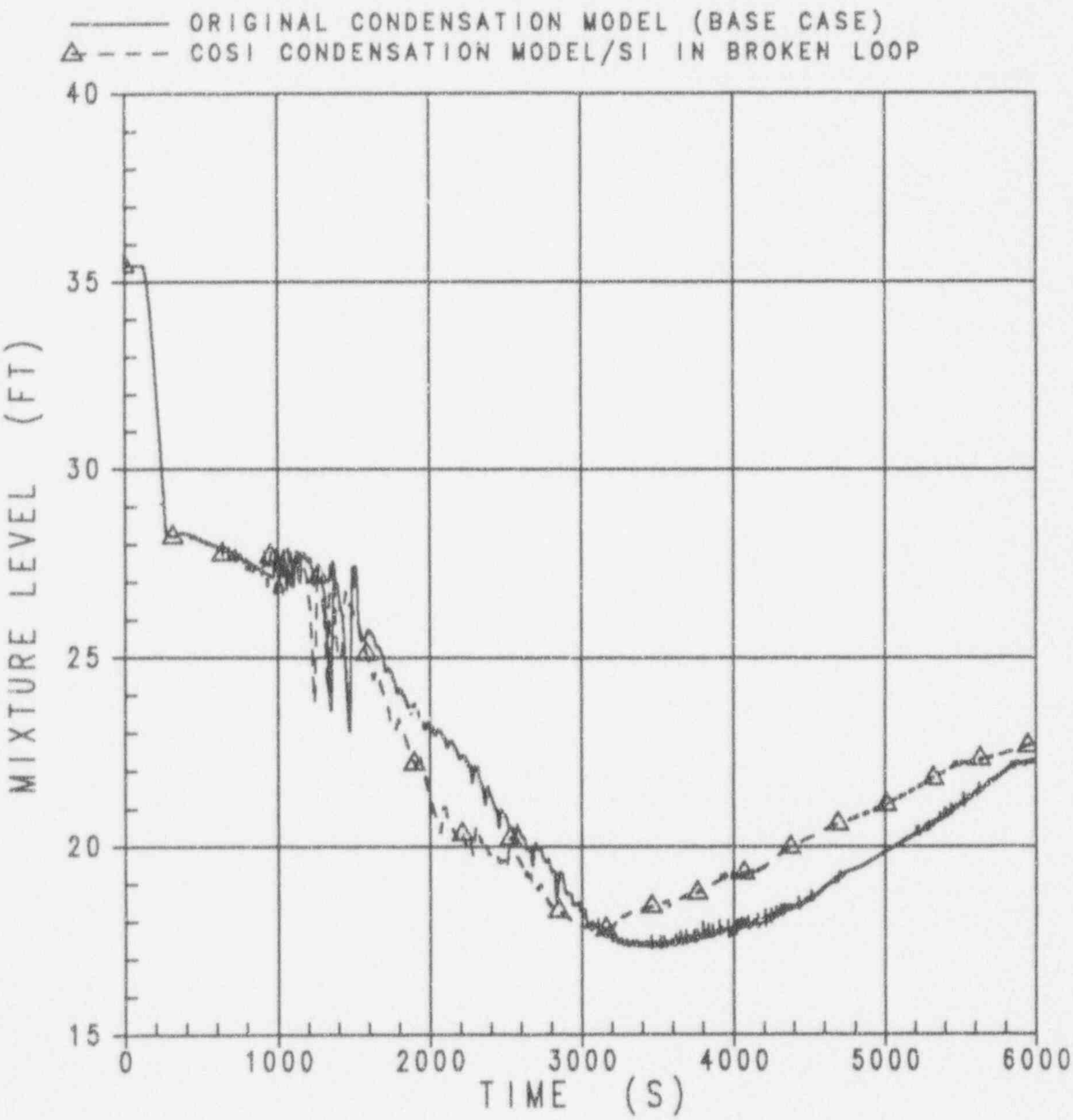

Figure 14
Core Mixture Level
4 Loop Plant, 2 Inch Break

a,c

Figure 15
Peak Clad Temperature
4 Loop Plant, 2 Inch Break

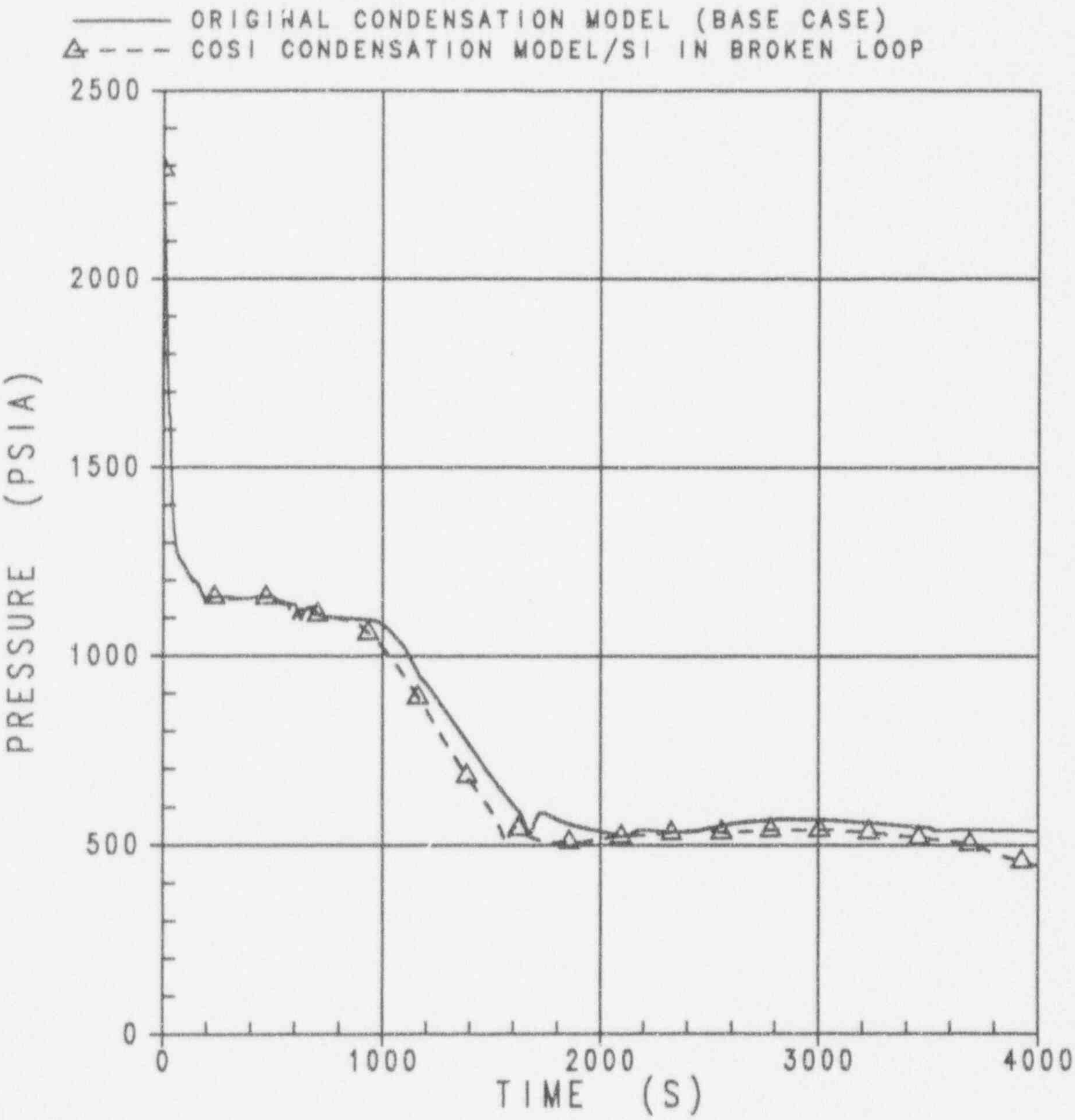

Figure 16
RCS Pressure
4 Loop Plant, 3 Inch Break

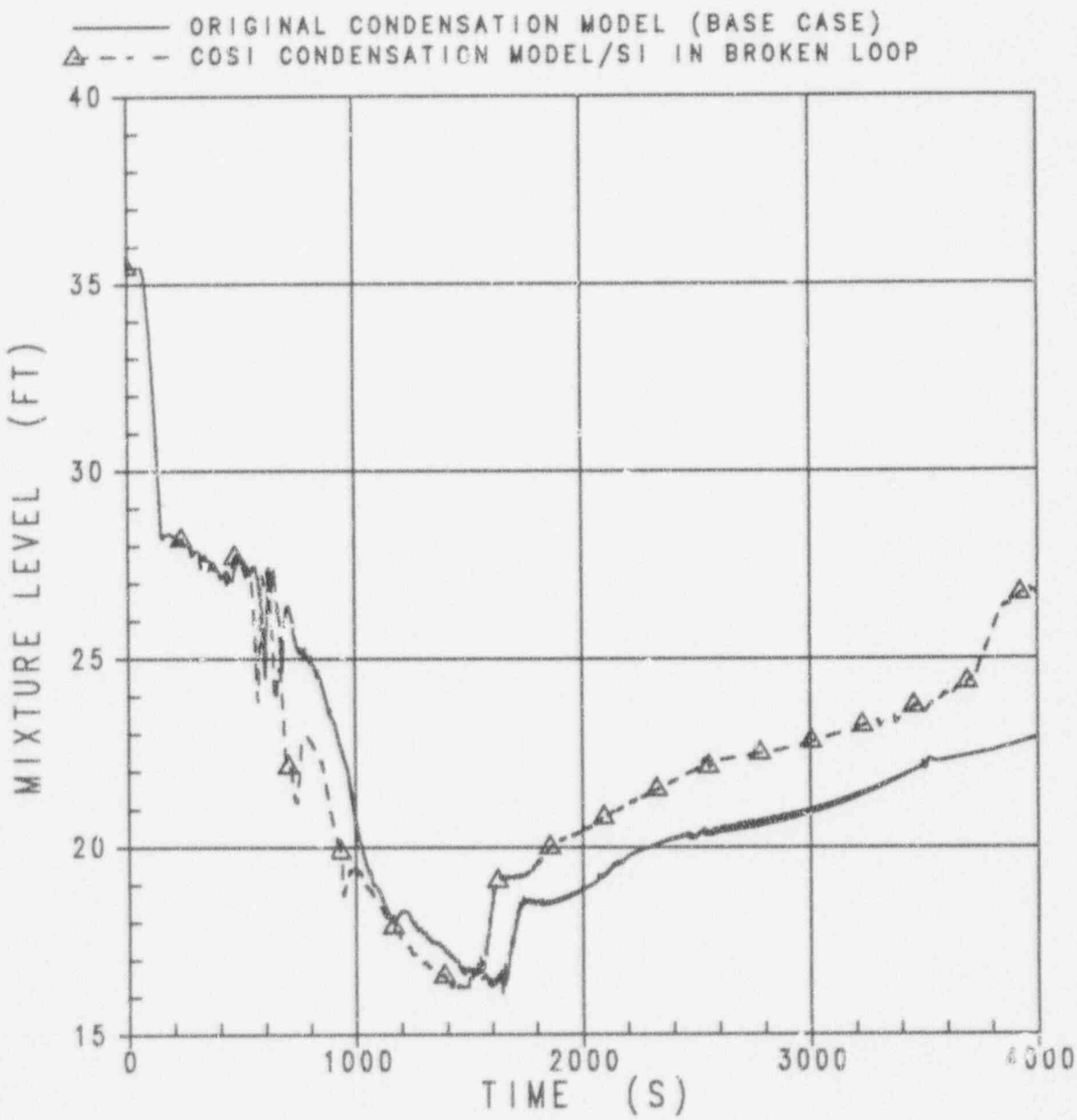

Figure 17
Core Mixture Level
4 Loop Plant, 3 Inch Break

a,c

Figure 18
Peak Clad Temperature
4 Loop Plant, 3 Inch Break

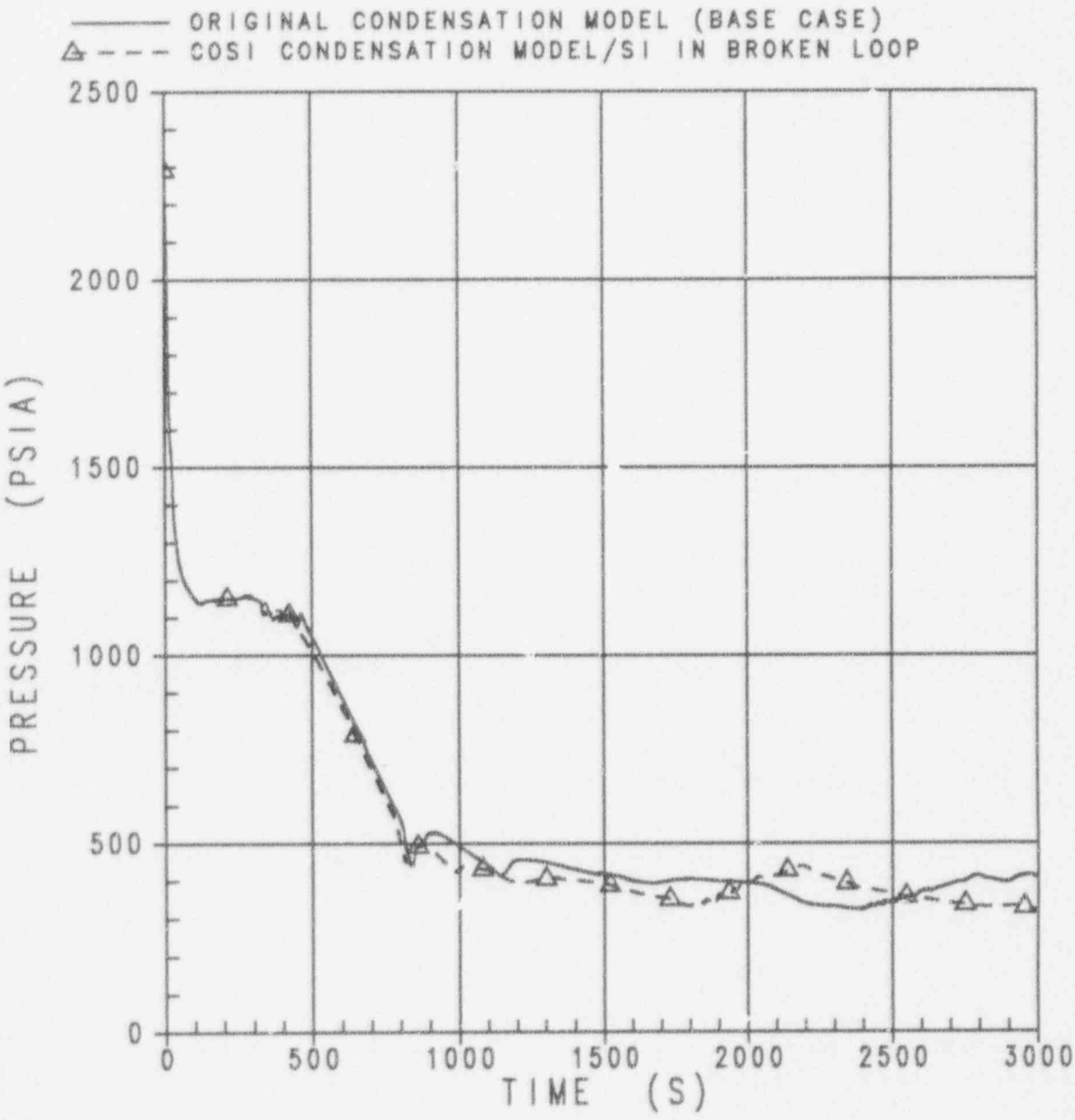

Figure 19
RCS Pressure
4 Loop Plant, 4 Inch Break

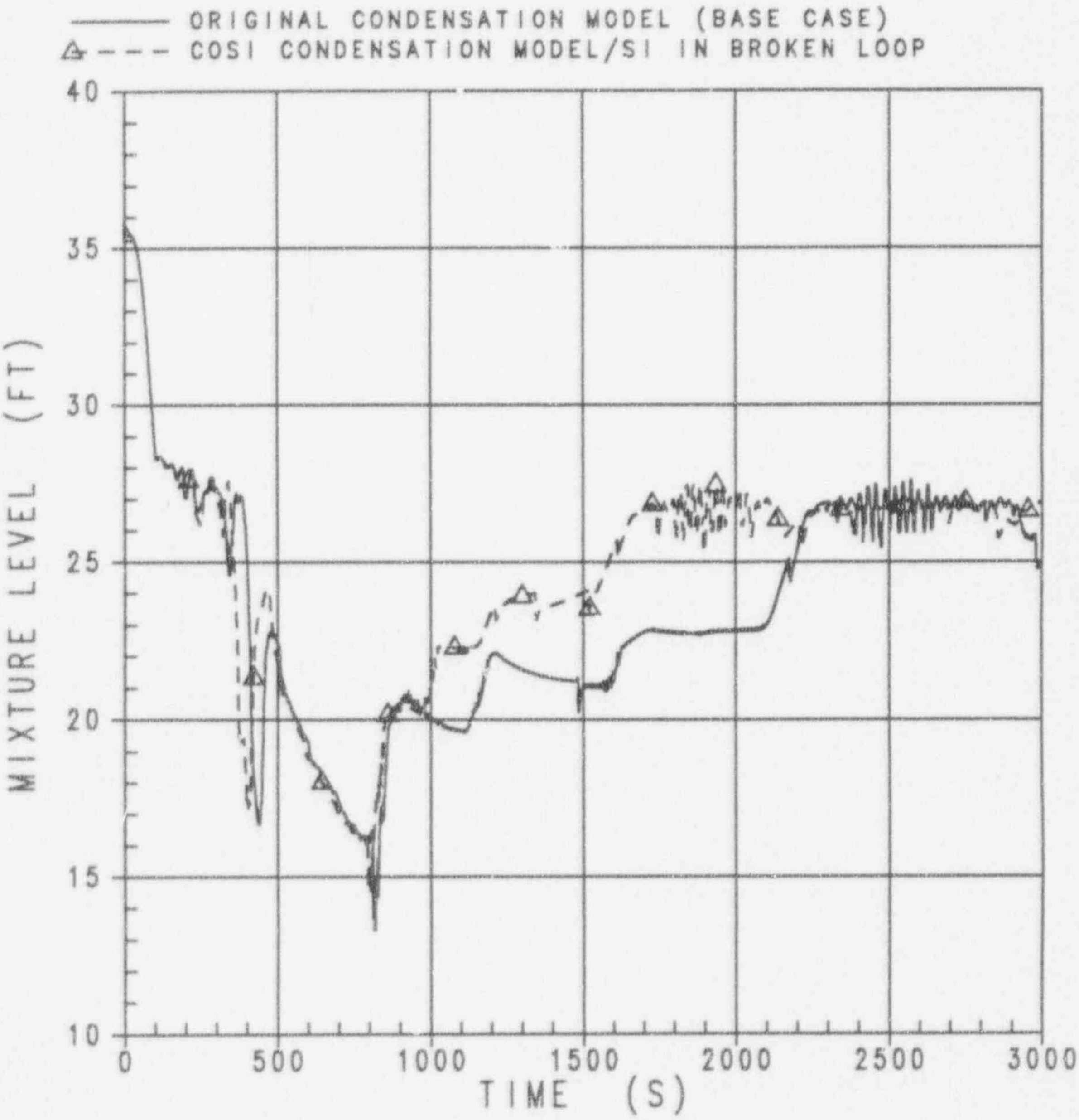

Figure 20
Core Mixture Level
4 Loop Plant, 4 Inch Break

[ ]a,c

Figure 21
Peak Clad Temperature
4 Loop Plant, 4 Inch Break