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SUPP. 1

MASS & ENERGY RELEASES FOLLOWING A STEAM LINE RUPTURE

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CALCULATION OF STEAM SUPERHEAT IN MASS/ ENERGY RELEASES FOLLOWING A STEAMLINE RUPTURE

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I. INTRODUCTION

During the Containment Systems Branch review of the Westinghouse topical report, "Mass and Energy Releases Following a Steam Line Rupture",WCAP-8822 (Proprietary) (Reference 1) the Staff noted that heat transfer to steam from the uncovered portion of the steam generator tube bundle was unaccounted for and questioned the effect upon the calculated mass/energy release and the subsequent effect on the containment temperature response. Westinghouse responded in a letter to the Staff (Reference 2) that it had determined the impact of the effect by conservatively treating the maximum amount of superheat to be the difference between the primary coolant temperature and the steam temperature. The letter noted that there would be an [ ]^{a,c} effect on dry type containments and that, based on the conservative model used, there would be an [ ]^{a,c} in containment temperature for ice condenser type containments. Based on the information supplied in Reference 2, the Staff noted in the draft SER (Reference 4), that a more refined analysis may be required to address this effect.

Since that time, Westinghouse has investigated the effects of tube bundle heat transfer from the viewpoint of a more refined modeling approach. This report describes the models and calculational methods used to determine the mass/energy blowdowns to be used in the containment analysis for ice condenser containments. This information is provided as additional information for WCAP-8822 and subsequent transmittals (References 1, 2 and 3) to aid in the staff review of WCAP-8822.

II. MASS AND ENERGY RELEASE CALCULATIONAL MODEL

A. LOFTRAN/MARVEL Comparison

Mass/energy releases can be calculated using either the LOFTRAN code (Reference 3) or the MARVEL code (Reference 8). The LOFTRAN code is used for non-LOCA FSAR accident analyses. The MARVEL code was specifically developed for assymmetric transients such as steamline breaks. These two codes are very similar because they were developed in an interrelating fashion and much of the modeling is common to both codes. The MARVEL code was used in the development of Reference 1 because LOFTRAN at that time was a lumped model which was used for symmetric loop transients. Furthermore, for steamline break analysis purposes, MARVEL contained a model for water entrainment. With the development of a more versatile, multiloop version of LOFTRAN (Reference 3) and the inclusion of an entrainment model, the use of MARVEL has been generally discontinued. This enables the use of LOFTRAN as a single system analysis code for non-LOCA transient analyses. A modified version of LOFTRAN is used in the analyses presented here, as described in Sections II.C and II.D.

The model of importance to blowdown calculations is the steam generator model. The primary side of the steam generator contains multiple nodes to model the tube bundle for both the modified version of LOFTRAN and MARVEL. Heat transfer calculations from the primary to secondary side are identical in the two codes, although the methods for initializing the heat transfer resistances are slightly different. The secondary side is effectively a one node, two region model of saturated steam and water. Heat transfer is assumed to occur to saturated water. If tube uncovery is predicted, the total heat transfer coefficient is accordingly reduced.

Both codes contain a detailed steam generator model which is used to predict tube uncovery. This model calculates the liquid volume in the steam generator shell and accounts for the detailed steam generator geometry. [ ]^{a,c} is used in both codes to predict the voiding in the tube region, although the correlation is modified for use in LOFTRAN. In MARVEL, tube uncovery is based on a comparison of the calculated water level and the height of the tube bundle. In LOFTRAN, the user specifies either a water volume in the steam generator corresponding to tube uncovery, or a void fraction in the riser section of the steam generator at which tube uncovery begins.

Both codes have similar models accounting for reverse heat transfer, thick metal heat transfer, feedline flashing, and safety injection system operation. Auxiliary feedwater flow can be input as a fraction of nominal feedwater flow, although LOFTRAN has an additional capability to model auxiliary feedwater flow as a separate system. For analysis of double ended ruptures, MARVEL accounts for the volume of steam in the piping downstream of the steam generators in the blowdown calculations. In LOFTRAN, this consideration is added on to the blowdown mass and energy results manually. For split ruptures, which the analysis presented here addresses, the steam piping masses are handled identically in both codes.

In summary, LOFTRAN and MARVEL are very similar codes, and either can be used to calculate mass/energy blowdowns. To demonstrate this, a comparison of the blowdowns for a typical case for a four loop plant is presented in Figures II-1 and II-2. Figure II-1 presents the mass release rate for a .86 ft^2 split rupture from 102% power. For this case, Figure II-2 shows the saturated steam enthalpy as a function of time. This blowdown is typical of results used in FSAR analyses prior to the modification noted in this report for the LOFTRAN code. As can be seen from the figures, the results show excellent agreement.

B. Prediction of Tube Uncovery in LOFTRAN

For a small steamline break, saturated steam will be released until steam generator tube bundle uncovery occurs. This section discusses the LOFTRAN (Reference 3) model which predicts this tube uncovery and the sensitivity of the model to variation in the time of tube uncovery.

In LOFTRAN, the user can specify either a water volume in the steam generator side secondary or a riser section void fraction at which tube heat transfer degradation (uncovery) begins.

- If a water volume is specified, this value is compared directly to the calculated total water volume of the steam generator and is used to modify the total heat transfer coefficient to the liquid in the steam generator.

- If a riser section void fraction is specified, a subroutine in LOFTRAN [

]^{a,c}. This subroutine (WTRVOL) is described in Reference 5 and uses [ ]^{a,c}

For all the cases presented in section III, a void fraction [ ]^{a,c} is used in the initial tube uncovery prediction. Sensitivities for the tube uncovery prediction in LOFTRAN are illustrated in Figures II-3 through II-6. The figures depict the results of a .86 ft^2 break from 102 percent power for a four-loop plant with a "predicted" (specified void fraction) tube uncovery occuring at [ ]^{a,c}, an "early" uncovery at [ ]^{a,c}, and a "late" uncovery at [ ]^{a,c} . The early and late uncovery cases are obtained through a user specified water volume at which the tube uncovery begins. The transients are identical up to the point of tube uncovery. After tube uncovery, [ ]^{a,c}. However, the late tube uncovery results in [ ]^{a,c} peak enthalpy value. After the peak enthalpy point is reached, an equilibrium condition in the steam generator is established where the steam flow exiting the steam generator is equal to the auxiliary feedwater flow into the steam generator. Once equilibrium conditions are established in the three transients, [ ]^{a,c} mass/energy releases result.

C. Heat Transfer Calculation Method

The LOFTRAN code has been modified to model heat transfer which may occur in the uncovered tube region. The modification utilizes the basic LOFTRAN model documented in Reference 5 and adds a calculation of the uncovered region heat transfer [ ]^{a,c}.

This modified version of LOFTRAN uses a variable noding scheme in the calculation of the uncovered region heat transfer. The "variable noding" reflects the capability of the coding to evaluate the general conditions of the uncovered tube region and determine an appropriate number of nodes to be used in the subsequent calculations. The noding scheme is applied to both the primary and secondary sections in the uncovered tube region. If more than one steam generator is uncovering tubes, each one is treated independently to determine its particular noding scheme and heat transfer in the uncovered tube region.

The major assumptions used in this modification are described below:

- A constant primary tube temperature is assumed throughout the uncovered tube region. This is applied [ ]^{a,c}. Additionally, this is applied [ ]^{a,c}. This provides a conservatively high heat transfer calculation for prediction of the steam superheat.

- The heat transfer coefficient used in the uncovered tube region is based on the [ ]^{a,c}. This is discussed further in Section II.D. The heat transfer calculation is based on the wall surface temperature and the steam bulk temperature.

- No credit is taken for either a primary film heat transfer resistance or a tube metal heat transfer resistance. Therefore, the wall surface temperature is assumed to be equal to the primary fluid temperature. This provides a conservatively high heat transfer calculation for prediction of the steam superheat.

- All heat transfer to the steam in the uncovered tube region is [

]^{a,c}. Condensation and/or recirculation of superheated steam is assumed [

]^{a,c} Heat transfer to uncovered tube regions in isolated, intact steam generators (i.e., no steam flow) is not calculated since there is no mass/energy release.

The heat transfer calculation to determine the outlet temperature of an individual node in the superheat region is based on the following expressions:

[ ]^{a,c}

[ ]^{a,c}

These expressions can be arranged into two equations with unknowns of [ ]^{a,c}. Solving these simultaneous equations for the steam temperature exiting the node, provides the following equation:

[ ]^{a,c} [1]

With a conservative assumption that [ ]^{a,c} this equation reduces to :

[ ]^{a,c} [2]

This equation [2] has been used to maximize the energy release calculations used for containment temperature response analyses and for the sensitivities presented in Section III of this report.

An iteration routine is used in each node to determine the outlet steam temperature. The convergence criteria used is based [ ]^{a,c}. The convergence criteria is [ ]^{a,c}.

The outlet temperature of one node is used as the inlet temperature of the next node.

D. Superheat Heat Transfer Coefficient

As previously indicated, the heat transfer coefficient used in the uncovered tube region is based on the [ ]^{a,c} which is described in Reference 7. The heat transfer coefficient (U) is calculated by the following expression:

[ ]^{a,c}

This correlation is presently used for superheat forced convection heat transfer calculations by the [ ]^{a,c} computer codes.

It should be noted that in Reference 7, the correlation is given as a function of [ ]^{a,c} as follows:

[ ]^{a,c}

A separate modification to LOFTRAN was made to investigate the effects of varying the heat transfer coefficient as a function of [ ]^{a,c}. The investigation showed [ ]^{a,c}. The transients investigated show [ ]^{a,c}.

In addition, an investigation was done on the effects of the [ ]a,c to calculate the heat transfer coefficient. The sensitivities show [ ]a,c.

Finally, Reference 7 discusses [ ]a,c.

[ ]a,c

A comparison of the results of using [ ]a,c is shown in Figure II-7. At initial tube uncovery, [ ]a,c. This value decreases, as the steam flowrate drops, till equilibrium conditions are reached. The variation in enthalpy is [ ]a,c in the early tube uncovery period and increases to a maximum difference [ ]a,c at the point of peak enthalpy with [ ]a,c predicting the higher enthalpy. [ ]a,c occur in the steam flowrates. Based upon this comparison with [ ]a,c in the calculated enthalpies and [ ]a,c is considered satisfactory for use in predicting the heat transfer to steam in the uncovered tube region of the steam generator.

III. MASS AND ENERGY RELEASE BLOWDOWN ANALYSIS

A. Considerations for Blowdown Calculations

In WCAP-8822, the methodology for mass/energy release calculations is presented. As shown in WCAP-8822, mass/energy releases are calculated for a spectrum of break sizes, power levels, and single failures. Each of these variables impacts the mass/energy releases to the containment. The choice of break size is based on the steam generator design (double ended rupture), whether or not entrainment occurs, and the type of protection signal actuated (split breaks). Power level affects both the mass released to the containment, since steam generator inventory is not constant with power level, and the energy, since the amount of stored energy and decay heat also depends upon the initial power level. The single failures are chosen to [ ]^{a,c} the total mass released to the containment. Note that the single failure of a containment safeguards train does not impact the mass/energy blowdown and will not be discussed here.

In this section, the results of sensitivity studies are presented which show the impacts of the above parameters in terms of the peak enthalpies reached during the blowdown and the time of tube uncovery. These studies address only split ruptures, since double-ended ruptures are not impacted by tube uncovery (Reference 2). Furthermore, the studies are based on dry steam blowdowns only. Currently, water entrainment is not assumed in the FSAR analyses for Westinghouse ice condenser plants. An explanation of the results is provided with each study, with a summary of the results provided in Table 1.

The Reference case, upon which the sensitivity studies are based, is a 4-loop plant with a .86 ft^2 split break initiating from 102% power. Steam generator inventory is assumed to be at the nominal level minus 5% level uncertainty [ ].^{a,c} Minimum safety injection flow is also assumed. Auxiliary feedwater flow is initiated at time zero [ ].^{a,c} It is also chosen to maximize the flow to the faulted steam generator by selecting a flow consistent with the failure of auxiliary feedwater runout protection. This is one of the single failures addressed in WCAP-8822. Note that the assumption of minimum safety injection flow in conjunction with any of the single failures assumed in WCAP-8822 is conservative because when combined with the single failures assumed in WCAP-8822 it is, in effect, the assumption of two single failures at once. Standard safety analysis delays are assumed for the actuation of protection.

The transient response for the reference case is shown in Figures III-1 and III-2. Figure III-1 shows the mass and energy blowdowns as a function of time. The first plot of Figure III-2 depicts the amount of tube uncovery. The second plot depicts the temperatures of the primary side inlet to the steam generator and the secondary side steam temperatures(saturation and including superheat). As seen in Figure III-2, tube bundle uncovery starts at [ ]^{a,c} with an equilibirum level in the steam generator reached at approximately [ ]^{a,c} This equilibrium level occurs when the mass of auxiliary feedwater flow into the generator equals the steam flow out. For this reference case the mass release at this condition is [ ]^{a,c} and the amount of tube bundle uncovery is [ ].^{a,c} At the time at which tube bundle uncovery begins, the steam enthalpy starts to increase, reaching a peak enthalpy of [ ]^{a,c} the equilibrium level in the generator is reached.

B. Sensitivity Studies

The effects of superheated steam are dependent upon the occurrence and extent of tube bundle uncovery. Parameters which could potentially affect tube uncovery are: initial steam generator inventory, power level, break size, feedwater flowrate (both main and auxiliary), protection system response times, and the single failure assumed.

1. Steam Generator Level

The initial steam generator inventory will affect the time of tube uncovery by either delaying uncovery if the inventory is large, or by causing earlier uncovery if the inventory is small. Since the time of tube uncovery will affect the total amount of superheat added to the containment, the sensitivity of this parameter is addressed.

The initial steam generator inventory depends upon the measurement errors associated with steam generator level and upon initial power level. The maximum error associated with the measurement of steam generator level under normal operating conditions is 5% of narrow range span. This is the error which would exist at the beginning of the transient and therefore corresponds to the amount by which the initial steam generator inventory may change. The effects of the change in inventory with power level will be discussed in the next section.

Figures III-3 and III-4 show the mass/energy releases for case 1 in which the initial inventory corresponds to the nominal level plus 5% measurement uncertainty, [ ].^{a,c} In all other respects, this case is identical to the reference case. For the case with increased inventory, tube uncovery begins at [ ]^{a,c}, which is approximately [ ]^{a,c} than the reference case. Thus it can be seen that there is a [ ]^{a,c} in the time of tube uncovery. However, the peak enthalpy of [ ]^{a,c} is [ ]^{a,c} from the reference case, although the time at which the peak enthalpy occurs is [ ].^{a,c} The equilibrium level in the steam generator is [ ]^{a,c} with respect to the reference case, although the final value is [ ].^{a,c}

2. Power Level

The initial power level affects the blowdown and tube uncovery in primarily two ways. First, the steam generator inventory increases with decreasing power level; this will tend to delay uncovery although the increased steam pressure will cause a faster blowdown at the beginning of the transient. Second, the amount of stored energy and decay heat is less for lower power levels. This will result in lower primary temperatures and less primary to secondary heat transfer.

The power level selected for this sensitivity study is 30% power. Initialization at a lower power level changes the primary coolant temperature, pressurizer water level, feedwater enthalpy, and steam generator level. At this power, the steam generator inventory is significantly greater than at full load and the feedwater enthalpy is less. There is also less decay heat. Figures III-5 and III-6 present the transient response for this case. The break size and all other assumptions are identical to the reference case.

As can be seen from Figure III-5, the mass blowdown rate is initially higher than the full power case, although it drops off after a few seconds. This is because of the initial high steam pressure. The effect of the increased steam generator inventory is seen in that tube uncovery does not begin until [ ]^{a,c} for the reference case. The time of peak enthalpy is [ ],^{a,c} although the value is [ ]^{a,c} to the reference case. Both the total integrated mass and integrated energy (at 600 seconds) are [ ]^{a,c} the reference case.

3. Break Size

The break size impacts tube uncovery in that larger break sizes result in faster blowdown of the steam generator and earlier tube uncovery. The case 3 blowdowns for a .6 ft^2 split break from 102% power are shown in Figures III-7 and III-8. When compared to the reference case, tube uncovery occurs [ ]^{a,c} the reference case. This is because [ ]^{a,c}. The peak enthalpy of [ ]^{a,c} is also [ ]^{a,c} the reference case at least in part because the decrease in blowdown rate causes a [ ]^{a,c} of level and a [ ]^{a,c} equilibrium level. Note that the equilibrium blowdown is unchanged from the reference case because this is a function of only the auxiliary feedwater flowrate.

4. Auxiliary Feedwater Flowrate

As discussed earlier, the auxiliary feedwater flowrates assumed for the analysis of WCAP-8822 were [ ]^{a,c} in order to [ ]^{a,c} the mass release to containment. Since tube uncovery was not considered, this assumption also served to [ ]^{a,c} the total energy release as well. However, with the inclusion of superheat into the calculations, mass [ ].^{a,c}

This is because large auxiliary feedwater flowrates delay tube uncovery, result in a higher equilibrium steam generator level (less tube uncovery), and consequently, a lower equilibrium steam enthalpy. On the other hand, while small auxiliary feedwater flow rates will result in less mass, the equilibrium steam enthalpy will be greater. Thus, the competing effects of flowrate (mass) and superheat (energy) are addressed in this study.

The auxiliary feedwater flow assumed for the reference case is typical of the flow supplied to the faulted steam generator when the runout protection on the auxiliary feedwater pumps fails (or if this protection does not exist). Two sensitivities are presented in this section: the first (case 4a) is typical of unfaulted auxiliary feedwater supply (no runout), the second (case 4b) is the loss of a turbine driven auxiliary feedwater pump. Note that this second case assumes a single failure not requiring consideration in WCAP-8822.

The results for case 4a are shown in Figures III-9 and III-10. For a decrease in auxiliary feedwater flow to the faulted steam generator of [ ],^{a,c} the peak enthalpy [ ].^{a,c} The time at which the tubes begin to uncover is [ ].^{a,c} The equilibrium water level for this case is lower than the reference case, which is to be expected, since the auxiliary feedwater flow rate is lower.

For case 4b assuming the loss of a turbine driven auxiliary feedwater pump, the results are shown in Figures III-11 and III-12. The auxiliary feedwater supplied to the faulted steam generator is [ ].^{a,c} The peak enthalpy of [ ]^{a,c} at [ ]^{a,c} is [ ]^{a,c} than both the reference case and case 4a. Not surprisingly, tube uncovery also begins [ ].^{a,c}

Similar sensitivities on auxiliary feedwater flowrates were also performed at 30% power. As for the full power studies, the peak enthalpy [ ]^{a,c} with [ ]^{a,c} auxiliary feedwater flowrate, but the impact is [ ].^{a,c}

5. Other Single Failures

As demonstrated in the previous section, the single failure assumed in the transient may impact the amount of water supplied to the steam generator and the amount of superheat produced. In light of the results presented above, some of the other single failures considered in WCAP-8822 can be evaluated for their impact on superheated steam.

Failure of the feedwater isolation valve will cause extra water to be supplied to the generator as the additional mass between the isolation valve and the check valve flashes to the generator. This will [ ]^{a,c} tube uncovery but will have no impact the equilibrium level in the steam generator.

The MSIV failure adds steam to the containment that exists in the steam piping downstream of the MSIV's in the unfaulted loops. This steam is blown down prior to complete tube uncovery in the faulted loop. However, prior to the complete blowdown of the steam in the main steam piping, the blowdown from the faulted loop will be reduced slightly. This will have a slight impact (delay) on the time at which tube uncovery occurs. Furthermore, there will be some mixing between the steam from the piping and the faulted loop, which will reduce the amount of superheat released to the containment. Thus, the failure of a MSIV provides a benefit with respect to the amount of superheated steam produced.

In all cases presented, the failure of a Safety Injection train is assumed as an added conservatism. The safety injection provides borated water to the core and can prevent or reduce the return to criticality following the cooldown caused by the steamline break. This will impact the amount of heat produced by the primary side if the core does return critical. A sensitivity study performed for a case which does return critical shows that nominal safety injection flow has a [ ]^{a,c} impact on the peak enthalpy reached during the blowdown. The time of tube uncovery is [ ].^{a,c}

6. Protection System Response Time

The final set of sensitivity studies addresses the response of the protection system. The standard safety analyses assume maxixmum delays in the response time of the system to actuate protection (e.g., reactor trip, steamline/feedline isolation, auxiliary feedwater, etc.). However, some of the safeguards features serve to again [ ]^{a,c} mass releases by the assumption of a slow response. In addition, the WCAP-8822 assumption of auxiliary feedwater on at time zero also [ ]^{a,c} mass release. In order to determine the effects of these previous assumptions, these studies take the opposite approach.

Two items are addressed in this sensitivity study. The first is the response of the steamline isolation function, which for split breaks is actuated by a high-2 containment pressure signal. The standard analysis assumes positive uncertainties on the containment pressure setpoint, and allows 2 seconds for signal processing, and 5 seconds for valve closure. Case 6 is identical to the reference case except that negative uncertainties are assumed for the high-2 setpoint and a total delay time for signal processing and valve closure is 3 seconds. In addition, auxiliary feedwater is assumed to be delayed 60 seconds after receipt of the high-1 signal. The delay time for auxiliary feedwater is the maximum allowable according to the Standard Technical Specifications.

Figures III-13 and III-14 show the transient response. The change in uncertainties on the high-2 signal causes the setpoint to be reached [ ]^{a,c} earlier. Steamline isolation occurs [ ]^{a,c} than the reference case. The peak enthalpy of [ ]^{a,c} is [ ]^{a,c} the reference case, although the time at which tube uncovery begins and at which the peak enthalpy occurs is [ ].^{a,c}

Case 4b (loss of a turbine driven auxiliary feedwater pump) was also analyzed assuming these changes in protection delays (case 6b). The [ ]^{a,c} changes in the results [ ]^{a,c} are seen as occurred with the comparison of the reference case and case 6a. The transient is presented in Figures III-15 and III-16.

Prior to steamline isolation, all four steam generators are blowing down through the break. Thus, the effective break area for the faulted loop prior to steamline isolation is smaller than after steamline isolation because the break area is "shared" by all steam generators before isolation. As a result, the blowdown from the faulted steam generator before steamline isolation is reduced, delaying uncovery. Consequently, earlier steamline isolation will cause the effective break area in the faulted loop to increase sooner, the blowdown will increase, and tube uncovery will also be sooner.

The delay of auxiliary feedwater flow to the faulted steam generator causes the level to drop faster. Until the 60 seconds has elapsed, there is no feedwater supplied to the generator after feedline isolation (actuated by a high-1 signal). At the same time, the generator is blowing down. Thus, tube uncovery and the production of superheated steam will occur sooner if auxiliary feedwater is delayed.

TABLE 1

SUMMARY OF BLOWDOWN SENSITIVITIES ON ENTHALPY OF STEAM

Case	Enthalpy, BTU/lb		Tube Uncovery, sec		Level, % of
	Peak	Time	Start	Equilibrium	Tubes Covered

a,c

C. **Conclusions**

The sensitivity studies presented here are intended to determine the effects on the mass/energy blowdown when the effects of superheated steam are included in the analysis. The results show that [

].^{a,c} Initial power level and steam generator inventory [ ]^{a,c} impact on the enthalpy. The time of tube uncovery is affected by [ ]^{a,c} parameters for which detailed results are presented.

Note that these results do not address the final assumptions that will be made for the blowdowns used in an ice condenser containment analysis. These assumptions must be based on the blowdowns which result in the highest temperatures reached inside the containment which, of course, are dependent upon the containment model.

IV. References:

1. Land, R. E., "Mass and Energy Releases Following A Steam Line Rupture" WCAP-8822 (Proprietary) September, 1976 and WCAP-8859 (Non-Proprietary).

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5. Burnett, T. W. T., et al., "LOFTRAN Code Description," WCAP-7907, June, 1972 (Proprietary).

6. Meyer, P. E., and Kornfilt, J., "NOTRUMP - A Nodal Transfer Small Break and General Network Code," November, 1982, WCAP-10079 (Proprietary) and WCAP-10080 (Non-Proprietary).

7. [

   ]a,c

8. Krise, R. and Miranda, S., "MARVEL - A Digital Computer Code for Transient Analysis of a Multiloop PWR System," November, 1977, WCAP-8843 (Proprietary) and WCAP-8844 (Non-Proprietary).

FIGURE II-1

LOFTRAN - MARVEL COMPARISON

.860 FT2 BREAK AT 102 PC POWER

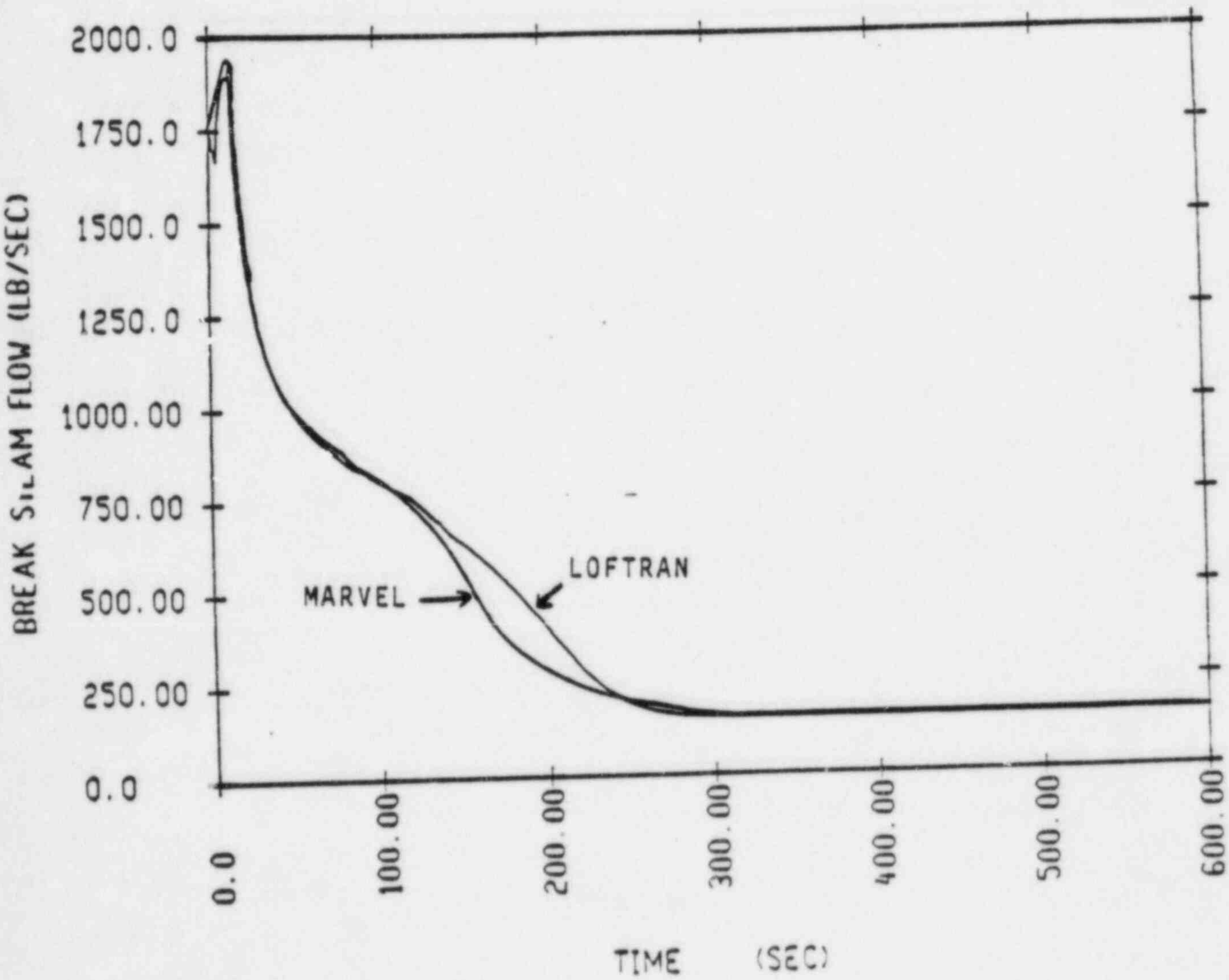

FIGURE II-2

LOFTRAN - MARVEL COMPARISON

.860 FT2 BREAK AT 102 PC POWER

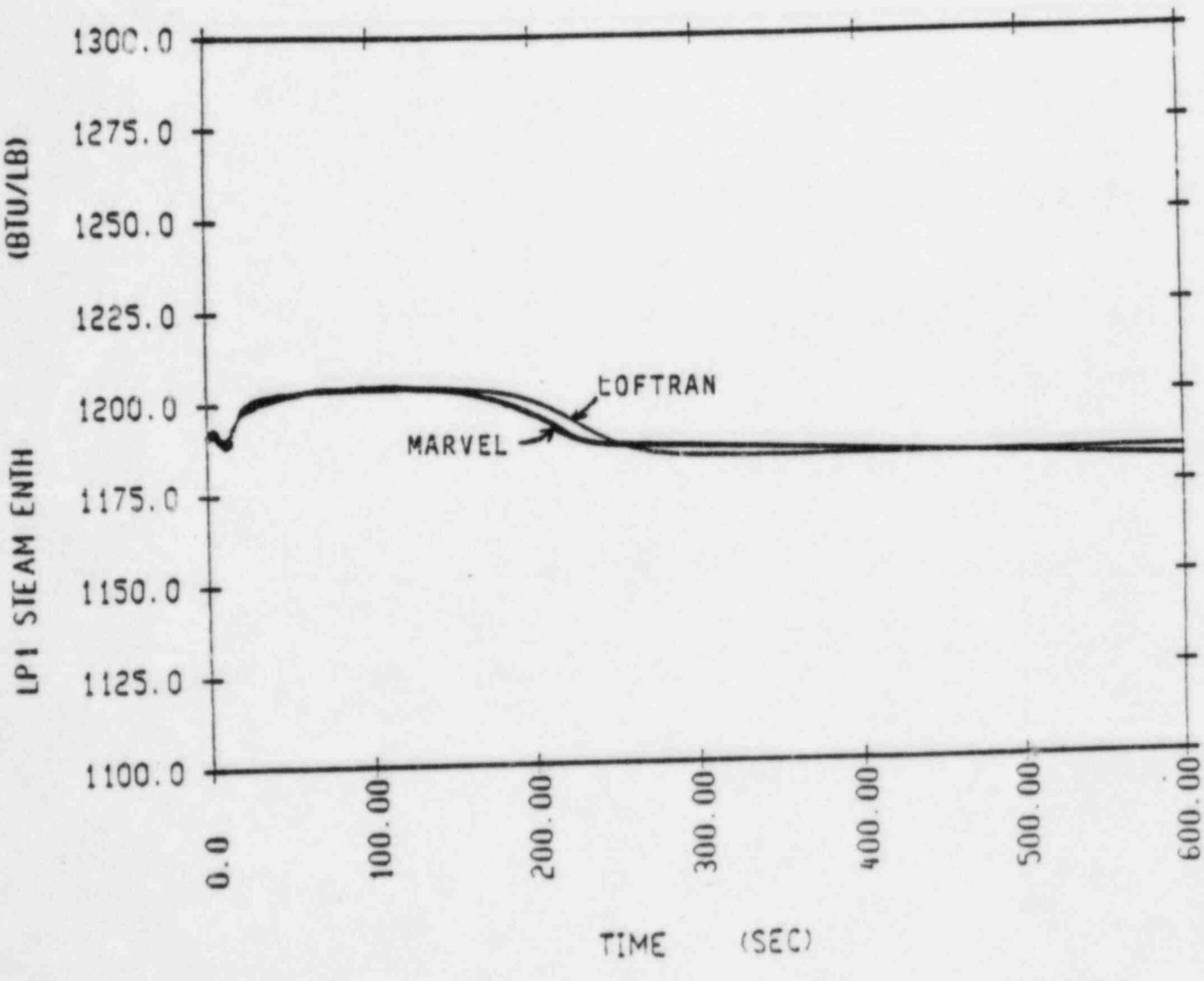

FIGURE II-3

TUBE UNCOVERY TRANSIENT COMPARISON
FOR VARIOUS TUBE UNCOVERY TIMES

a,c

FIGURE II-4

MASS FLOWRATE TRANSIENT COMPARISON
FOR VARIOUS TUBE UNCOVERY TIMES

a,c

FIGURE II-5

STEAM ENTHALPY TRANSIENT COMPARISON
FOR VARIOUS TUBE UNCOVERY TIMES

a,c

FIGURE II-6

TUBE INLET AND STEAM TEMPERATURE TRANSIENTS
COMPARISON FOR VARIOUS TUBE UNCOVERY TIMES

a,c

FIGURE II-7

STEAM ENTHALPY COMPARISON USING THE

a,c

FIGURE III-1

CASE R - .86ft^2 SPLIT RUPTURE 102% POWER

a,c

C8 ABDQOWP

FIGURE III-2

CASE R - .86ft^2 SPLIT RUPTURE 102% POWER

a,c

C8 ABDQCWP

FIGURE III-3

CASE 1 MAXIMUM STEAM GENERATOR LEVEL

[ ]a,c

C9 ABDQOWS

FIGURE III-4

CASE 1 MAXIMUM STEAM GENERATOR LEVEL

[ ] a,c

C9 ABDQOWS

FIGURE III-5

CASE 2 30% POWER

a,c

C32 ABDOOGH

FIGURE III-6

CASE 2 30% POWER

a,c

C32 ABDQOGH

FIGURE III-7

CASE 3 .6 ft^2 SPLIT BREAK

a,c

C16 ABDQOWM

FIGURE III-8

CASE 3 .6 ft^2 SPLIT BREAK

a,c

C16 ABDQOWM

FIGURE III-9

CASE 4a NO AUXILIARY FEEDWATER RUNOUT

a,c

C10 ABDQOZT

FIGURE III-10

CASE 4a NO AUXILIARY FEEDWATER RUNOUT

a,c

C10 ABDQOZT

FIGURE III-11

CASE 4b LOSS OF AUXILIARY FEEDWATER PUMP

a,c

C12A ABDQOGR

FIGURE III-12

CASE 4b LOSS OF AUXILIARY FEEDWATER PUMP

a,c

C12A ABDQOGR

FIGURE III-13

CASE 6a EARLY STEAMLINE ISOLATION, DELAYED NORMAL AUXILIARY FEEDWATER

a,c

C33 ABDQOPIC

FIGURE III-14

CASE 6a EARLY STEAMLINE ISOLATION, DELAYED NORMAL AUXILIARY FEEDWATER

a,c

C33 ABDQOPIC

FIGURE III-15

CASE 6b EARLY STEAMLINE ISOLATION, DELAYED AUXILIARY FEEDWATER
WITH LOSS OF AUXILIARY FEEDWATER PUMP

a,c

C34 ABDQOUF

FIGURE III-16

CASE 6b EARLY STEAMLINE ISOLATION, DELAYED AUXILIARY FEEDWATER WITH LOSS OF AUXILIARY FEEDWATER PUMP

a,c

C34 ABDQOUF