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Docket No.: STN-52-003

September 15, 1994

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: MR. R. W. BORCHARDT

SUBJECT: ADDITIONAL INFORMATION IN SUPPORT OF WESTINGHOUSE RESPONSE TO RAI 952.95 (ADS 4 VALVE SENSITIVITY STUDY)

Dear Mr. Borchardt:

The attachment to this letter provides information in support of an NRC request for additional information (RAI) on the AP600 design (Q952.95). This RAI requests the submittal of a sensitivity study of the AP600 Automatic Depressurization System (ADS) stage 4 design.

The following information is attached:

Attachment 1 AP600 Fourth Stage ADS Valve Sensitivity Study, September, 1994

The attachment documents a sensitivity study to assess the effects of uncertainty in the critical flow models used to represent the flow through the AP600 fourth stage ADS valves. The study investigated 15% and 30% reductions in valve areas. The results indicate that the AP600 design provides sufficient fourth stage venting capacity to enable the plant to reach stable IRWST injection without core uncovery even when accounting for uncertainty in critical flow modeling.

Please contact Brian A. McIntyre on (412) 374-4334 if you have any questions concerning this transmittal.

N. J. Liparulo, Manager
Nuclear Safety Regulatory And Licensing Activities

/nja

Attachments

cc: T. Kenyon, NRC (w/o Enclosure)
R. Hasselberg, NRC
A. Levin, NRC
B. Jones, NRC
B. A. McIntyre, Westinghouse (w/o Enclosures)

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Attachment to Westinghouse Letter NTD-NRC-94-4298

AP600 Automatic Depressurization System

Fourth Stage Valve Area Sensitivity Study

August, 1994

BACKGROUND

A sensitivity study has been performed to assess the effects of the uncertainty in the critical flow models used to represent the flow through the fourth stage ADS valves of the AP600. As in the SSAR analysis, the NOTRUMP small-break LOCA computer code was used for this purpose. The critical flow modeling used for the ADS valves is the Henry-Fauske correlation, for short tubes, nozzles and orifices, and the homogeneous equilibrium model. The Henry-Fauske (H/F) model is used for flow qualities from subcooled conditions to 10%. When the flow quality is greater than 10%, the homogeneous equilibrium (HEM) model is used.

APPROACH

In order to obtain a range of uncertainty to be used in the NOTRUMP AP600 plant calculations, the literature and the original papers were examined. Figures 1 to 6 were taken from Reference 1 for the H/F model for the subcooled and low quality portion of the flow. The references quoted in the figure title refers to the references given in the original paper. The figures show the agreement of the specific H/F correlation for different data sets. Super-imposed on these figures is the value of the prediction multiplied by 0.85 (to indicate a 15% uncertainty), and in some cases a second curve is shown with the prediction multiplied by 0.7 (to indicate a 30% uncertainty). The prediction curves which have been multiplied by either 0.85 or 0.7 represent lower bounds of the H/F correlation and are compared to the data scatter from the experiments. Only a lower bound is considered since the concern is that the ADS valves may not pass the desired flow rate. As these figures show, the H/F correlation agrees very well with the experimental data and a lower bound uncertainty limit of 15% captures the majority of the data scatter relative to prediction.

Similar plots for the HEM model are shown in Figures 7 to 9 from Reference 1 and 2. There are curves representing the HEM model predictions which are multiplied by 0.85 and 0.7 to represent a 15% and 30% uncertainty in the model prediction relative to the data. As seen in the figures, most of the predictions for the HEM model agree within 15% for the low values. Also, in some cases the HEM model without a multiplier is already a lower bound to the data. This means that additional, unquantified margin, exists in the HEM correlation such that use of this correlation is somewhat conservative when examining venting capability of the fourth stage ADS.

Using the above comparisons as a basis, AP600 plant sensitivities have been performed to investigate the venting capability of the ADS fourth stage accounting for the uncertainty in the critical flow model used to calculated the flow through the valves.

PLANT SENSITIVITY CALCULATIONS

Introduction

The AP600 SSAR LOCA analysis is a spectrum of postulated break sizes ranging from a one-inch equivalent diameter break to double-ended hot leg (DEHLG) and cold leg (DECLG) guillotine breaks. To achieve the stable long-term core cooling condition required by 10CFR 50.46 for LOCA events the AP600 reactor coolant system must be depressurized to near containment pressure to enable IRWST injection. The performance of the fourth stage of the AP600 automatic depressurization system (ADS) is crucial to accomplishing this in 10CFR50.46 analyses. A sensitivity study has been conducted to investigate the performance of the ADS fourth stage valves. A containment pressure boundary

condition of 14.7 psia is assumed in the study because Appendix K to 10CFR50 identifies that a minimum containment pressure should be applied in design basis ECCS performance analyses.

The inadvertent ADS actuation is chosen from among the AP600 SSAR spectrum cases for this study. For this postulated event the ADS alone is available to depressurize the AP600 to achieve IRWST injection. The NOTRUMP computer code, which was used in the SSAR small break LOCA analysis, was utilized in this analysis. Only passive, safety- related systems were modeled. The NOTRUMP AP600 input model used for the SSAR analyses complies with the standard Westinghouse Small Break LOCA Evaluation Model methodology (References 3 and 4). To obtain a better representation of the AP600, the following changes have been made to the SSAR Revision 0 model:

1) The double-link horizontal stratified flow links between the reactor coolant pump and cold leg fluid nodes are abandoned and replaced with single links. The purpose of applying double links was to properly consider the possible spillover of liquid from the cold legs into the standard plant loop seals. Since AP600 pumps do not possess loop seals it is more appropriate to use a single link model.

2) The double-link horizontal stratified flow links are no longer used for the surge line connections. Rather, single links with a side entry into the pressurizer node are utilized because they more appropriate model the surge line flow path.

3) The AP600 design changes identified in the February 15, 1994 and June 30, 1994 design change reports (References 5 and 6) were incorporated into the model.

4) A multi-node PRHR representation of the heat exchanger is used. PRHR HX actuation occurs on a Safeguards ("S") signal. Standard condensation heat transfer correlations are applied when primary side steam condenses in the PRHR.

The potential impact of the limiting uncertainties in fourth stage ADS performance on the AP600 is the focus of this study of the inadvertent ADS actuation case. Therefore, the single active failure assumed herein is the failure of one of the four fourth-stage ADS valves to open on demand. A parametric study is performed in which 15% and 30% reductions in the available fourth stage ADS valve area are modeled and compared with the full area base case.

Sensitivity Study Results

Since the current study investigates the sensitivity of the AP600 to fourth stage ADS valve performance, the transients are identical through the actuation of the fourth stage of ADS. The first, second and third stage ADS valves actuate based on a spurious signal and the design time delays, respectively. At the 20 percent mixture level in the core makeup tank, the fourth stage ADS valves, which are connected to the hot legs, receive signals to open. The sequence of events for the base case transient modeling full ADS fourth stage valve capability (after consideration of the assumed single failure) is given in Table 1. This base case was later restarted at the time of fourth stage ADS actuation, modeling reduced valve critical flow areas. Note that the AP600 SSAR Revision 0 analysis has modeled a design in which there are two fourth stage ADS paths, and that only one of the two is available when the other is the postulated single active failure. A comparison of fourth stage ADS vent areas, assuming the failure of one fourth stage valve to open, is shown below:

CASE	VENT AREA/PATH	PATHS	TOTAL AREA
SSAR Revision 0	76 sq. in.	X one	76 sq. in.
Current Base Case	38 sq. in.	X three	114 sq. in.
Base Case Less 15%	32.3 sq. in.	X three	96.9 sq. in.
Base Case Less 30%	26.6 sq. in.	X three	79.8 sq. in.

Therefore, even the most degraded case for the current design possesses more fourth stage ADS vent area than the SSAR analysis cases.

The opening of the first stage of ADS initially depressurizes the RCS, and the reactor trip, reactor coolant pump trip and safeguards "S" signals are generated via the pressurizer low pressure signals with appropriate delays. Upon generation of the reactor trip signal the main steam isolation valves begin to close. Five seconds after an "S" signal the main feedwater isolation valves begin to close. The differing assumptions regarding ADS fourth stage capability have no effect until the fourth stage valves receive signals to open.

As anticipated, the differing fourth stage ADS valve critical flow areas have virtually no effect on core makeup tank empty time, which occurs 2335 seconds into the transient, give or take one or two seconds. From that point forward the system mass inventory continuously decreases until IRWST injection begins. The cases which model reduced fourth stage valve capability require more time to depressurize the RCS to achieve IRWST injection; the IRWST begins delivery of water into the vessel at 2730 and 3180 second transient times for the 15% and 30% reduced fourth stage ADS valve area cases respectively.

Figures 10 through 12 demonstrate that even with a 30% reduction in fourth stage ADS valve critical flow capability the AP600 exhibits significant margin to core uncovery. The hot leg liquid mixture level is presented for each case in the three figures. In each case the hot leg retains some amount of liquid. The mixture level above the core remains within the hot leg perimeter, at an elevation well above the top of the active fuel (18.83 feet), in each case analyzed. In all three cases the RCS mass inventory at the time of IRWST injection exceeds the minimum value obtained during the inadvertent ADS actuation transient, which occurs immediately before the accumulators first actuate. Figures 13 through 15 show the liquid flow which passes through the fourth stage ADS valves for the three cases. When the full flow area of three fourth stage valves is modeled, and also when a 15% reduction in area is imposed, the venting capability is large enough that the depressurization to IRWST is accomplished while liquid is a part of the discharge flow. When a 30% reduction is imposed, a lowering of the hot leg mixture level, as depicted in Figure 12, leads to a period of single phase steam flow. This enables the RCS to depressurize to the extent needed to begin IRWST actuation while losing mass inventory at a much lower rate than when the ADS discharge is a two-phase mixture .

CONCLUSIONS

The range of uncertainty was determined for the Henry/Fauske and Homogenous Equilibrium critical flow models from comparisons to existing data. Plant calculations were performed for the most limiting small-break LOCA case where venting capacity is minimized. The case which was examined was the inadvertent ADS case, in which there is no added venting from the break; rather the ADS alone must depressurize the primary system down to containment pressure. The calculations indicate that the design provides more than sufficient fourth stage venting capacity such that when the uncertainty in the critical flow modeling is conservatively accounted for, the plant will reach IRWST injection without core uncovery.

REFERENCES

1. Henry, R.E. and H.K. Fauske, " The Two-Phase Critical Flow of One-Component Mixtures in Nozzles, Orifices, and Shot Tubes" , Trans ASME J. Heat Transfer, vol 93, pg 179-187, May 1971.

2. Hutcherson, M.N., "Contribution to the Theory of the Two-Phase Blowdown Phenomena", ANL-75-82, 1975.

3. Meyer, P.E., "NOTRUMP - A Nodal Transient Small Break and General Network Code," WCAP-10079-P-A, (Proprietary) and WCAP-10080-A (Nonproprietary), August 1985.

4. Lee, N., Rupprecht, S.D., Schwartz, W.R., and Tauche, W.D., "Westinghouse Small Break ECCS Evaluation Model Using the NOTRUMP Code," WCAP-10054-P-A (Proprietary) and WCAP-10081-A (Nonproprietary), August 1985.

5. AP600 Design Change Report, February 15, 1994, Westinghouse Electric Corporation, Enclosure to Letter NTD-NRC-94-4064.

6. AP600 Design Change Report, June 30, 1994, Westinghouse Electric Corporation, Enclosure to Letter NTD-NRC-94-4175.

TABLE 1: BASE CASE SEQUENCE OF EVENTS TABLE

Inadvertent ADS Actuation	Time of event
Break open	0.0 seconds
Reactor trip signal	25.7 seconds
"S" signal	29.2 seconds
Reactor coolant pumps start to coast down	45.4 seconds
Accumulator flow starts	208 seconds
PRHR/CMT Actuation	30.4 seconds
ADS stage 2 flow starts	70 seconds
ADS stage 3 flow starts	190 seconds
Accumulator injection ends	565 seconds
ADS stage 4 flow starts	1984 seconds
IRWST injection starts	2594 seconds

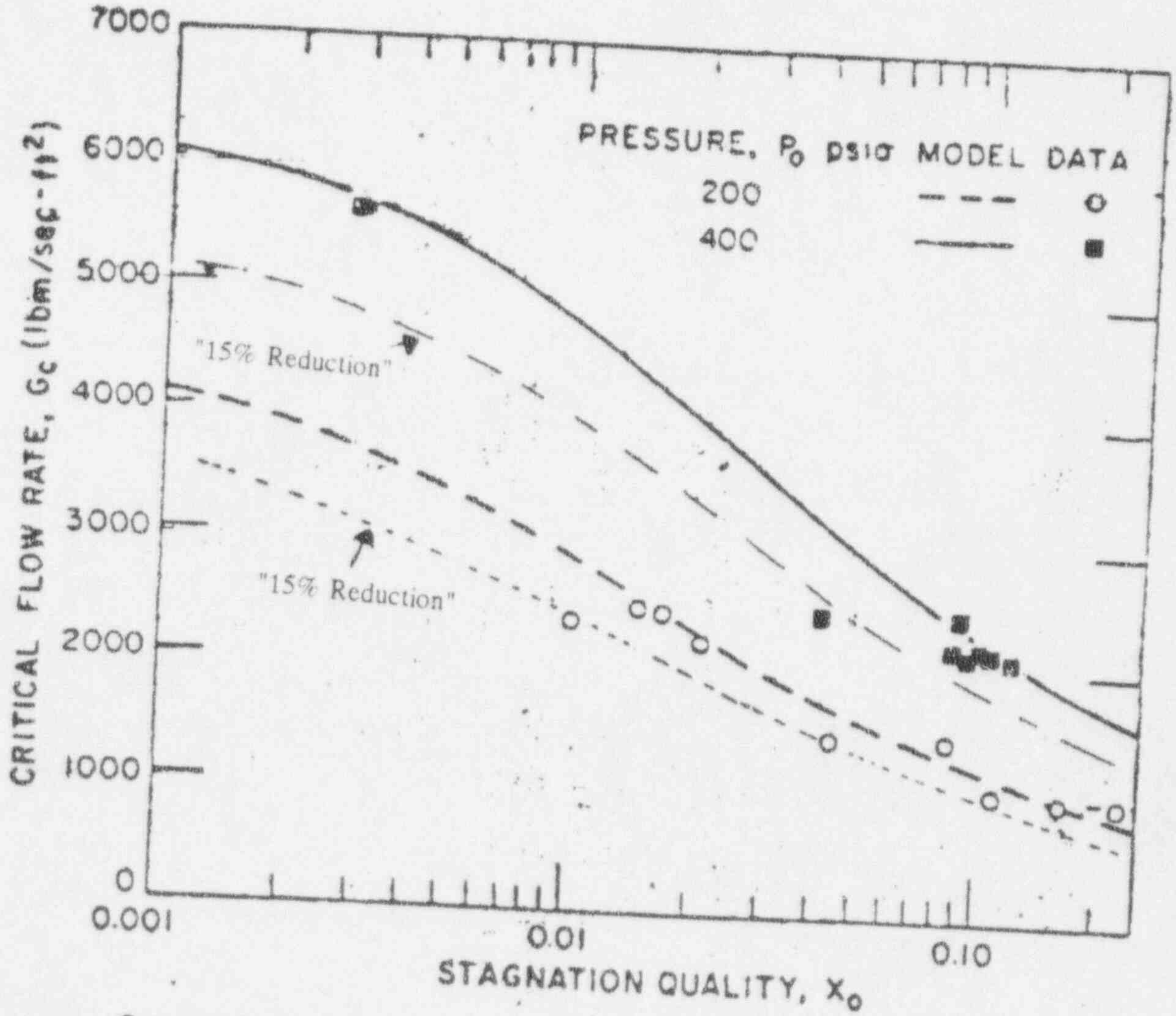


Figure 1

Comparison between proposed model and experimental data of references [26, 27]

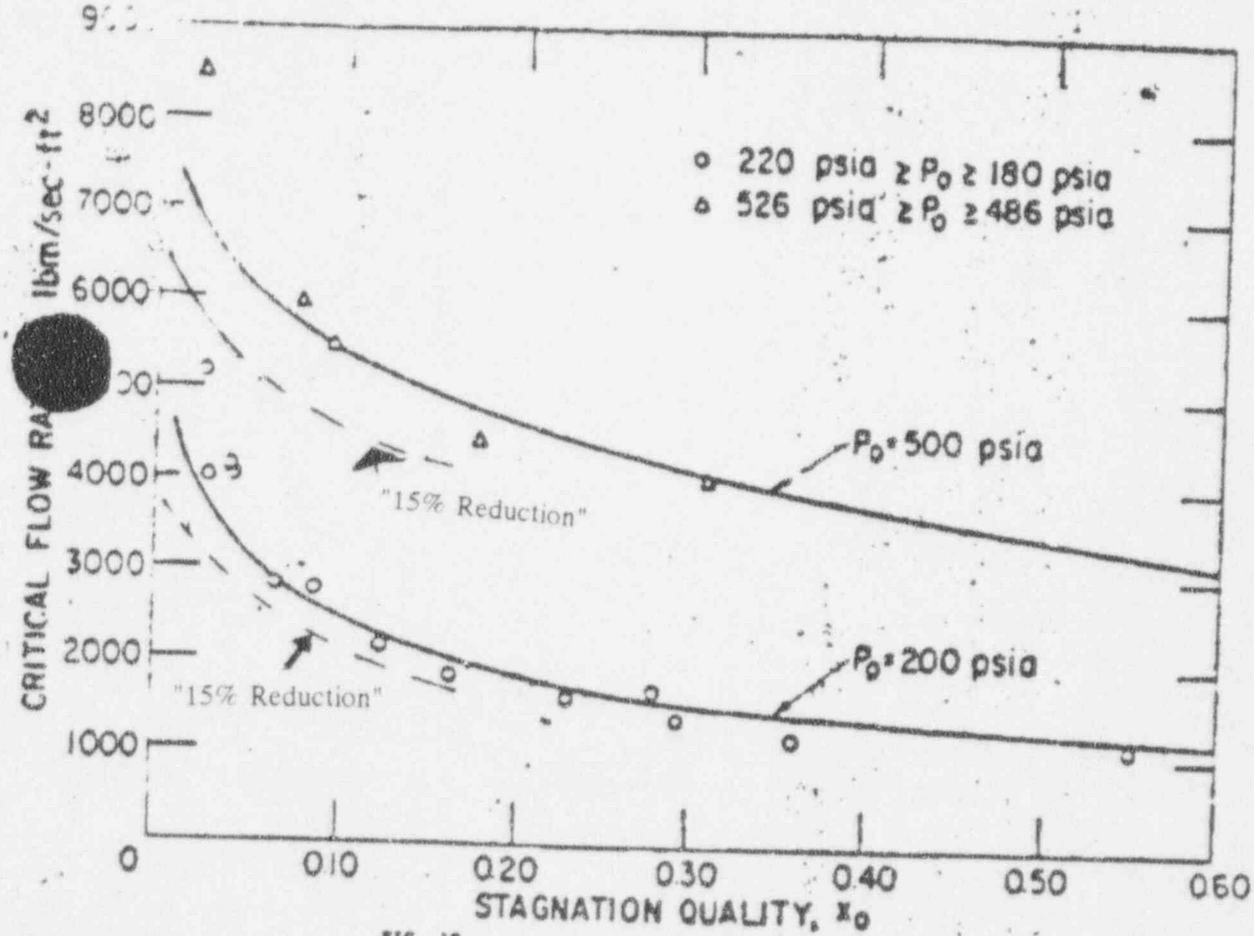


FIG. 10

Figure 2

Comparison between proposed model and carbon dioxide data of reference [17]

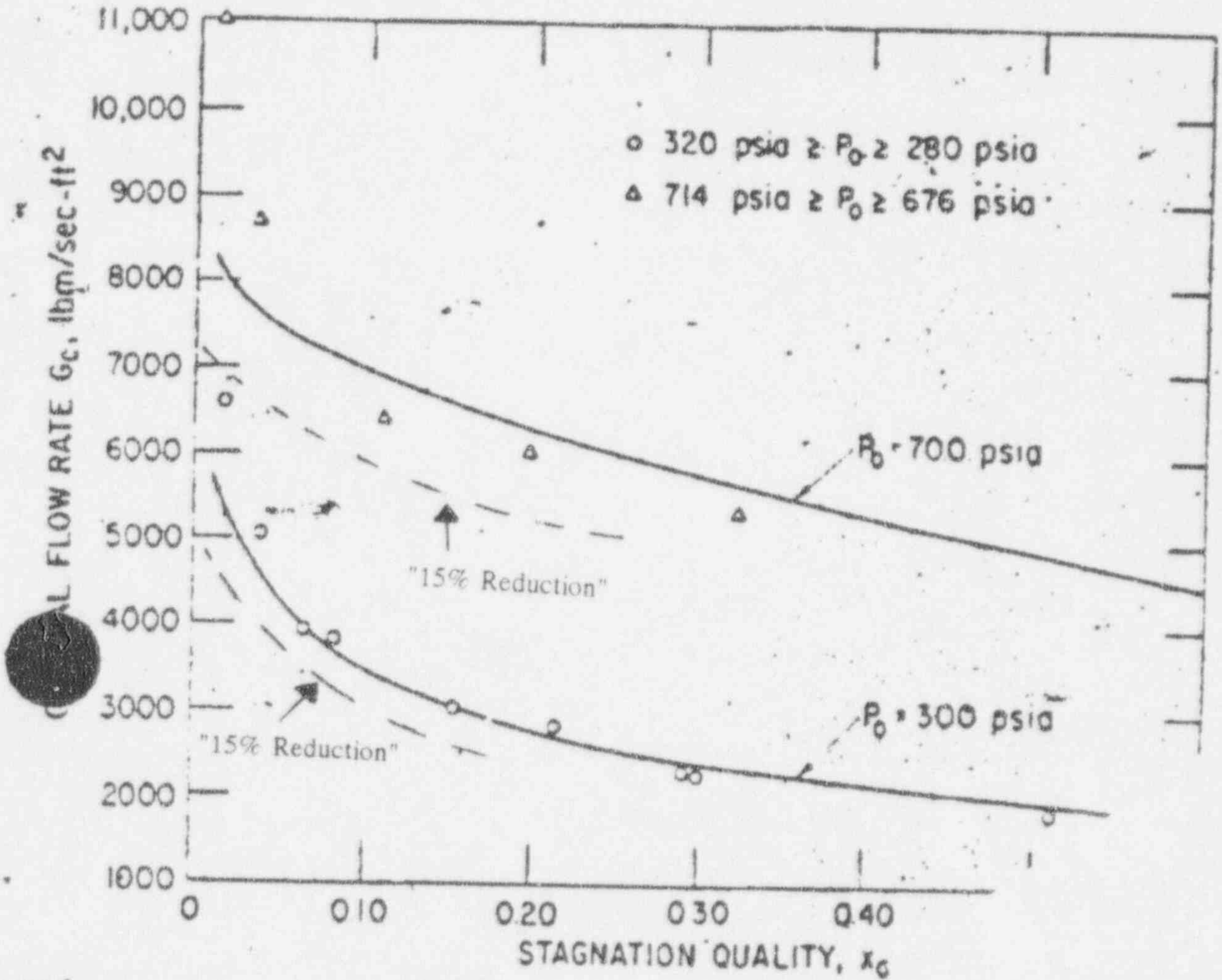


Figure 3

Comparison between proposed model and cc. of reference [17]

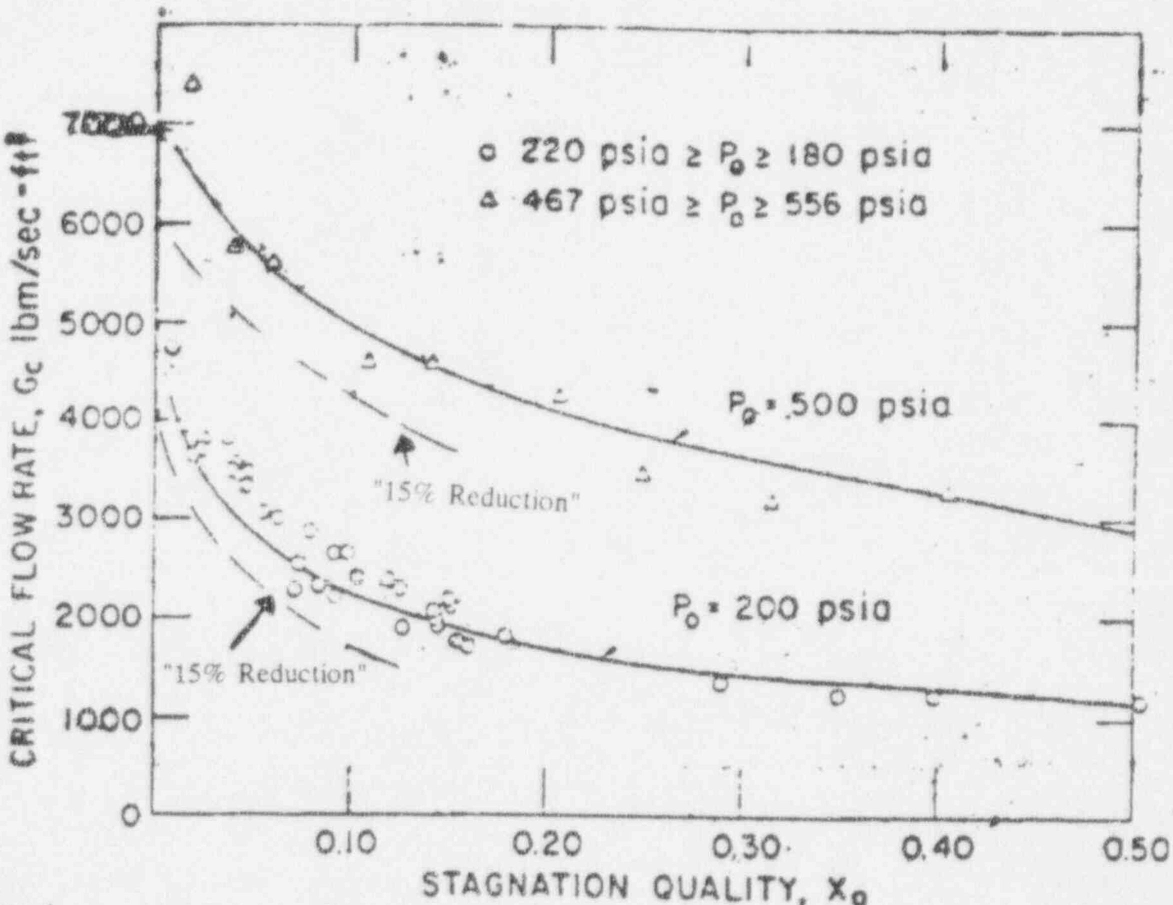


Figure 4

Comparison between proposed model and two-phase orifice data of reference [17]

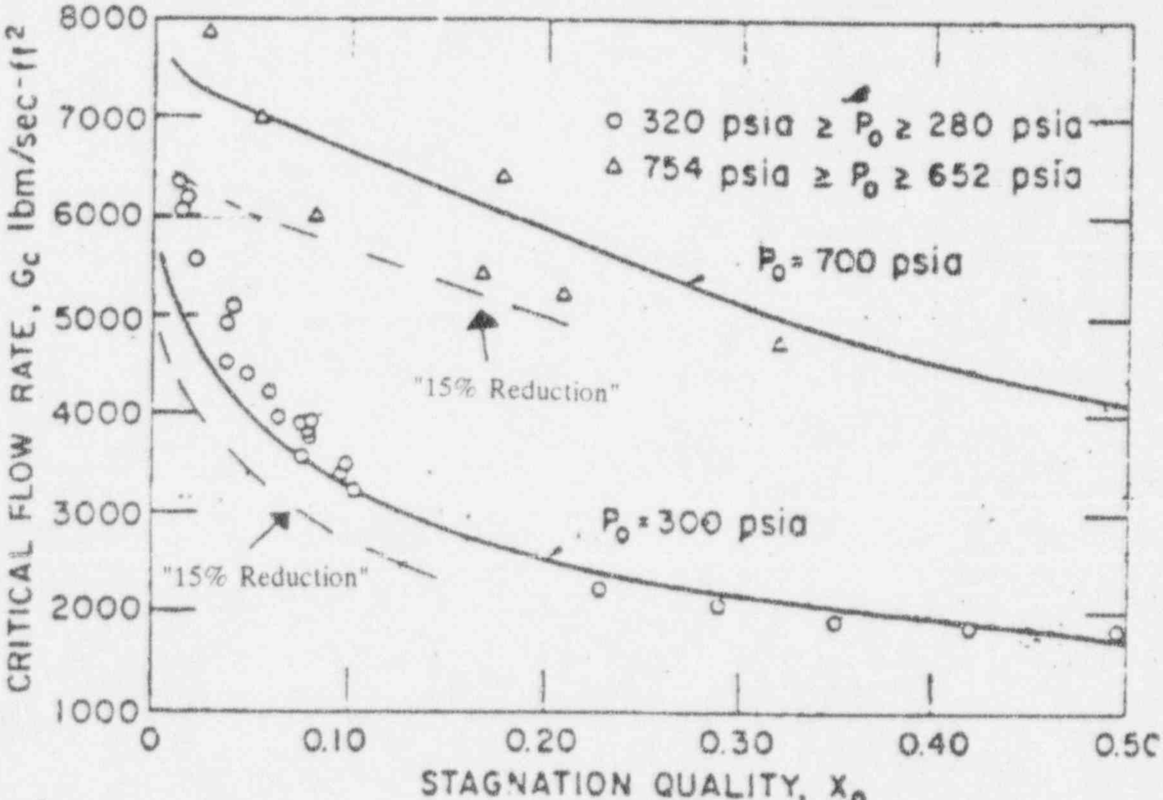


Figure 5

Comparison between proposed model and two-phase orifice data of reference [17]

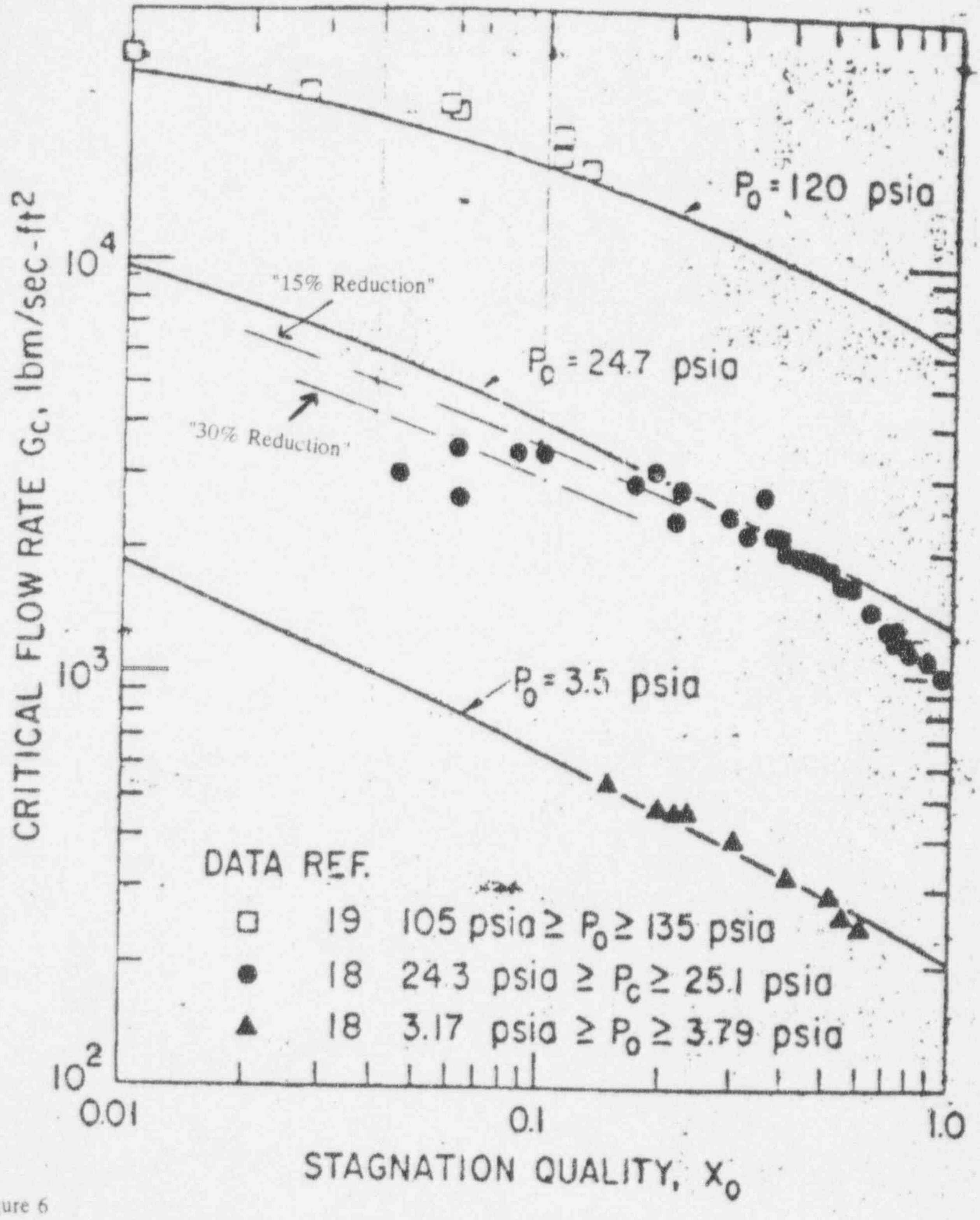
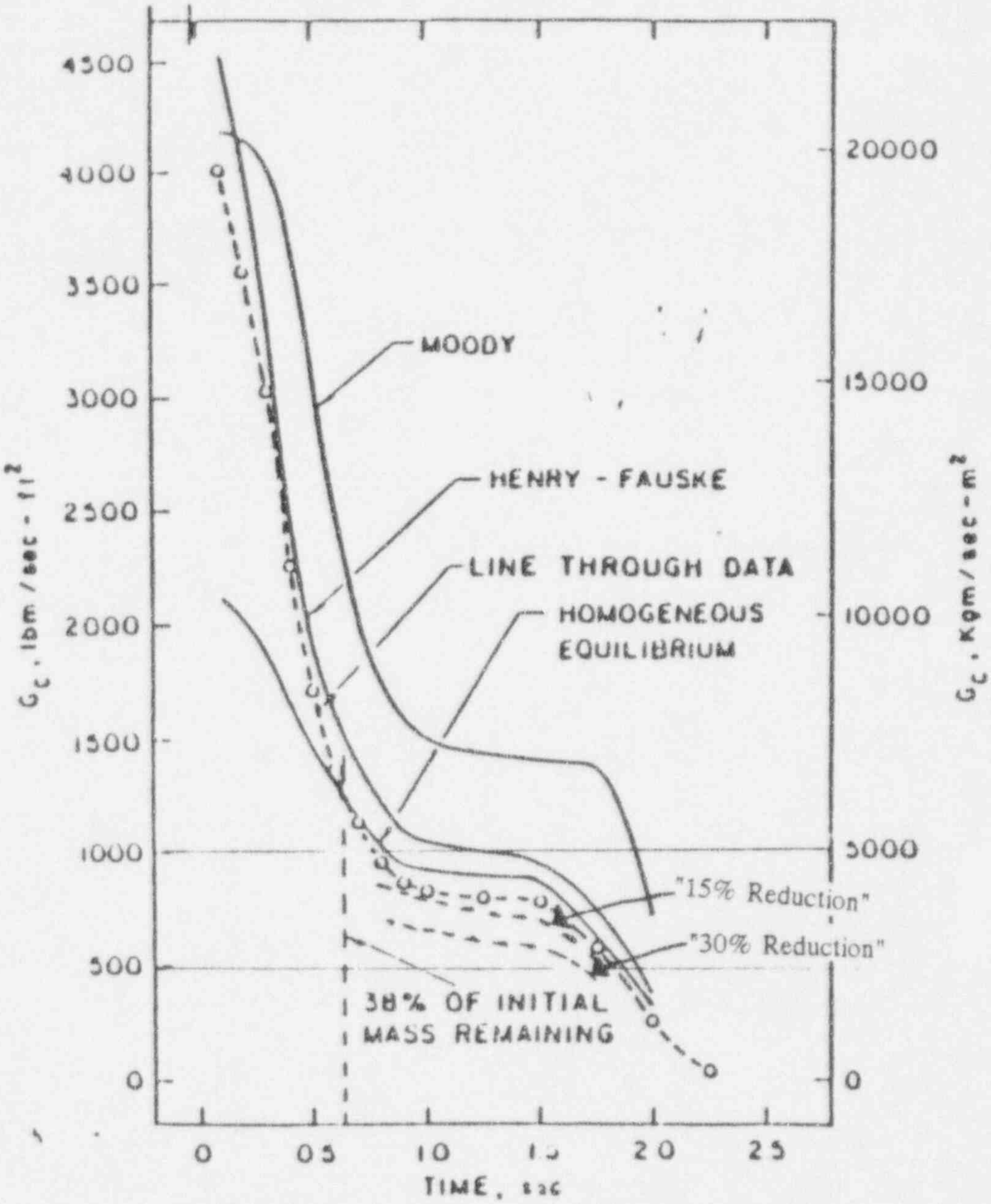


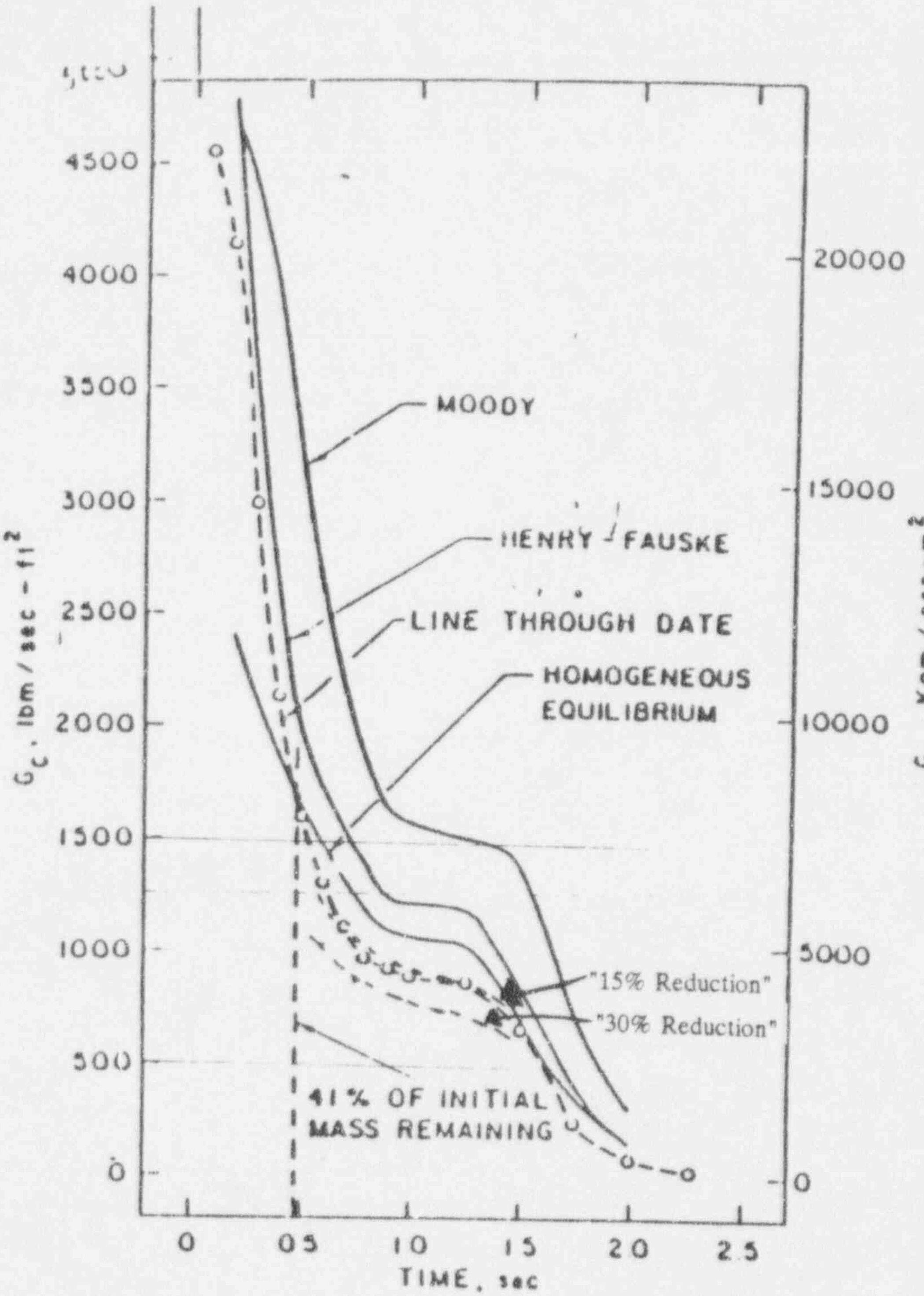
Figure 6

Comparison between proposed model and two-phase nitrogen orifice data of references [18, 19]



MOODY
HENRY - FAUSKE
LINE THROUGH DATA
HOMOGENEOUS EQUILIBRIUM
"15% Reduction"
"30% Reduction"
38% OF INITIAL MASS REMAINING
TIME, sec

Figure 7



MOODY
HENRY - FAUSKE
LINE THROUGH DATE
HOMOGENEOUS
EQUILIBRIUM
"15% Reduction"
"30% Reduction"
41% OF INITIAL
MASS REMAINING
4500
4000
3500
3000
2500
2000
1500
1000
500
0
20000
15000
10000
5000
0
0
0.5
1.0
1.5
2.0
2.5
TIME, sec

Figure 8

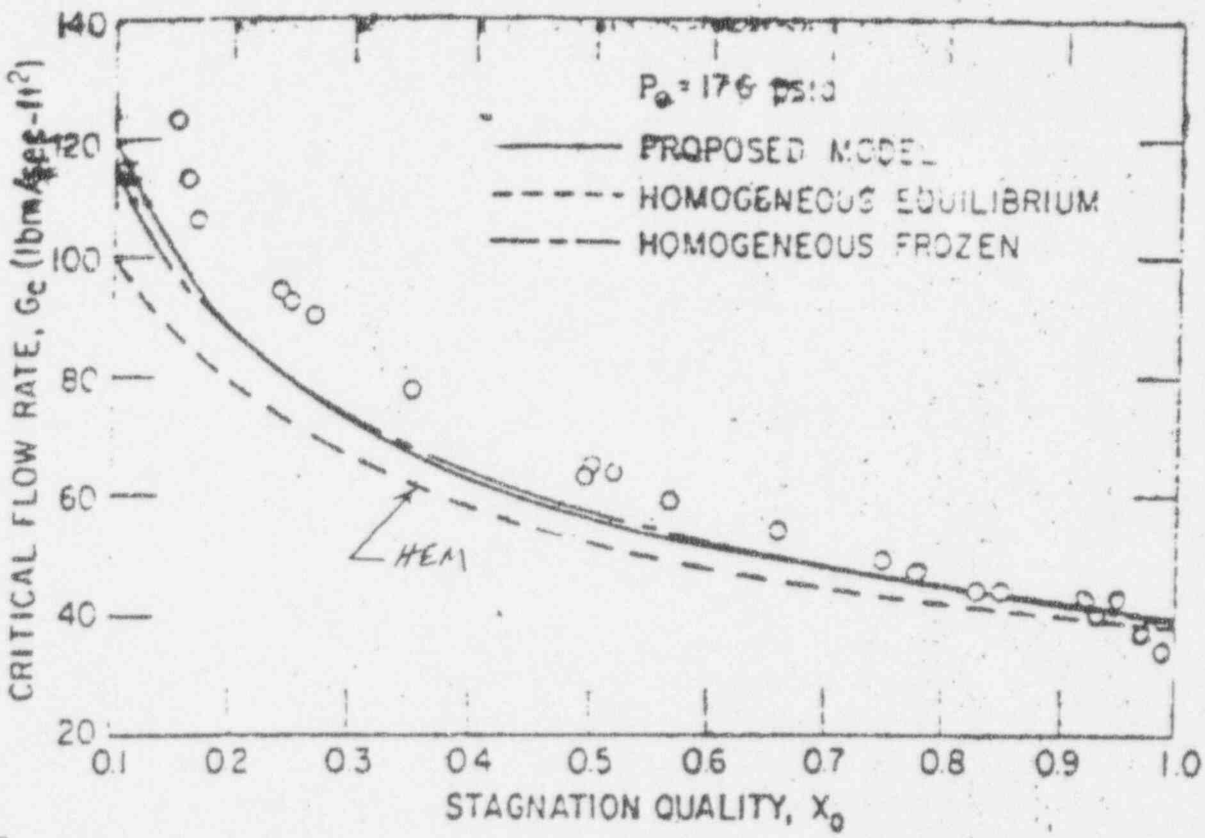


Figure 9

Comparison of critical flow predictions and experimental data of reference [30]

FIGURE 10

HOT LEG MIXTURE LEVEL, FULL FOURTH STAGE FLOW AREA

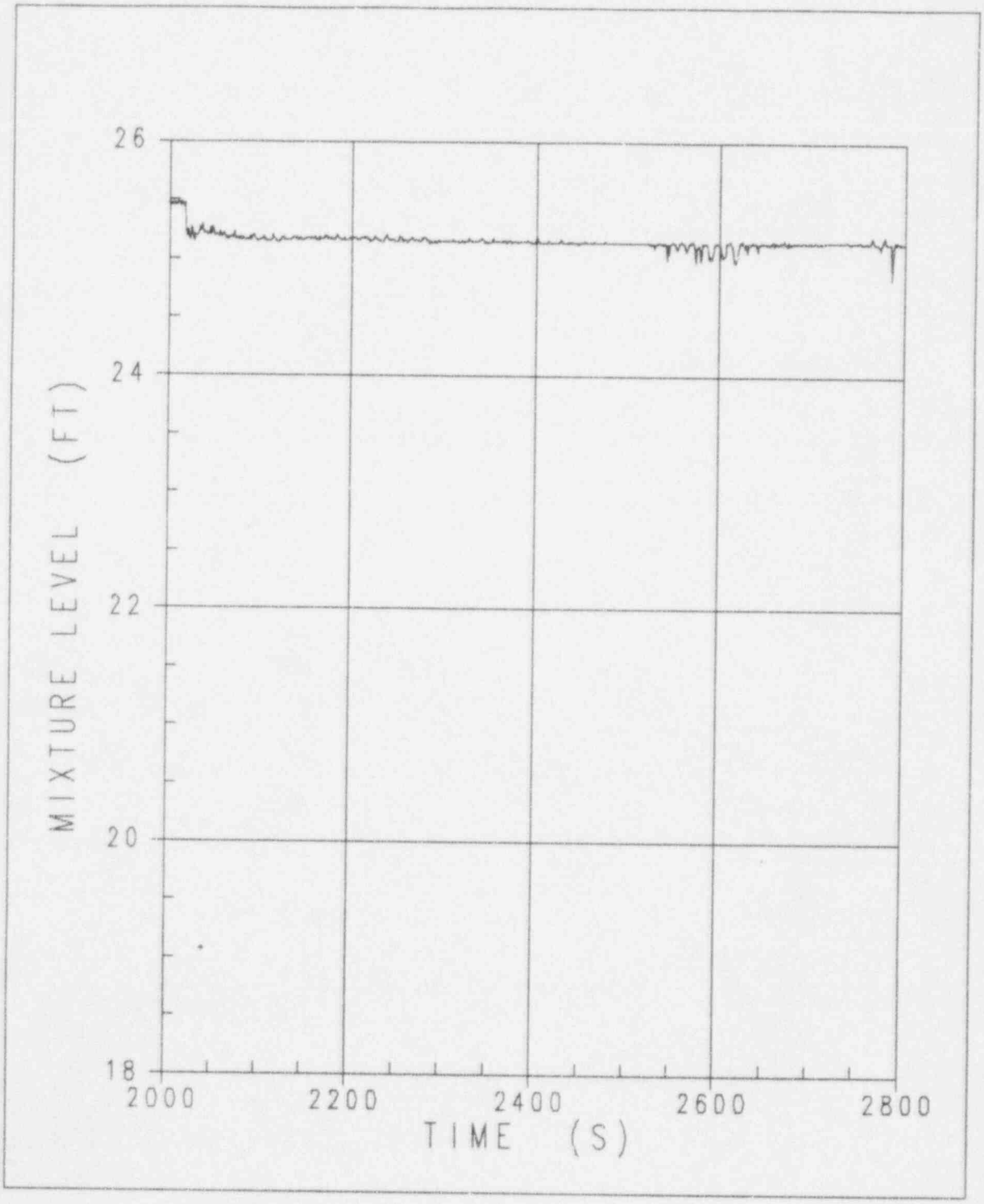


FIGURE 11

HOT LEG MIXTURE LEVEL, 15% REDUCED FOURTH STAGE FLOW AREA

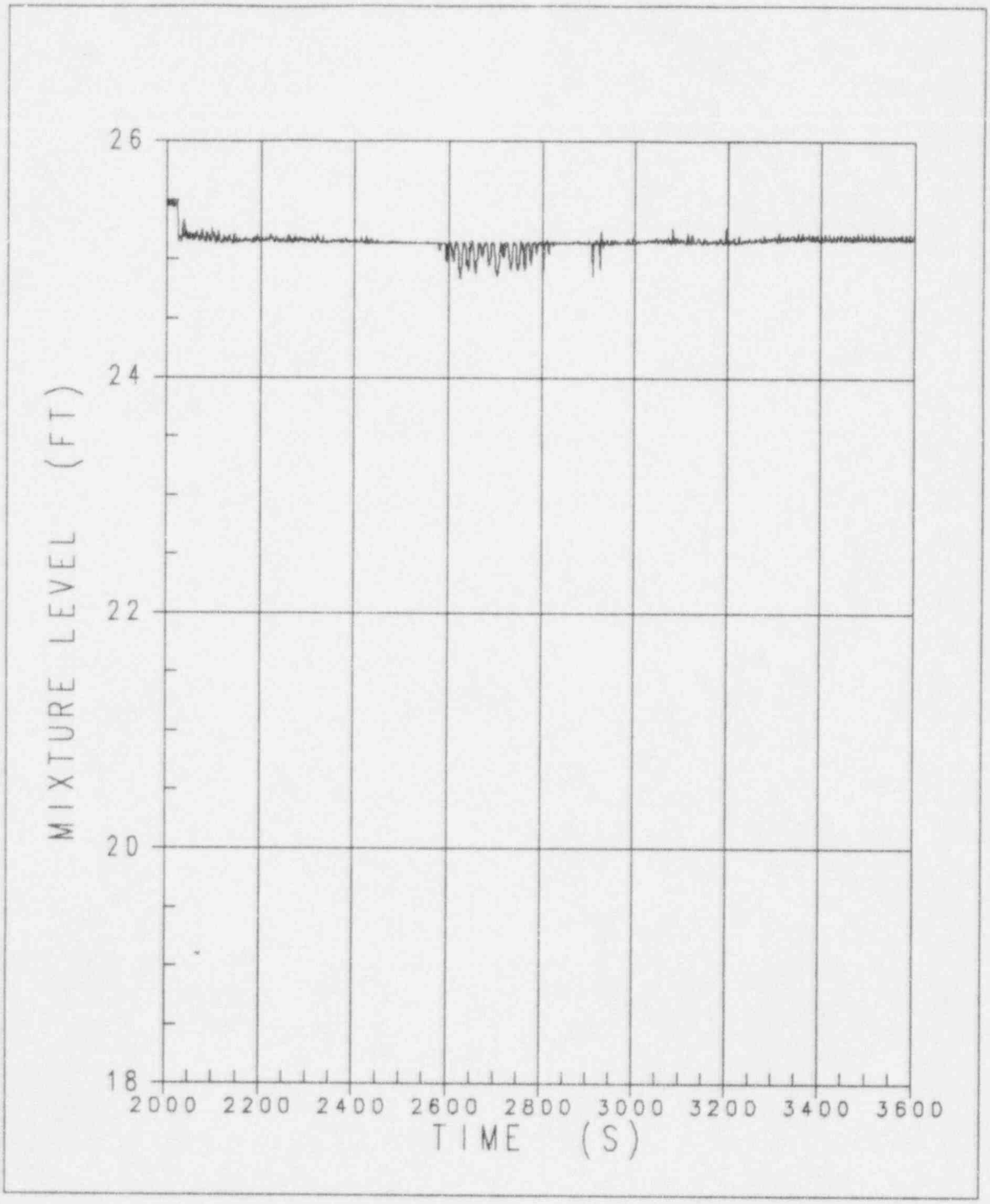


FIGURE 12

HOT LEG MIXTURE LEVEL, 30% REDUCED FOURTH STAGE FLOW AREA

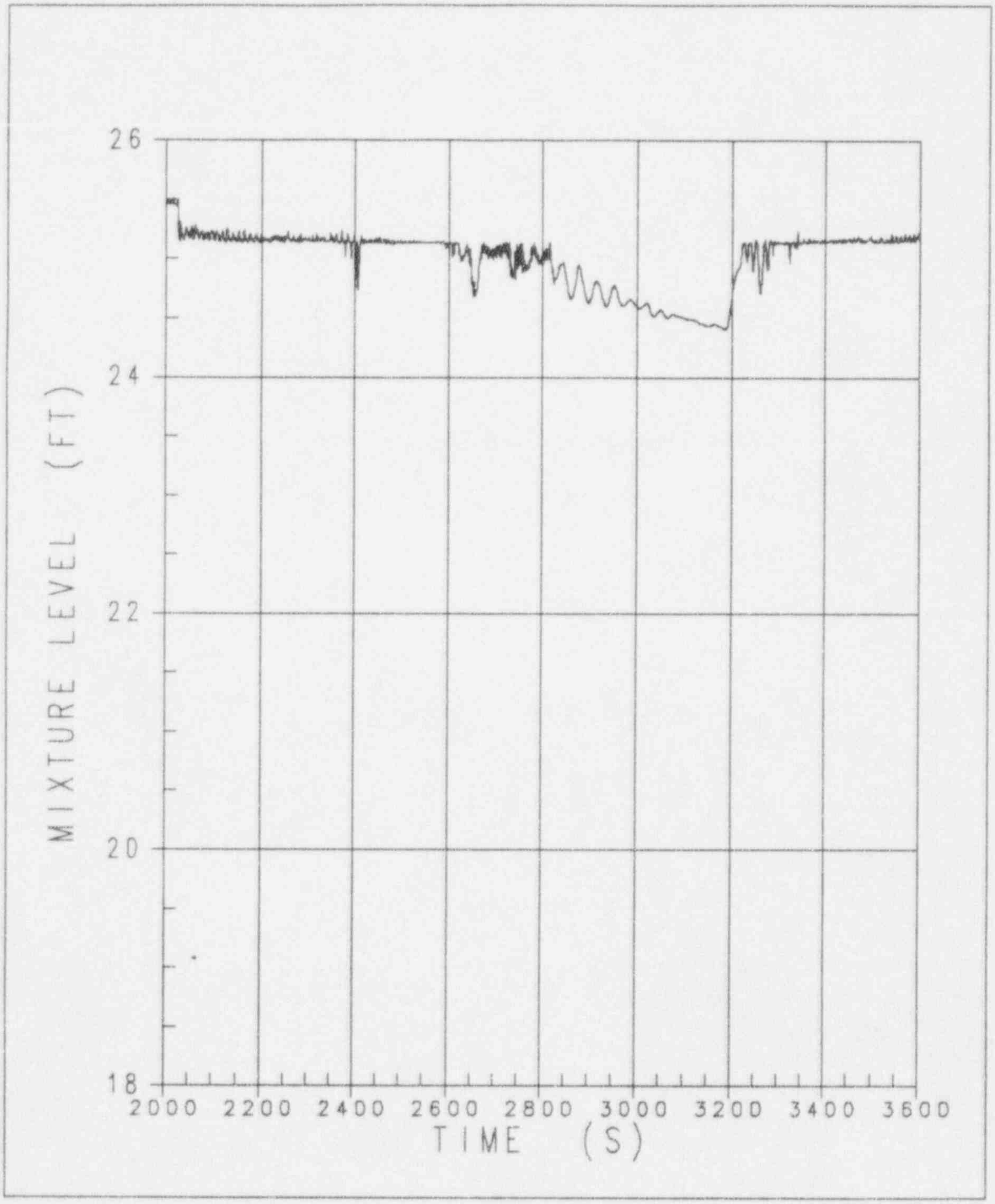


FIGURE 13

FOURTH STAGE ADS LIQUID FLOW, BASE CASE

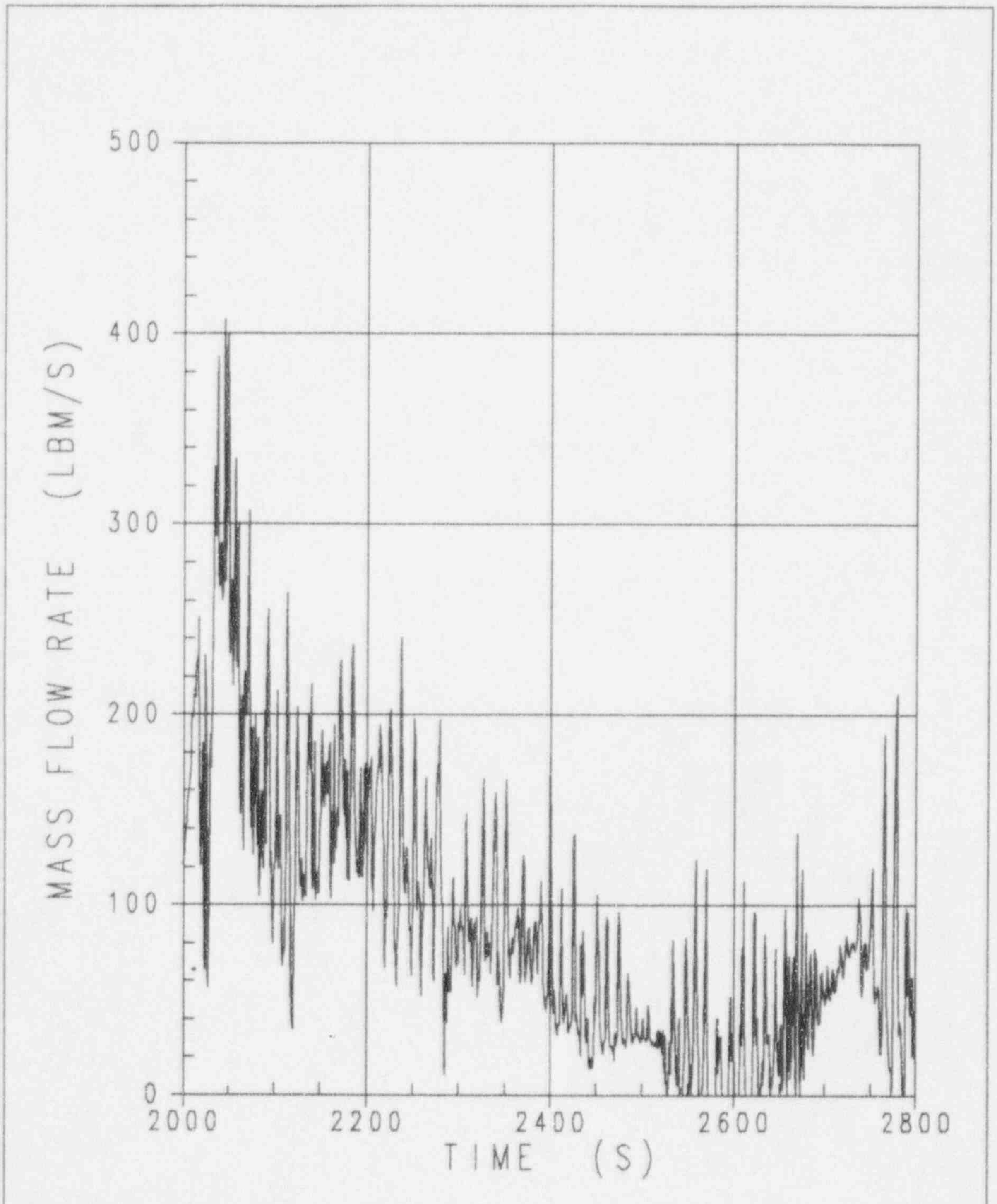


FIGURE 14

FOURTH STAGE ADS LIQUID FLOW, 15% REDUCED FOURTH STAGE FLOW AREA

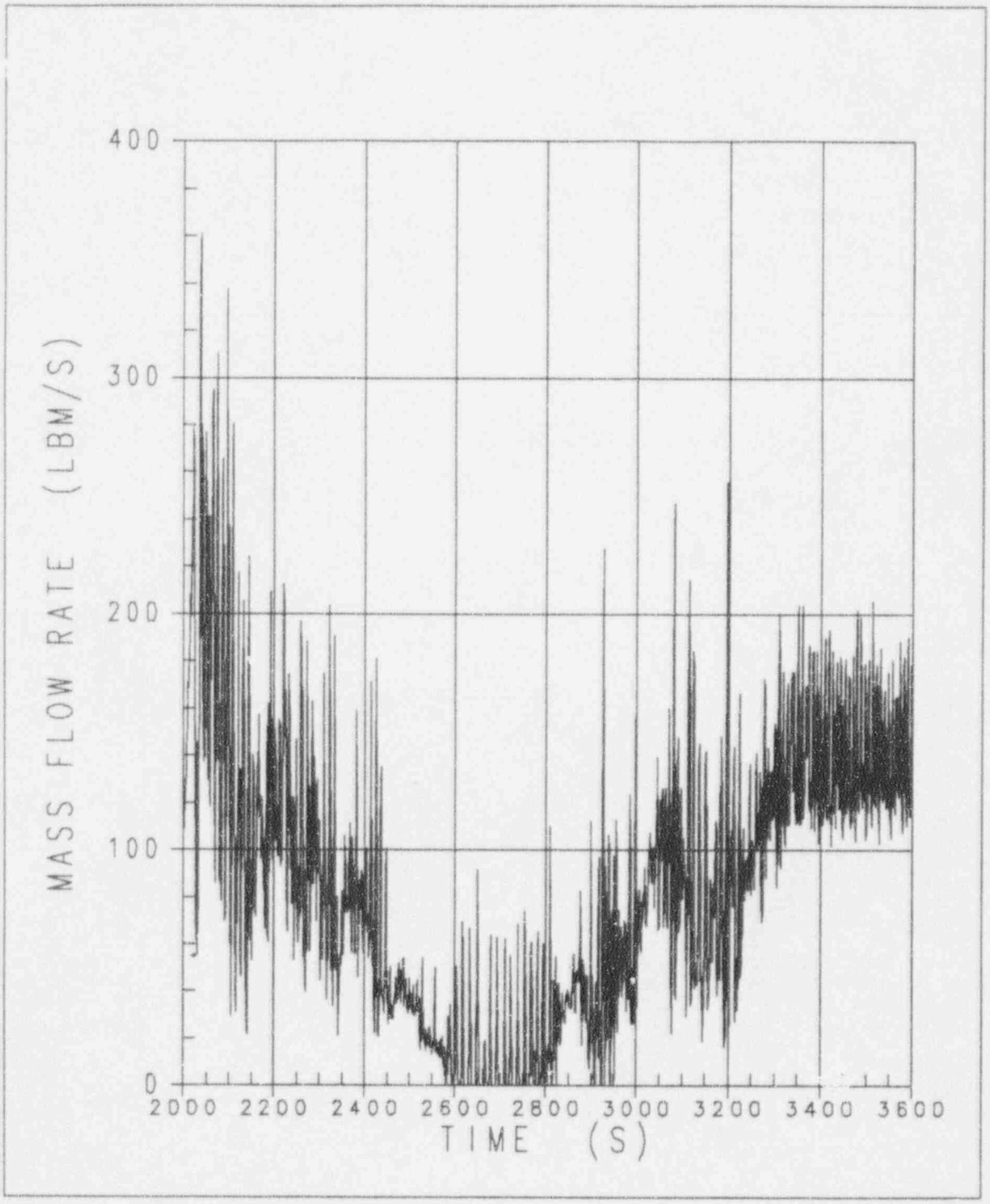


FIGURE 15

FOURTH STAGE ADS LIQUID FLOW,30% REDUCED FOURTH STAGE FLOW AREA