Commonwealth Edison
One First National Plaza, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690

September 28, 1979
OG-10

Mr. Denwood F. Ross, Jr.
Deputy Director
Division of Project Management
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Ross:

Responses to most of the NRC concerns on WCAP-9600 were previously transmitted to you via our C. Reed to D. Ross letter dated September 11, 1979. Transmitted herewith are the responses to the balance of the NRC concerns with the exception of concern D.26. In accordance with our letter (C. Reed to D. Ross dated August 23, 1979) with regard to our schedule for responses to the NRC concerns, the response to D.26 is still in preparation and will be submitted later this year subsequent to the responses to NUREG 0578.

Please note that per an NRC request, the plots included in the response to concern C.2 were telecopied to the NRC (Mr. P. O'Reilly) on September 10, 1979. Additional concerns (3) on WCAP-9600 for pressurizer drain and core level calculations were received by telecopy on August 24, 1979. The responses to these concerns are also included.

This submittal contains proprietary information that is withheld from public disclosure in conformance with the requirements of 10CFR Section 2.790, paragraph (b)(1) of the Commission's regulations. Enclosed with this submittal is a Westinghouse application for withholding from public disclosure. Correspondence with respect to the application for withholding should reference CAW-79-35, and should be addressed to R. A. Wiesemann, Manager, Regulatory and Legislative Affairs, Westinghouse Electric Corporation, P. O. Box 355, Pittsburgh, Pennsylvania 15230.

Please note that we have enclosed forty (40) copies of the full proprietary responses and twenty (20) copies of the non-proprietary responses. Only response B.1 contains proprietary information.

If you have any questions, please contact us.

Very truly yours,

Cordell Reed

Cordell Reed, Chairman
Westinghouse Operating Plants
Owners' Group

CR/pab
Attachment

Westinghouse Electric Corporation
Water Reactor Divisions

Nuclear Technology Division

Box 355
Pittsburgh Pennsylvania 15230

September 24, 1979
CAW-79-35

Mr. D. F. Ross, Assistant Director
Division of Systems Safety
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: Report on Small Break Accidents for Westinghouse NSSS System

REF: Letter from Reed (Commonwealth Edison Company) to Ross, dated September, 1979

Dear Mr. Ross:

The proprietary material transmitted by the referenced letter supplements the proprietary material previously submitted concerning the Westinghouse development of ECCS models. Further, the affidavit submitted to justify the material previously submitted, AW-77-18, was approved by the Commission on October 28, 1977, and is equally applicable to this material.

Accordingly, withholding the subject information from public disclosure is requested in accordance with the previously submitted affidavit and application for withholding, AW-77-18, dated April 6, 1977, a copy of which is attached.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference CAW-79-35, and should be addressed to the undersigned.

Very truly yours,

Robert A. Wiesemann

Robert A. Wiesemann, Manager
Regulatory & Legislative Affairs

/bek
Attachment

cc: J. A. Cooke, Esq.
Office of the Executive Legal Director, NRC

1071 095

POOR ORIGINAL

Westinghouse Electric Corporation   Power Systems

PWR Systems Division

Box 355
Pittsburgh Pennsylvania 15230

April 6, 1977

AW-77-18

Mr. John F. Stolz, Chief
Light Water Reactors Branch No. 1
Division of Project Management
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
7920 Norfolk Avenue
Bethesda, Maryland 20014

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: Westinghouse WCAP-8970 "Westinghouse Emergency Core Cooling System Small Break October 1975 Model"

REF.: Westinghouse Letter No. NS-CE-1403, Eicheldinger to Stello, dated April 6, 1977

Dear Mr. Stolz:

This application for withholding is submitted by Westinghouse Electric Corporation pursuant to the provisions of paragraph (b)(1) of 10 CFR Section 2.790 of the Commission's regulations and is accompanied by a proprietary and a non-proprietary affidavit.

The proprietary affidavit sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of Section 2.790 of the Commission's regulations. Because this affidavit contains Westinghouse proprietary information, it is being submitted in confidence and is marked Westinghouse Proprietary Class 2. Accordingly, pursuant to the provisions of Section 2.790(b)(1)(ii), we request that the proprietary affidavit be withheld from public disclosure.

The undersigned has reviewed the information sought to be withheld and is authorized to apply for its withholding on behalf of Westinghouse, WRD, notification of which was sent to the Secretary of the Commission on April 19, 1976.

1071 096

It is requested, therefore, that the Westinghouse proprietary information being transmitted by our letter (referenced above) be withheld from public disclosure in accordance with the provisions of 10 CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to the proprietary aspects of this application for withholding or the accompanying affidavits should reference AW-77-18 and should be addressed to the undersigned.

Very truly yours,

Robert A. Wiesemann, Manager
Licensing Programs

/smh

cc: J. A. Cooke, Esq.
Office of the Executive Legal Director, NRC

[illegible]

AW-77-18

AFFIDAVIT

POOR ORIGINAL

COMMONWEALTH OF PENNSYLVANIA:
ss
COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Robert A. Wiesemann, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Corporation ("Westinghouse") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Robert A. Wiesemann
Robert A. Wiesemann, Manager
Licensing Programs

Sworn to and subscribed
before me this 20 day
of April 1977.

Notary Public

[illegible], 1978

POOR ORIGINAL

(1) I am Manager, Licensing Programs, in the Pressurized Water Reactor Systems Division, of Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing or rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Water Reactor Divisions.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse Nuclear Energy Systems in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

POOR ORIGINAL

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

(g) It is not the property of Westinghouse, but must be treated as proprietary by Westinghouse according to agreements with the owner.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition in those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information is not available in public sources to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is attached to Westinghouse Letter Number NS-CE-1403, Eicheldinger to Stolz, dated April 6, 1977. The letter and attachment are being submitted in support of the Westinghouse emergency core cooling system evaluation model.

Public disclosure of the information sought to be withheld is likely to cause substantial harm to the competitive position of Westinghouse, taking into account the value of the information to Westinghouse, the amount of effort and money expended by Westinghouse in developing the information, and considering the ways in which the information could be acquired or duplicated by others.

Further the deponent sayeth not.

A. Michelson's Concerns

7. HPSI/LPSI Piping/Operation

The response states "for most plants". Revise your response to provide information for all plants.

Response

The HPSI pumps take suction from the LPSI pumps for all Westinghouse operating plant designs. During recirculation from the sump, only the LPSI pumps take suction from the sump for Westinghouse operating plants. There are a few plants in review/design for which the intermediate head SI pumps also take suction from the sump during recirculation.

B. Treatment of Non-condensible Gases

1. Discuss the applicability and application of the Roshenow Correlation. (In deriving the non-condensible heat transfer models, the assumption was made that this correlation predicts the liquid film conduction only.) This discussion should address the verification of the model, namely, the predictability of the model versus the non-condensible gas concentration/prototypic conditions and geometry.

2. Discuss the introduction of accumulator nitrogen for the case of a small pipe break larager than 2 inches in diameter.

3. Discuss how the reactor is brought to a cold shutdown condition following a small break LOCA in the primary system in which non-condensible gas accumulates in bends in the steam generator U-tubes.

Response to B.1

One important assumption which was made in the development of the analytical model for condensation in the steam generator tubes was that available correlations for laminar film condensation on vertical surfaces would predict heat transfer coefficients which were conservatively low.

The situation of interest is illustrated in Figure B.1-1. As discussed in reference 1, the heat transfer rate across the liquid boundary layer is calculated as follows:

$$q''_{4-3} = h_{4-3} (T_4 - T_3) \qquad (B.1-1)$$

where:

$T_4 = T_i$
$T_3 = T_{wp}$

and:

$$h_i = 0.943 \quad \frac{4\, g\rho\, (\rho-\rho_v) K^3\, (\lambda + 0.68\, c\Delta T)}{L\mu\, (T_4 - T_3)} \qquad (B.1\text{-}2)$$

where:

c = specific heat
g = gravity
K = thermal conductivity
L = length
λ = latent heat of vaporization
μ = viscosity
ρ = density

Unsubscripted properties are those of the liquid and are evaluated at:

$$T_{ref} = T_3 + 0.31\, (T_4 - T_3) \qquad (B.1\text{-}3)$$

Equations B.1-2 and B.1-3 were taken directly from reference 2. Its use is recommended for predicting heat transfer performance of vertical flat plates and larger size vertical tubes. This is consistent with the geometry of PWR steam generator tubes.

Since the correlation given in equation B.1-2 was developed for laminar film condensation, it will be conservative with respect to the turbulent film condensation which could occur in a plant. References 3 and 4 illustrate the conservatism of the assumption of laminar film condensation for a situation in which turbulent film flow exists.

The utilization of T_4 in equations B.1-2 and B.1-3 rather than the bulk primary side temperature, T_5, is justified, since the condensation is occurring at the interface between the non-condensible gas and liquid boundary layers. This is consistent with the correlation's application in a situation where no non-condensible gas is present, and T_{bulk} is used. This methodology also results in lower heat transfer coefficients.

The applicability of this correlation can be shown by comparing it to available test data. Tests at the R&D test facility provide experimental data for verification.

Figure B.1-2 gives a schematic of the test facility. As this figure shows, steam enters the inside of the simulated steam generator tubes and is condensed. The condensate runs down the inside of the tubes and flows counter-currently with the steam. Tests were run for primary side steam fluxes ranging from [ ]^{a,c} lbm/tube-hr with primary system pressures ranging from [ ]^{a,c} psia, and secondary side pressures ranging from [ ]^{a,c} psia. The tube steam flows correspond to those which could be generated by decay heats of approximately 1 to 6 percent in a typical four loop Westinghouse PWR. The range of test conditions cover those expected to occur following a small break LOCA. Therefore the test condensation heat transfer coefficients should be similar to those in a plant following a small break LOCA, with no non-condensibles present.

By comparing test heat transfer coefficients to those calculated for laminar film condensation (equation B.1-2), justification can be provided for this aspect of the model presented in reference 1.

Condensation heat transfer coefficients were calculated from test data by utilizing tube wall temperatures at the vertical midplane. Table B.1-1 presents test conditions along with the calculated primary side condensation coefficients. As Table B.1-1 shows condensation coefficients ranged from [ ]^{a,c}.

In order to compare the heat transfer coefficients calculated by equations B.1-2 and B.1-3, calculated condensation heat transfer coefficients were compared to test coefficients for the same conditions. Table B.1-2 presents this comparison.

As Table B.1-2 shows, the test heat transfer coefficients are greater than the calculated condensation heat transfer coefficients in 96 out of 98 cases. This provides additional justification of the methodology for the calculation of the heat transfer coefficients.

The conservatism of the methodology for the inclusion of the effect of non-condensibles into the model presented in reference 1 can be shown by reviewing the assumptions made.

1. Assuming no heat conduction through the non-condensible film neglects a mechanism for heat transfer which is physically present.

2. Assuming the non-condensible film is stagnant minimizes mixing and thus heat transfer.

3. Assuming all the non-condensible gas is present in the non-condensible boundary layer maximizes the non-condensible resistance to heat transfer. Additionally the non-condensible is double accounted for since all of the non-condensible is assumed to be in both the bulk mixture and in the gas boundary layer.

A review of these assumptions should provide assurance of the conservatism of the model.

As indicated, experimental verification of the subject model in the presence of non-condensible gases is difficult due to the scarcity of relative test data. However, further evidence of the conservatism of the evaluation model can be demonstrated using the methodology given in reference 1, and assuming pool boiling type heat transfer on the secondary side, and [ ]^{a,c} lb-moles of non-condensible gas (reference 1) in the steam generators of a typical four loop Westinghouse plant, and calculating overall heat transfer coefficients. These calculated heat transfer coefficients can be compared to the evaluation model.

Table B.1-3 compares these calculated heat transfer coefficients to those currently being used by WFLASH. As Table B.1-3 illustrates, the WFLASH heat transfer coefficients are low by approximately a factor of two(2). Therefore, since WFLASH's condensation heat transfer coefficients are low compared to those calculated conservatively, WFLASH will underpredict primary to secondary heat transfer. This provides conservatism to the calculation.

References

1. Westinghouse Electric Corporation, "Report on Small Break Accidents for Westinghouse NSSS Systems," WCAP-9600, Volume I (Proprietary), pgs. 2.6-1 to 2.6-17, June, 1979.

2. Roshenow, W. M. and Hartnett, J. P., Handbook of Heat Transfer, McGraw-Hill Inc., pgs. 12-9 and 12-10, 1973.

3. Kirkbride, C. G., Heat Transfer by Condensing Vapor on Vertical Tubes, Trans AICHE, Vol. 30, pgs. 170 to 186, 1933-1934.

4. Colburn, A. P., Heat Transfer by a Condensing Vapor, Trans AICHE, Vol. 30, pgs. 187 to 193, 1933-1934.

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Response to B.2

Break sizes greater than 2 inches in diameter may depressurize to the cold leg accumulator injection setpoint, but in order for the cold leg accumulators to empty and begin injecting large amounts of free nitrogen into the RCS, the system pressure must drop below approximately 150 psia. In order to achieve a RCS pressure in this range during a LOCA, a break size of 6 inches in diameter or greater is required. There is no possible break of this size that may be isolated. This break size is large enough, with substantial margin, to remove all the core decay heat. No reliance exists for the steam generators to remove decay heat. As system pressure drops below 150 psia, accumulator tank free nitrogen begins to enter the RCS. With a break of this size, most of the nitrogen will be swept out of the RCS through the break. Some nitrogen may partially fill the steam generator tubes, but this will have no effect since the steam generators are not removing heat from the system, and are likely to be a heat source to the primary at this time. Also in this range of RCS pressure, pumped safety injection flow increases dramatically due to the introduction of the low head safety injection pumps to assure that the core will remain in a flooded condition.

Response to B.3

WCAP-9600 presented small break behavior characteristics for a range of break sizes. It was demonstrated that a long term stable condition is established for all break sizes in which RCS pressure stabilizes, and decay heat removal mechanisms are assured. The break size and SIS characteristics that exist for the plant determine the stable RCS pressure and volume of non-condensibles that may form at the upper elevations in the RCS. The long term stable mode of energy removal will be established, with the presence of a realistic amount of non-condensibles. Section 5 of WCAP-9600 contains descriptions of various scenarios with non-condensibles present.

TABLE B.1-1

TEST CONDITIONS AND PRIMARY SIDE CONDENSATION COEFFICIENTS

Case	Test	Secondary Pressure PSS (psia)	Secondary Temperature TSS (^{o}F)	Primary Pressure PPRIM (psia)	Primary Temperature TPRIM (^{o}F)	Steam Flux GS (lbm/tube-hr)	Primary Side Condensation Heat Transfer Coefficient HC (BTU/hr-ft^{2}-^{o}F)

a,c

TABLE B.1-1 (sheet 2)

Case	Test	Secondary Pressure PSS (psia)	Secondary Temperature TSS (^oF)	Primary Pressure PPRIM (psia)	Primary Temperature TPRIM (^oF)	Steam Flux GS (lbm/tube-hr)	Primary Side Condensation Heat Transfer Coefficient HC (BTU/hr-ft^2-^oF)

a,c

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TABLE B.1-1 (sheet 3)

Case	Test	Secondary Pressure PSS (psia)	Secondary Temperature TSS (^oF)	Primary Pressure PPRIM (psia)	Primary Temperature TPRIM (^oF)	Steam Flux GS (lbm/tube-hr)	Primary Side Condensation Heat Transfer Coefficient HC (BTU/hr-ft^2 - ^oF)

a,c

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TABLE B.1-2

COMPARISON OF TEST AND CALCULATED HEAT TRANSFER COEFFICIENTS

a,c

I	Test	HC (Btu/hr-ft^2-^{o}F)	HNU (Btu/hr-ft^2-^{o}F)	HC/HNU
1	824			
2	835			
3	836			
4	825			
5	827			
6	826			
7	1099			
8	1024			
9	1026			
10	1034			
11	1033			
12	1025			
13	1098			
14	1036			
15	1035			
16	1037			
17	1097			
18	1039			
19	1016			
20	1027			
21	1038			
22	1047			
23	1095			
24	890			
25	891			
26	892			
27	9593			
28	9594			
29	9595			
30	9590			
31	1193			
32	1194			
33	1190			
34	1191			
35	1192			

HC = Test condensation coefficient
HNU = Analytical model condensation coefficient

TABLE B.1-2 (Sheet 2)

a,c

I	Test	HC (Btu/hr-ft^2-^{o}F)	HNU (Btu/hr-ft^2-^{o}F)	HC/HNU
36	850			
37	851			
38	852			
39	899			
40	853			
41	854			
42	855			
43	856			
44	857			
45	858			
46	859			
47	860			
48	8520			
49	1860			
50	861			
51	862			
52	8620			
53	863			
54	864			
55	865			
56	866			
57	867			
58	868			
59	869			
60	9550			
61	9551			
62	9552			
63	9553			
64	9554			
65	9555			
66	9556			
67	9557			
68	9558			
69	9559			
70	9560			

HC = Test condensation coefficient
HNU = Analytical model condensation coefficient

TABLE B.1-2 (Sheet 3)

I	Test	HC (Btu/hr-ft^2-^{o}F)	HNU (Btu/hr-ft^2-^{o}F)	HC/HNU
71	9561			
72	9562			
73	9563			
74	9564			
75	9565			
76	9566			
77	9567			
78	9568			
79	9569			
80	1150			
81	1151			
82	1152			
83	1153			
84	1154			
85	1155			
86	1156			
87	1157			
88	1158			
89	1159			
90	1160			
91	116[illegible]			
92	1163			
93	1164			
94	1165			
95	1166			
96	1167			
97	1168			
98	1169			

a,c

HC = Test condensation coefficient
HNU = Analytical model condensation coefficient

TABLE B.1-3

COMPARISON OF OVERALL HEAT TRANSFER COEFFICIENTS

$U = f\,(T_{primary}, T_{secondary})$ in Btu/hr-ft^2-^oF

U (Btu/hr-ft^2-^oF)	$T_{secondary}$ (^oF) 320	350	400	450	500	550
$T_{primary}$ (^oF)						
350						
400						
450						
500						
550						
600						

a,c

*WFLASH

**Calculated using methodology in reference 1.

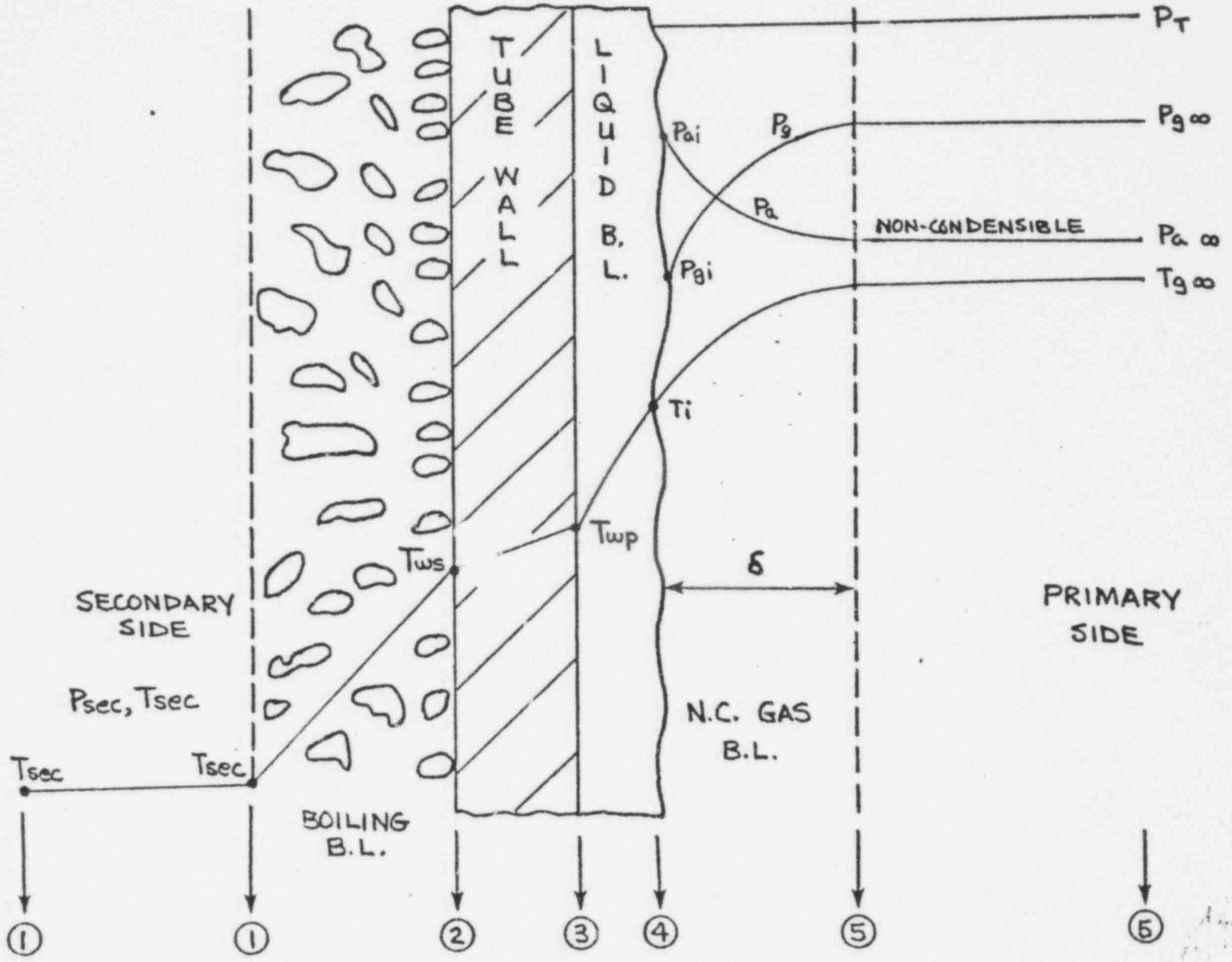


Figure B.1-1 Schematic of Reflux Condensation

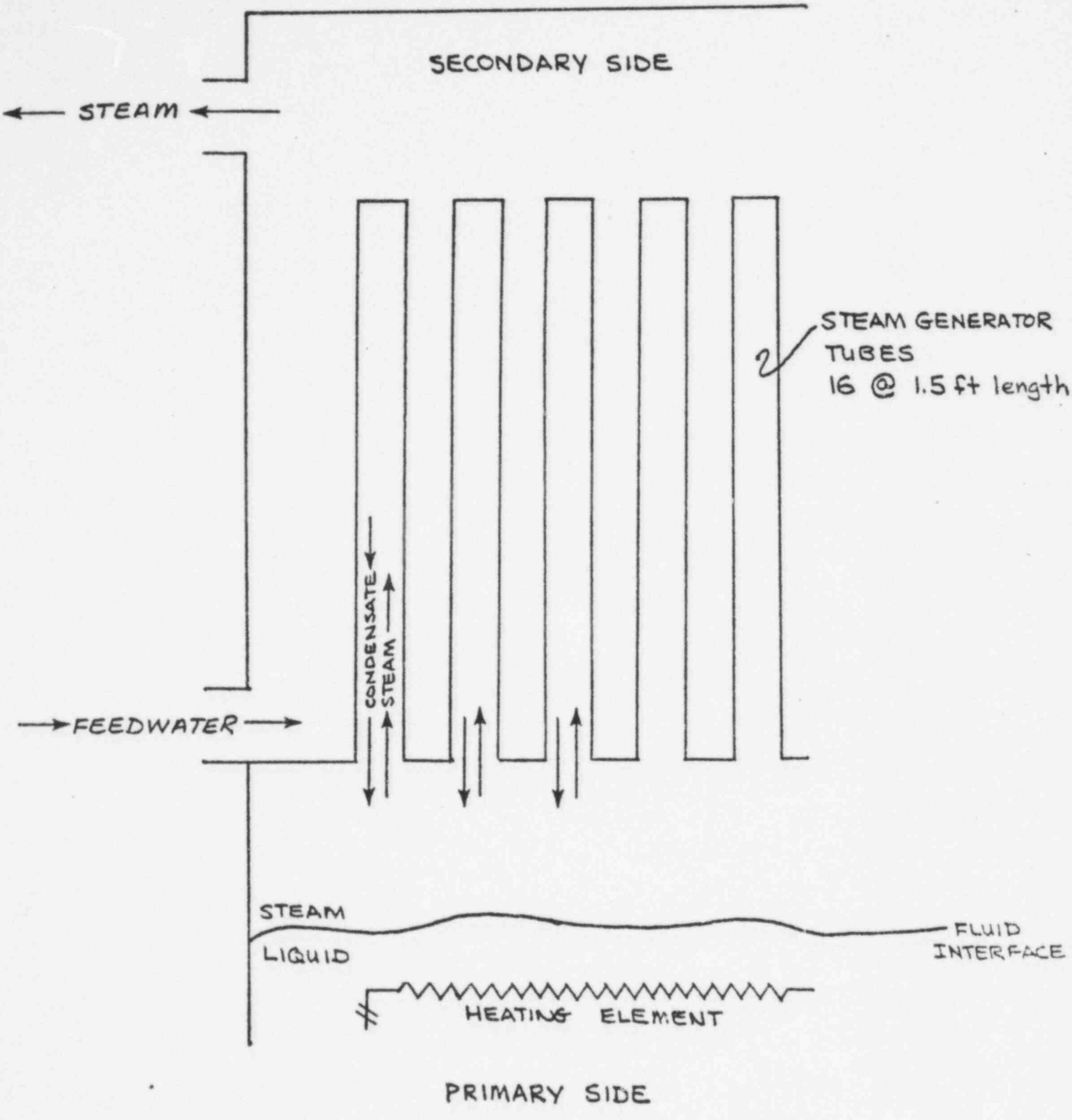


Figure B.1-2 Schematic of R&D Test Facility

C. Audit Calculations

1. Considering the analysis of a 4.0-inch diameter pipe break in a 4-loop PWR, provide the results of an assessment of the impact on the transient of allowing SI and accumulator injection into the broken loop node upstream of the break. Discuss how the system response would change under the above assumption for the 0.5-inch and 1.0-inch diameter pipe breaks.

2. For the analysis of a 4.0-inch diameter pipe break in a 4-loop PWR, plots of certain steam generator parameters were provided for the broken loop. Provide plots of the same parameters for the steam generator in the intact loop.

3. For the analysis of a 0.5-inch diameter pipe break in a 4-loop PWR, provide results of an assessment of numerical instability of the core volumetric heat rate input. Include in this assessment the impact on reactor trip, reactor coolant system pressure, and steam generator water level. Provide the results of an assessment of the same behavior for the 1.0-inch and 4.0-inch diameter breaks.

Response to C.1

The effect of allowing pumped SI into the broken loop upstream of the break has been assessed. Analysis was not performed because it would not be appropriate to model a break path and a subcooled SI path in a single WFLASH control volume that assumes thermodynamic equilibrium. The following discussion is provided to respond to the question and document an earlier conversation with members of the NRC staff. For the 4-inch cold leg break, the main impact of inclusion of broken loop SI is during the time period of core uncovery, at which time all steam flow is present in the broken loop cold leg. Prior to this time, the RCS is draining, and the cold leg is filled with subcooled liquid. The inclusion of the broken loop SI during this draining period would have a small effect on the transient.

The time of first core uncovery may be delayed by an insignificant amount due to the contribution of this SI to the primary liquid inventory. In order to evaluate the effect of the additional subcooled SI during the core uncovery period for the 4-inch break, two effects of the SI introduction on break flow must be considered. The first effect is local depressurization due to condensation, which by itself, would reduce the break flow. However, results from the Westinghouse steam-water mixing tests indicate that with the small amount of pumped SI available, approximately 15 to 25 lb/sec in this pressure range, there would be a negligible effect on downstream pressure due to condensation. The second effect present is due to the mixing of the subcooled SI flow with passing steam. Condensation of steam to saturated liquid will occur, and this liquid along with steam will be discharged out the break as a two phase mixture. A scoping calculation was performed to better quantify the net change in steam removed from the RCS through this process as compared with all steam flow existing when this source of SI is ignored. In order to maximize the impact on break flow, the calculation was performed at a pressure just above the accumulator setpoint, since break flow is minimized and SI flow maximized, as compared to higher pressures that may exist during the uncovery period. This calculation indicated that approximately all the SI liquid injected will be discharged, and about 3.5 percent additional total steam will be removed from the break. This slight increase in steam flow rate will make the transient appear as a slightly larger break size transient beginning from the time of core uncovery.

For the 4-inch break size considered, the cold leg accumulators inject and rapidly recover the core and turnaround the PCT. If broken loop accumulator flow was assumed to enter the broken loop cold leg, some additional water would flow to the downcomer, since the break cannot instantaneously remove all the liquid. However, since the recovery process for the 4-inch break by the intact loop accumulators is so rapid, the inclusion of broken loop accumulator flow would not have a significant effect on the calculated PCT.

Similar assessment of the impact of broken loop SI and accumulator flows on 0.5-inch and 1.0-inch break transients was also performed. As discussed in WCAP-9600, for breaks in this range of size, no core uncovery occurs, and the RCS pressure stabilizes at the pressure where the pumped SI equals the subcooled liquid break discharge. No RCS drain occurs, and the SI mixes with liquid in the cold leg. If broken loop pumped SI was included in the analysis, the major effect on the transient would be to shift the equilibrium pressure to a higher level. No core uncovery is expected. For breaks of this size, the RCS stabilizes at a pressure well above the accumulator backpressure, therefore, for these transients, inclusion of the broken loop accumulator has no effect.

Response to C.2

Figures C.1-1 through C.1-15 present the plots for the intact loop steam generators for the 4.0-inch cold leg break reported as Case F in Section 3.1 of WCAP-9600.

Response to C.3

As was discussed verbally with the NRC, an upward roundoff of initial core volumetric heat rate input existed in the 0.5-inch diameter break analyzed as Case A in Section 3.1 of WCAP-9600. This slight mismatch in core heat generation and secondary side heat removal caused certain unrealistic trends in the analysis results presented. Specifically, a slight RCS repressurization, steam generator pressurization, and steam generator secondary side mixture level decrease occurred in the first 3500 seconds in the transient prior to the reactor trip time. The effect of this slight inconsistency would have no impact on core uncovery; no core uncovery would be expected. However, if a perfect heat balance was established initially, the RCS pressure would not increase, and a slowly decreasing trend would exist and result in reactor trip earlier in the transient than predicted in Case A. Secondary side pressure would remain constant or decrease slightly prior to trip, rather than increase to the safety valve setpoint early in the transient. Nevertheless, even with incorporation of the corrected initial core power, the secondary pressure will rise to the safety valve setpoint immediately after RCS trip since the steam generator is isolated at reactor trip time in FSAR type analysis due to a loss of offsite power assumption.

Similarly, the steam generator secondary level will remain constant, rather than decrease as in Case A. This will result in higher levels of secondary mixture prior to and after reactor trip, providing better heat removal capability. In general, since the upward roundoff of the initial core heat rate increases heat generation and decreases heat removal capability, it is conservative from an overall heat balance respect.

Similar effects would be expected to occur on a 1.0-inch break transient, but to a lesser extent, because of an earlier reactor trip time due to an increased depressurization rate. After reactor trip occurs, the direct effects of the initialization problem disappear since core power goes to decay heat, and the steam generator secondary steam flow is shut down due to loss of offsite power.

For the 4.0-inch cold leg break analyzed in WCAP-9600, RCS depressurization occurs rapidly due to the larger break, and no RCS repressurization is seen by the results. For these break sizes the reactor trips very early in the transient, and the initial power mismatch between core and secondary has a negligible impact on the calculated transient. Any insignificant effects that do occur tend to overpredict the energy released by the core and stored in the primary fluid, and thus is conservative.

For runs performed in the future, especially very small breaks less than 1.0-inch in diameter, or breaks analyzed to be utilized for operator training, more attention will be paid to the initial energy balance, and more realistic steady state runs will be made with the input decks.

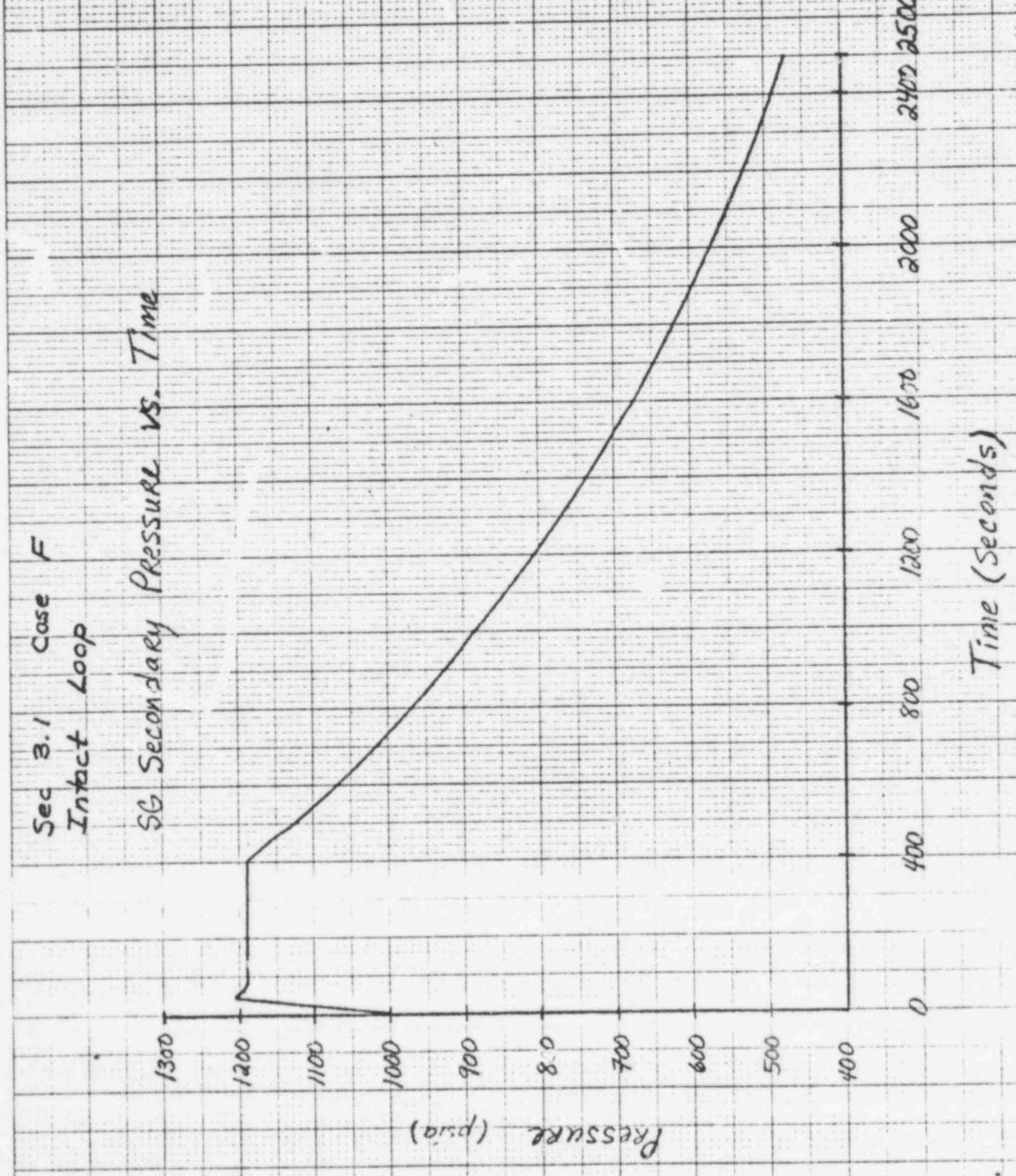

Sec 3.1 Case F
Intact Loop
SG Secondary Pressure vs. Time
Pressure (psia)
1300
1200
1100
1000
900
800
700
600
500
400
Time (Seconds)
0
400
800
1200
1600
2000
2400
2500

Figure C.1-1

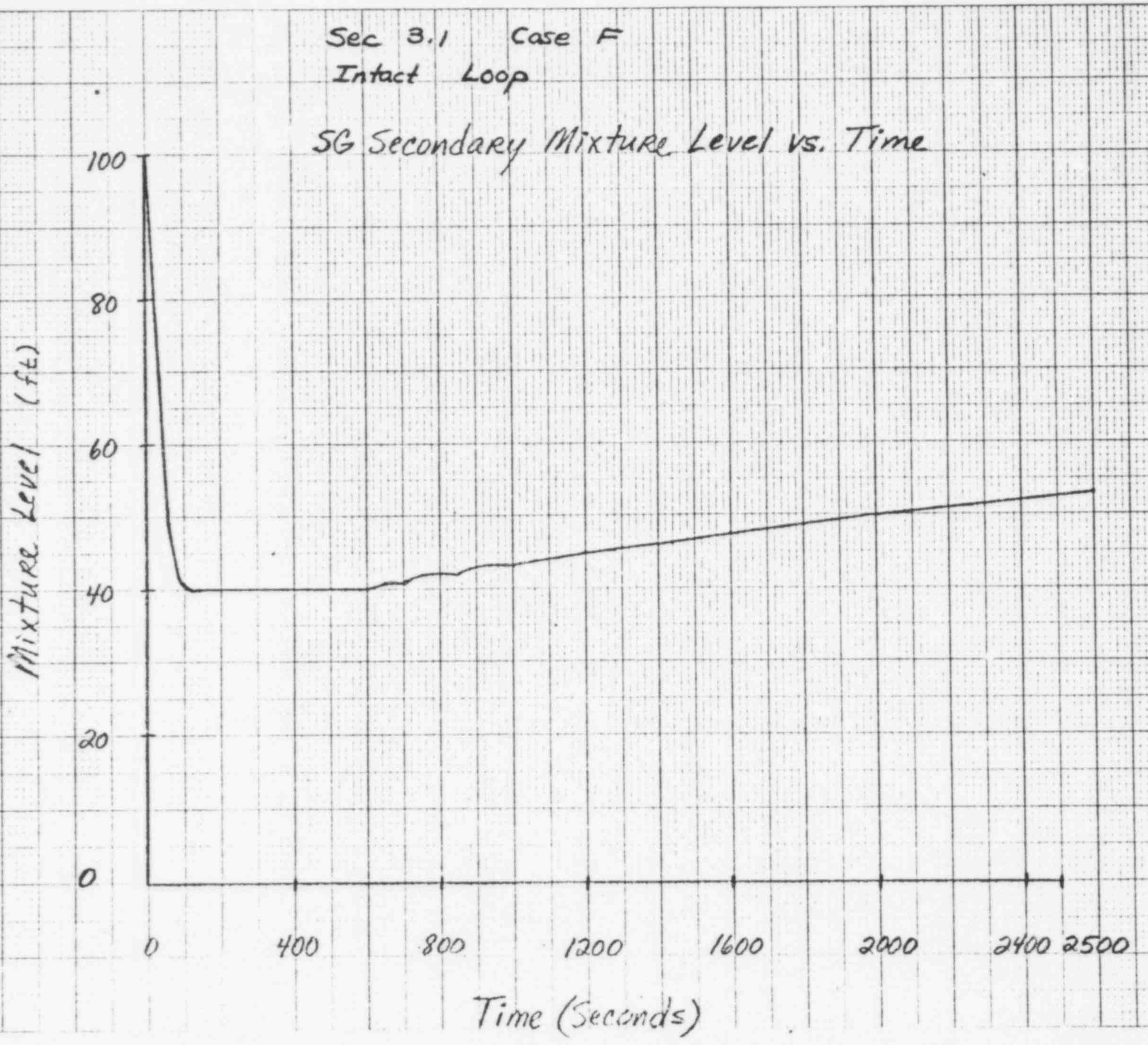

Sec 3.1 Case F
Intact Loop
SG Secondary Mixture Level vs. Time
Mixture Level (ft)
100
80
60
40
20
0
0
400
800
1200
1600
2000
2400
2500
Time (Seconds)

Figure C.1-2

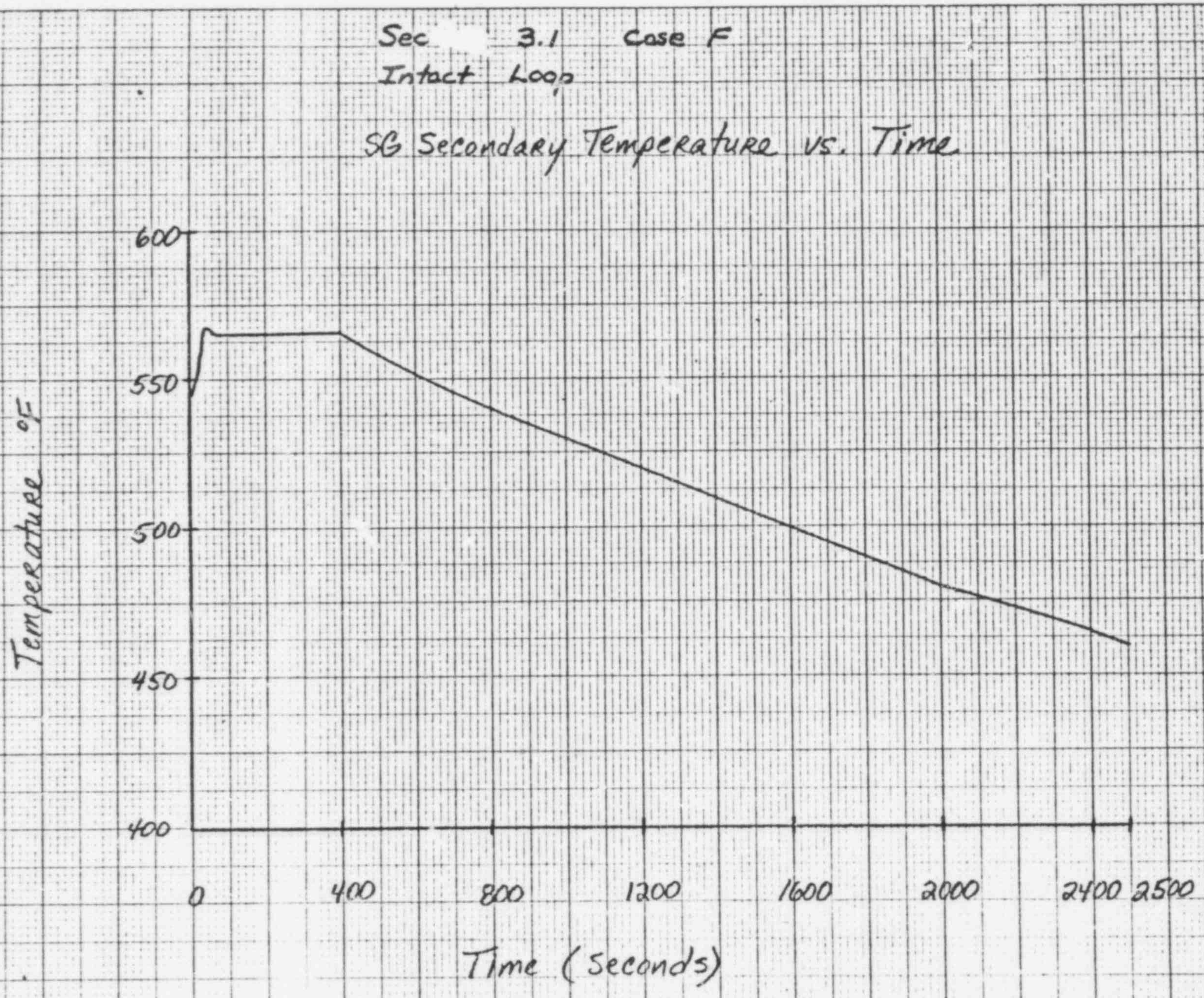

Sec 3.1 Case F
Intact Loop
SG Secondary Temperature vs. Time
600
550
500
450
400
Temperature °F
0
400
800
1200
1600
2000
2400
2500
Time (Seconds)

Figure C.1-3

POOR ORIGINAL

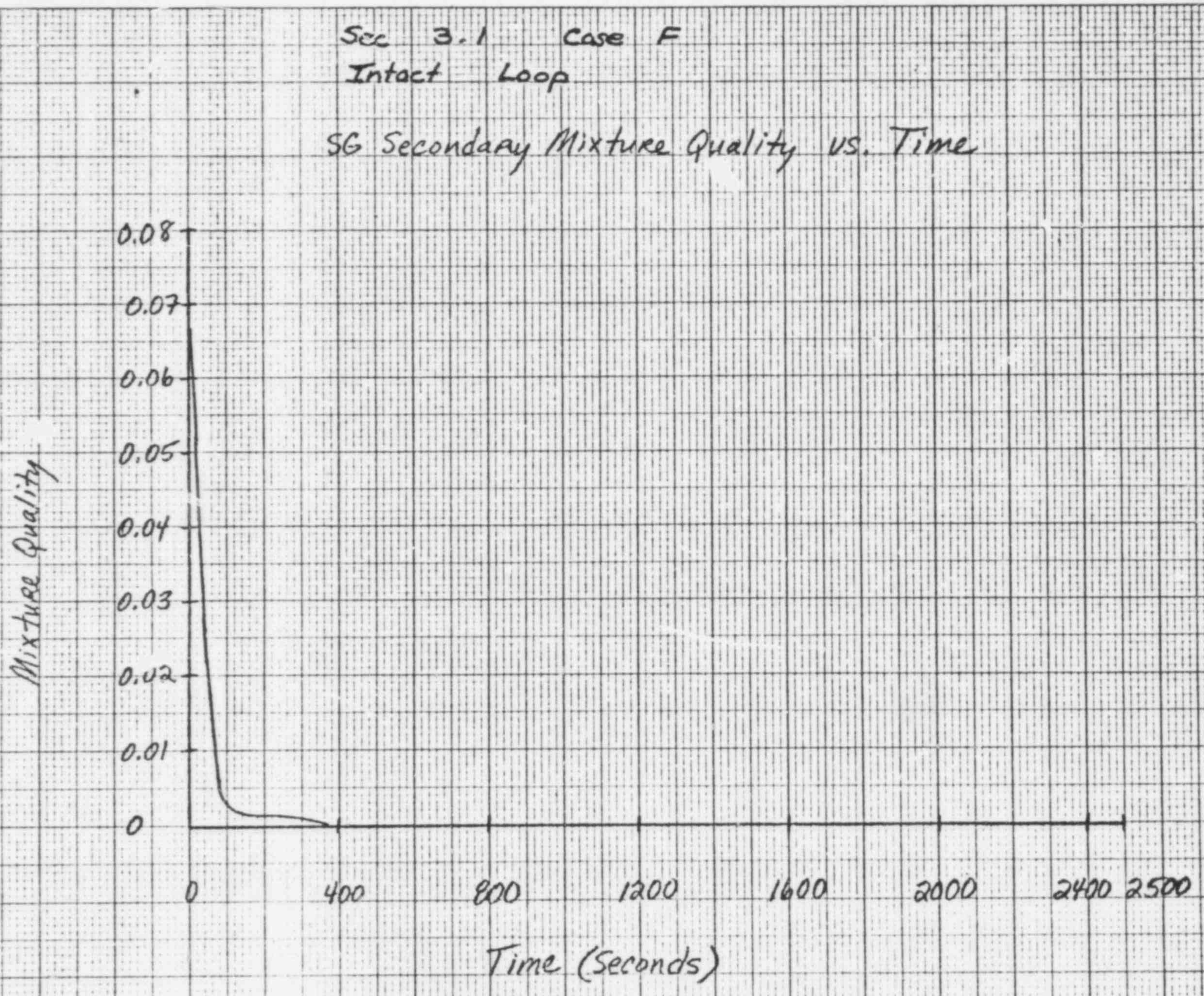


Figure C.1-4

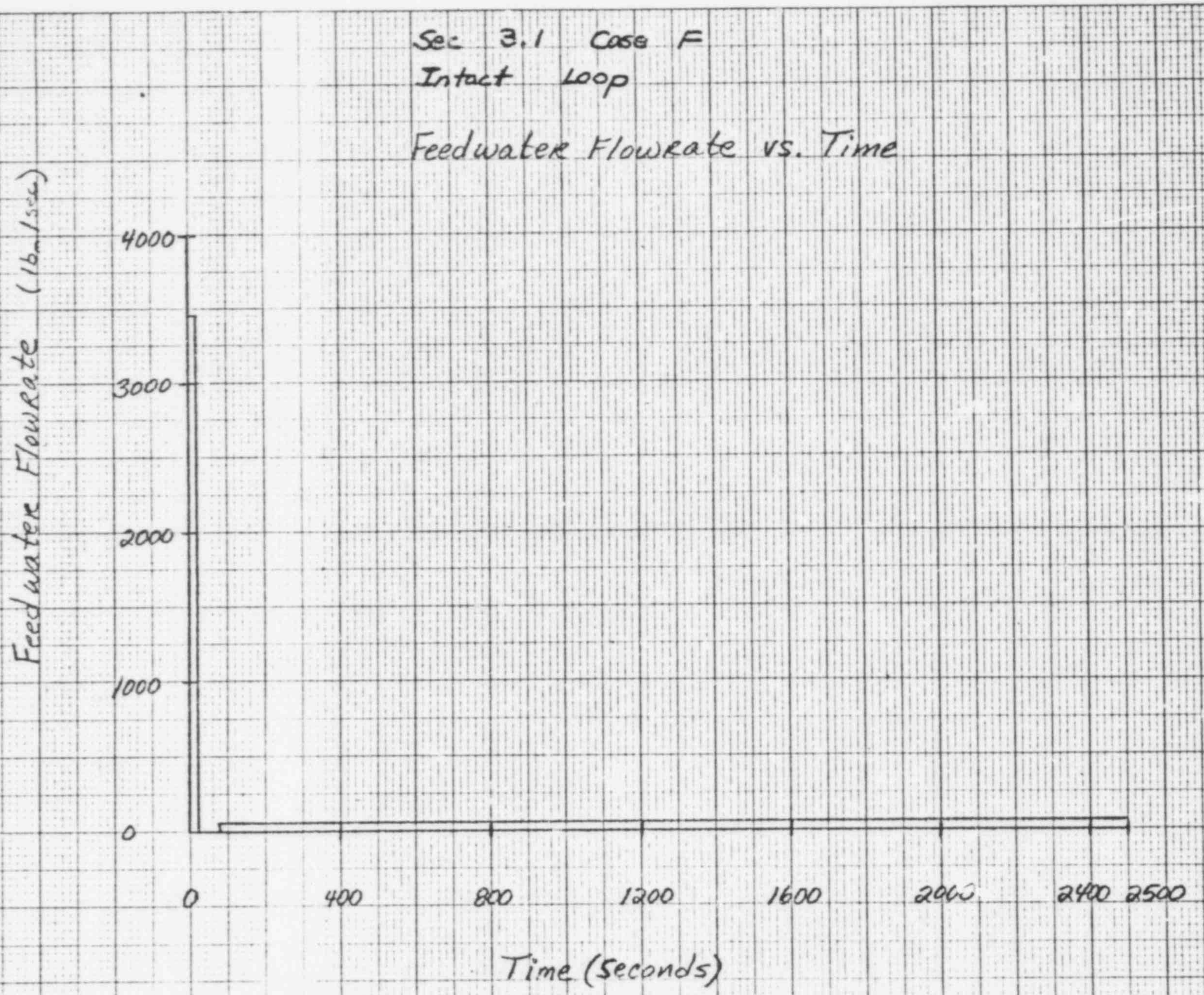

Sec 3.1 Case F
Intact Loop
Feedwater Flowrate vs. Time
Feedwater Flowrate (lbm/sec)
4000
3000
2000
1000
0
0
400
800
1200
1600
2000
2400
2500
Time (Seconds)

Figure C.1-5

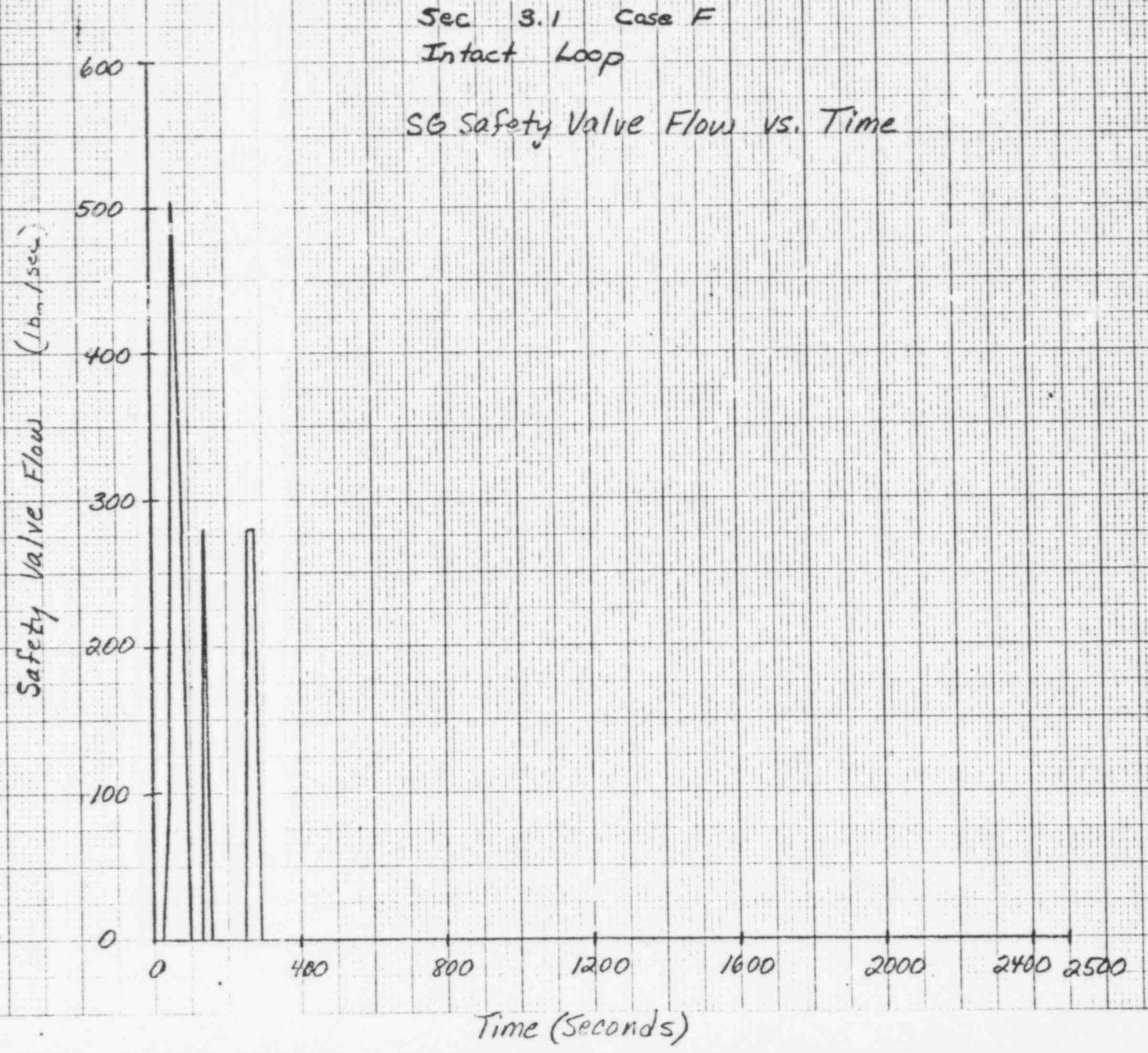

Sec 3.1 Case F
Intact Loop
SG Safety Valve Flow vs. Time
Safety Valve Flow (lbm/sec)
600
500
400
300
200
100
0
0
400
800
1200
1600
2000
2400
2500
Time (Seconds)

Figure C.1-6

POOR ORIGINAL

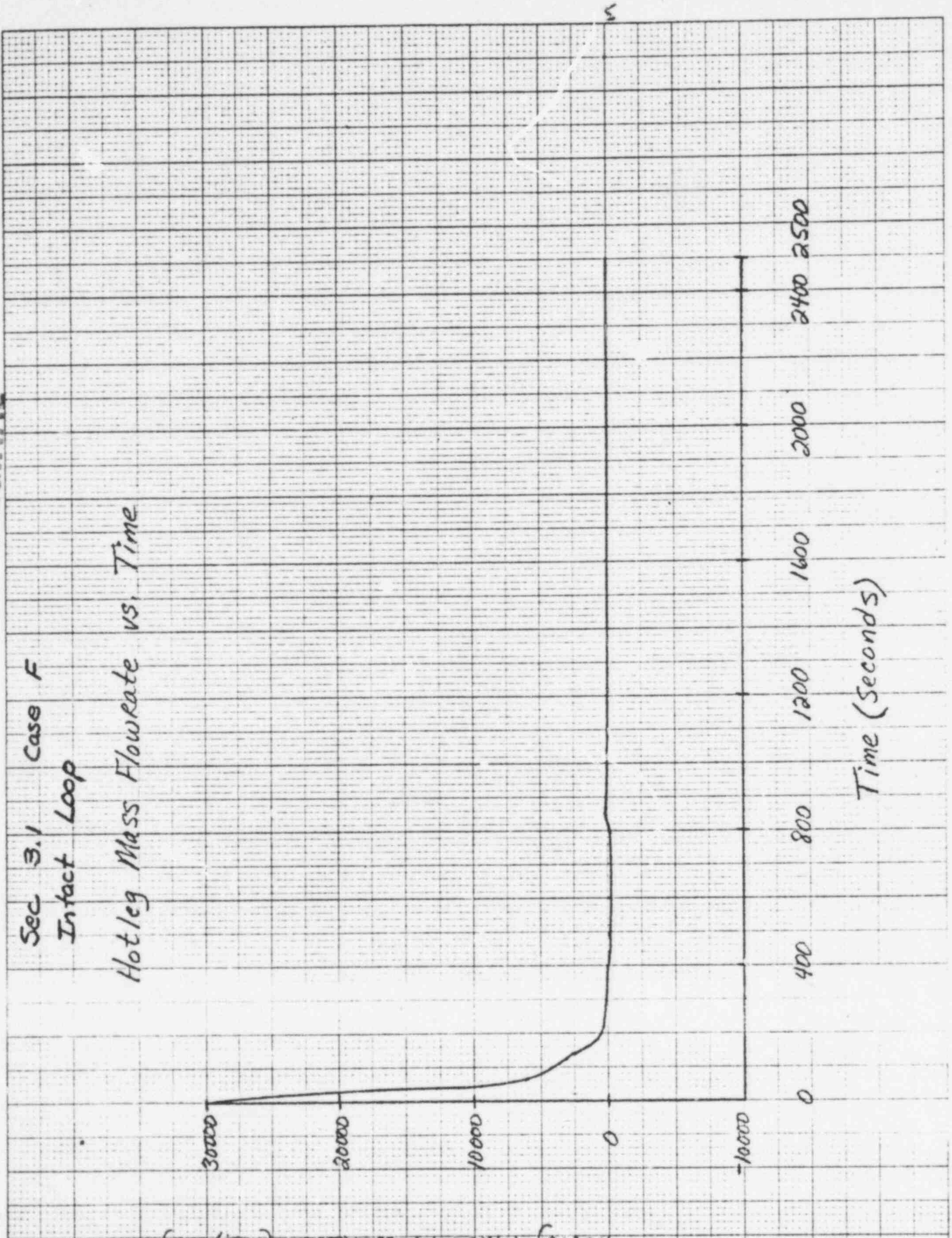


Figure C.1-7

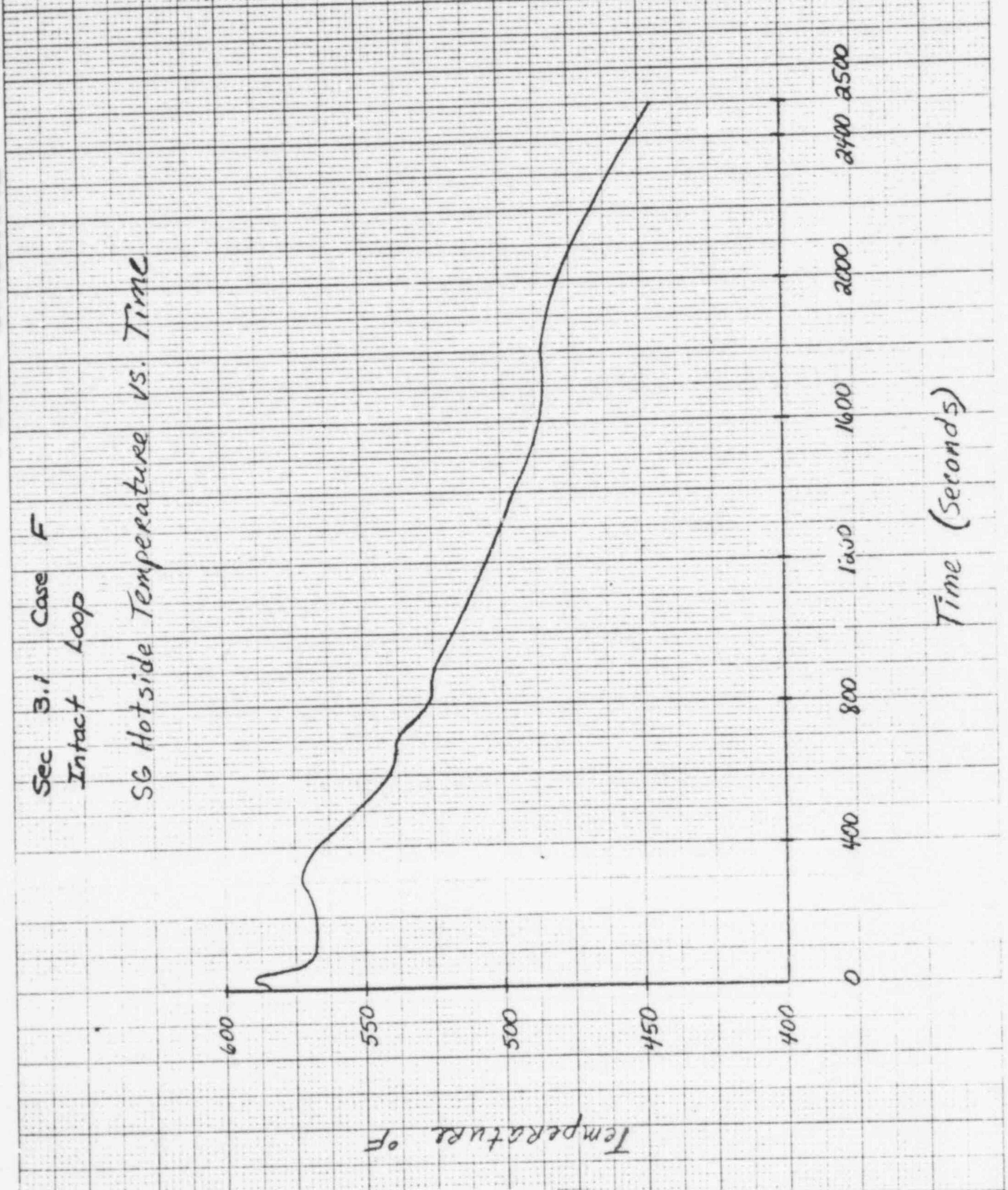
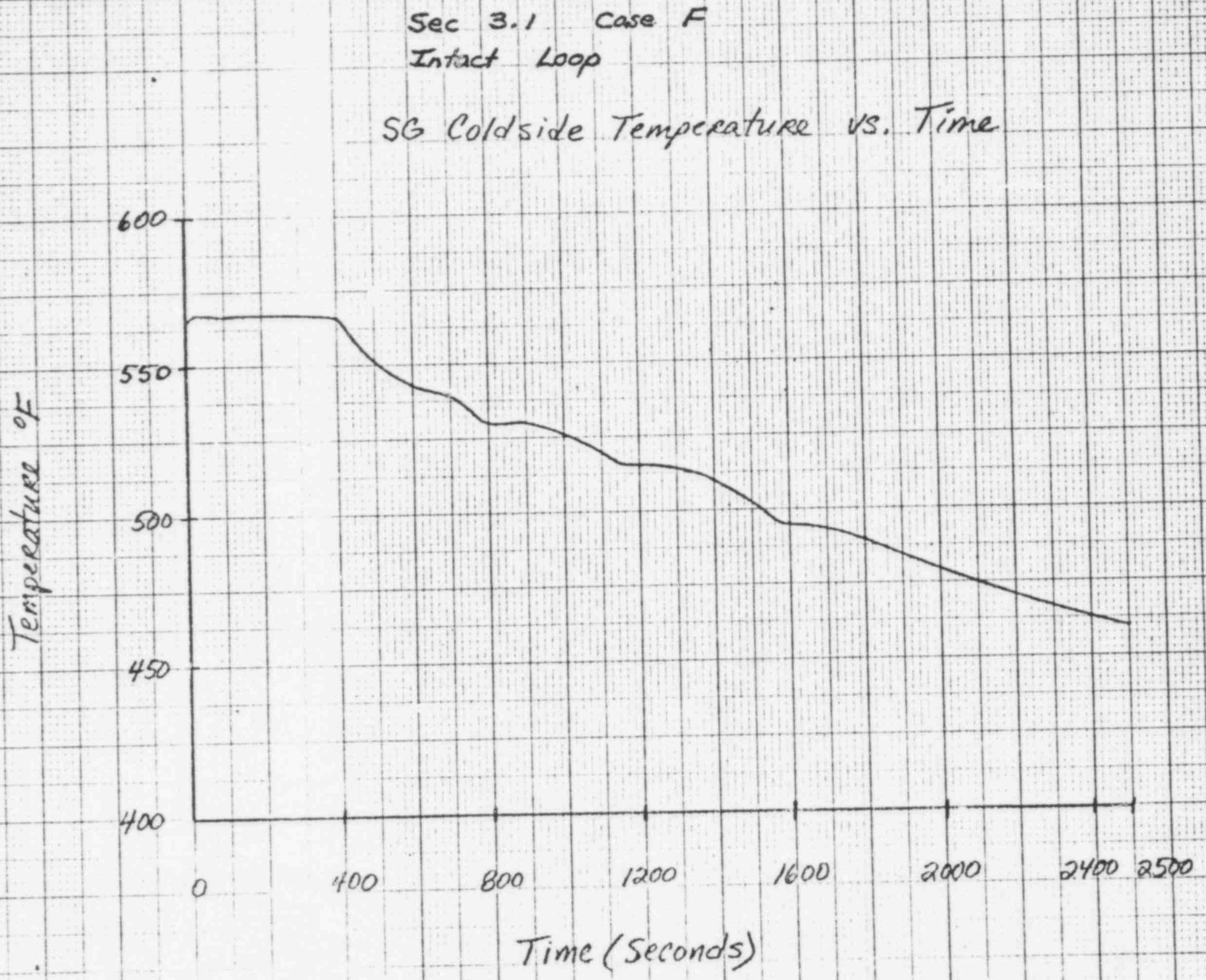

Sec 3.1 Case F
Intact Loop
SG Hotside Temperature vs. Time
0
400
800
1200
1600
2000
2400
2500
Time (Seconds)
600
550
500
450
400
Temperature °F

Figure C.1-8

POOR ORIGINAL



Sec 3.1 Case F
Intact Loop

SG Coldside Temperature vs. Time

Figure C.1-9

POOR ORIGINAL

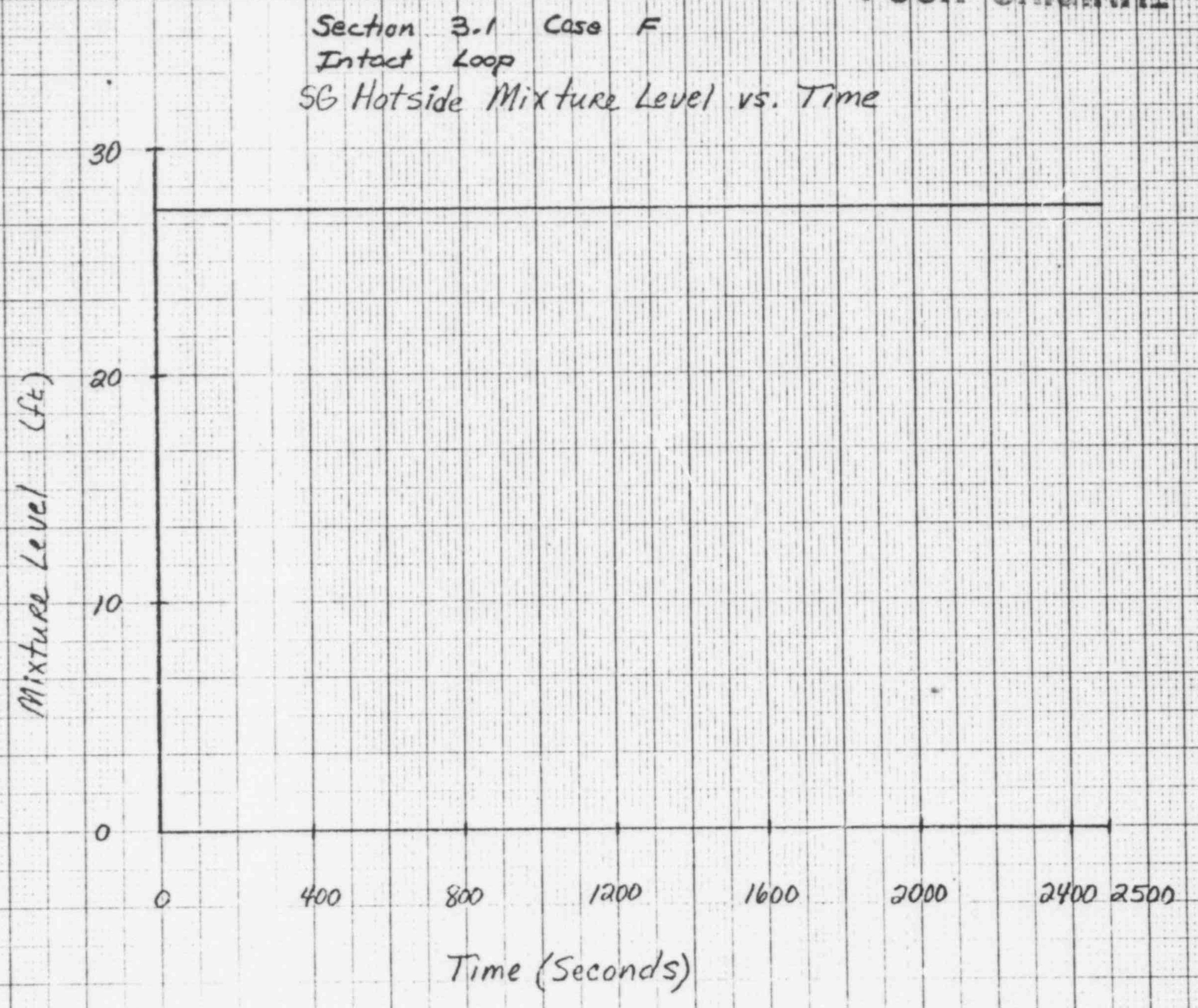


Figure C.1-10

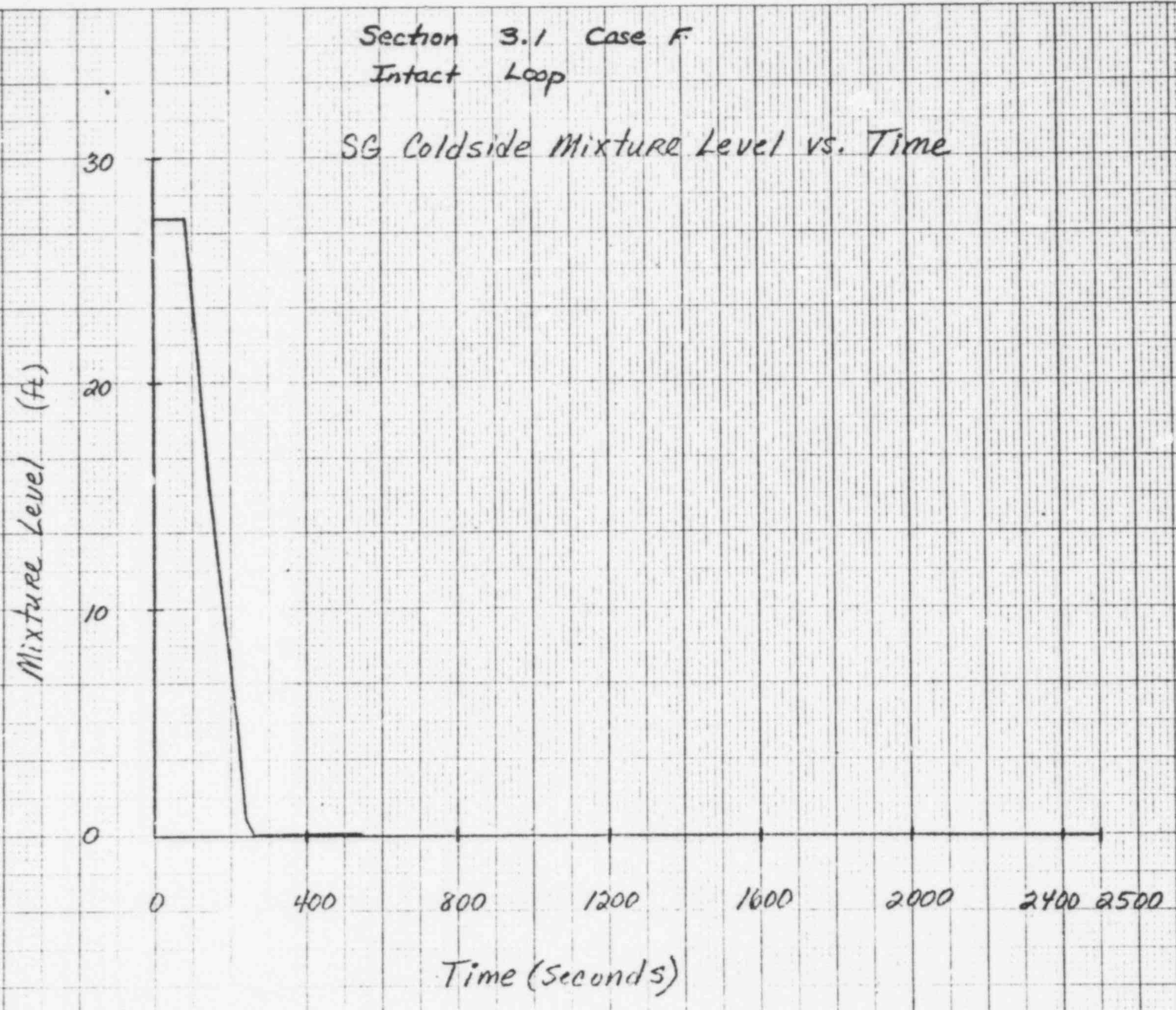

Section 3.1 Case F
Intact Loop
SG Coldside Mixture Level vs. Time
Mixture Level (ft)
30
20
10
0
0
400
800
1200
1600
2000
2400
2500
Time (Seconds)

Figure C.1-11

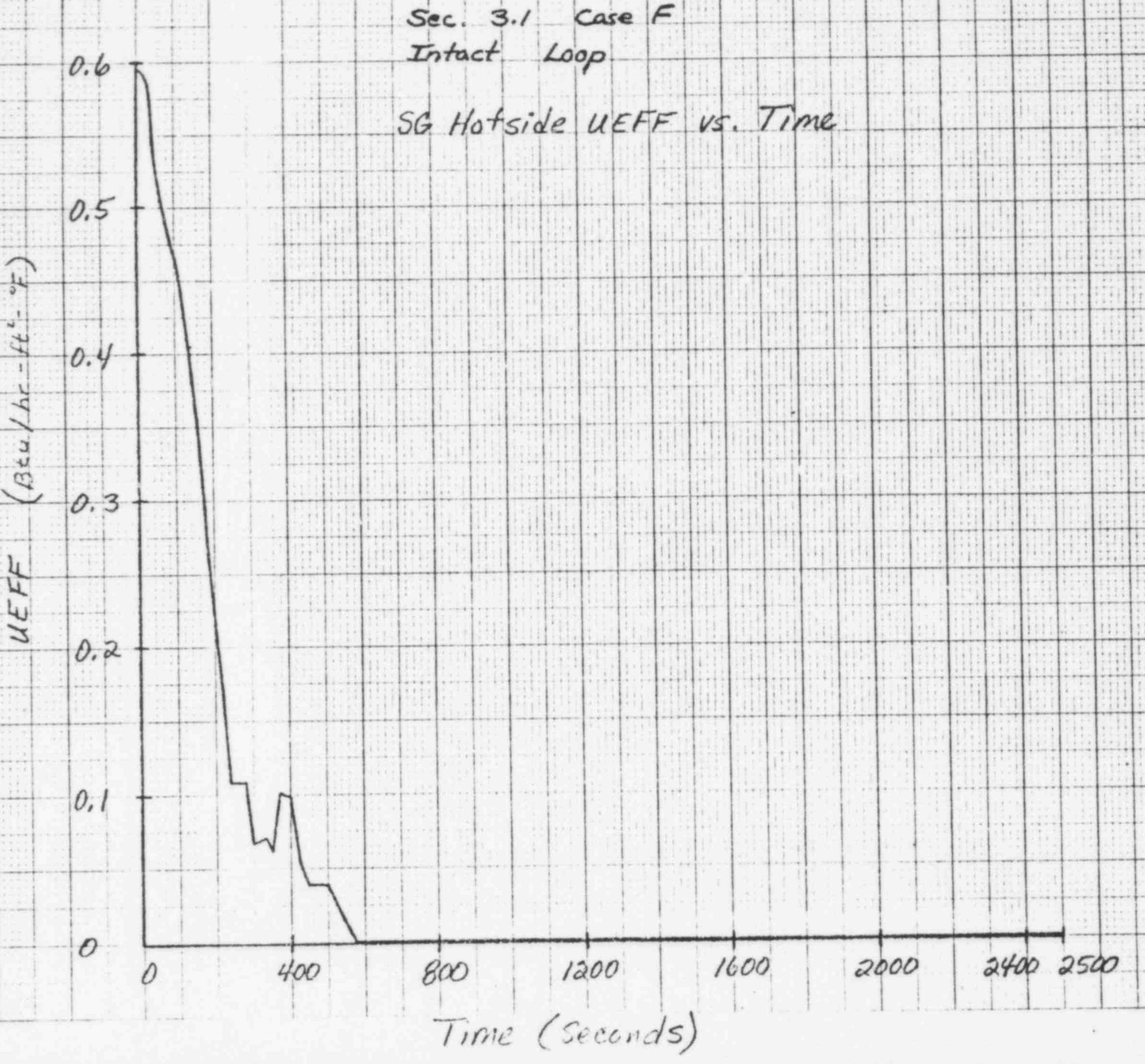

Sec. 3.1 Case F
Intact Loop
SG Hotside UEFF vs. Time
UEFF (Btu/hr-ft²-°F)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
400
800
1200
1600
2000
2400
2500
Time (Seconds)

Figure C.1-12

Sec. 3.1 Case F
Intact Loop

SG Coldside UEFF vs. Time

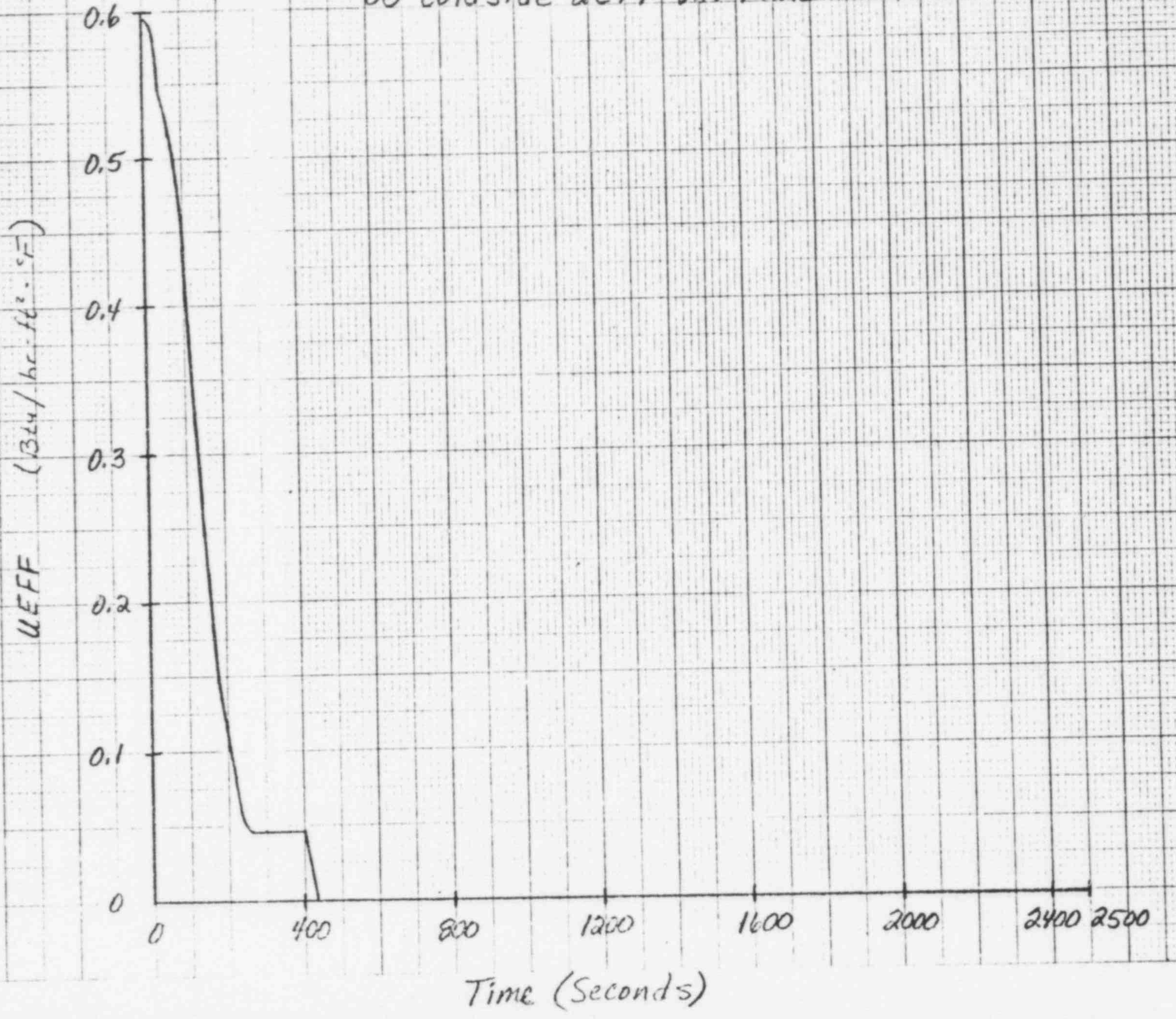


Figure C.1-13

POOR ORIGINAL

Section 3.1 Case F
Intact Loop
SG Hotside Mixture Quality vs. Time

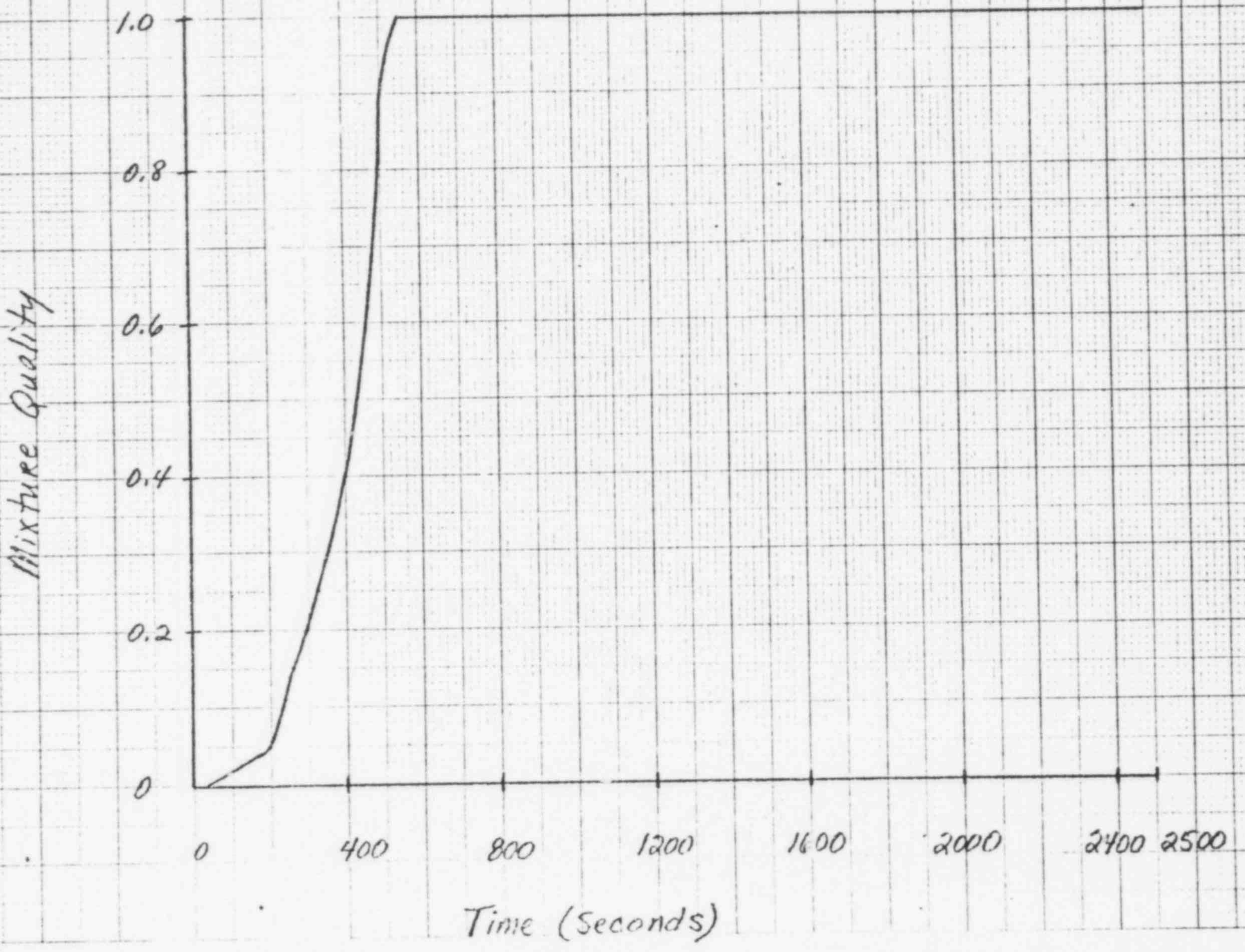


Figure C.1-14

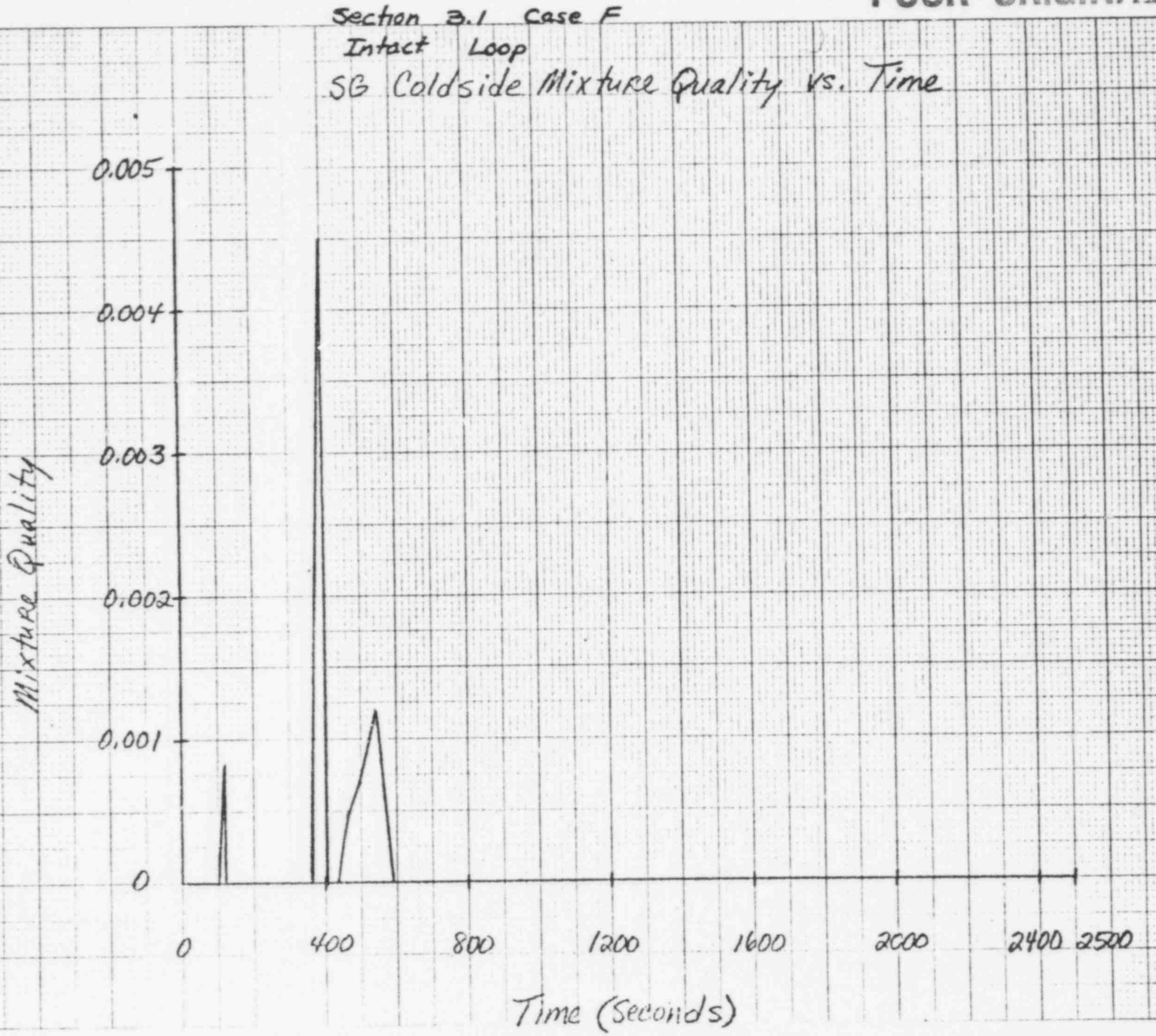

Section 3.1 Case F
Intact Loop
SG Coldside Mixture Quality vs. Time
Mixture Quality
0.005
0.004
0.003
0.002
0.001
0
0
400
800
1200
1600
2000
2400
2500
Time (Seconds)

Figure C.1-15

D. Guidelines for Operators

32. The generic guidelines are supported analytically by WCAP-9600. Provide more definitive guidance on the applicability of WCAP-9600 for reference by licensees in the form of a table of key parameters used as input to these calculations.

Response

A discussion of the applicability of each analytical section of WCAP-9600 to Westinghouse plant designs is provided below. Key input parameters are listed for those sections when appropriate.

Sections 2.2 and 2.3 - Pressurizer Modelling - These sections consider PORV break sizes ranging from one of the smaller sized valves to 3 of the larger sized valves available in Westinghouse plants. The conclusions of these sections are applicable to all plants.

Sections 2.4, 2.5, and 2.6 - Steam Generator Hydraulic and Heat Transfer Modelling - These sections represent an analytical method study which is applicable to all plant types.

Section 2.7 - Two Phase Natural Circulation - This section presents verification of evaluation model capabilities to represent two phase natural circulation and is applicable to all plants.

Section 2.8 - Break Flow Model - This study considered a range of pressures, temperatures, and qualities representative of all Westinghouse plant types.

Section 2.9 - Estimate of Non-condensibles During a Small LOCA - The sources of non-condensibles considered are typical for all plants with zircaloy fuel cladding. The calculated volume of non-condensibles per steam generator is applicable to all plant types. It is conservative for stainless steel plants.

Section 2.10 - Vessel Mixture Level - This section presents an analytical method study based on Westinghouse experimental programs utilizing conditions applicable to all plant types.

Section 3.1 - Small Break Behavior - The small break thermal and hydraulic behavior modes characterized by break size and SIS characteristics and assumptions are presented in this section. Important plant parameters are included in the text of this section. The behavior modes characterized in this section are applicable to all plant types. As stated in this section, limits of break sizes producing each characteristic behavior mode may vary from plant to plant depending on the SIS, but general characteristics and conclusions are valid for all plants.

Section 3.2 - Limiting Small Break Size and Location - A three loop plant was utilized, due to the high power rating per loop as compared to other plant types. Pertinent input parameters were included in Table 3.2-1 of WCAP-9600. The general behavior and conclusions of the limiting break approximate size and location are applicable to all plant types. Exact worst break size and PCT are determined by plant specific analysis in the FSAR.

Section 3.3 - Pressurizer Vapor Space Breaks - See the response for Sections 2.2 and 2.3; also the first paragraph of the text of Section 3.3. The results and conclusions are applicable for all plants.

Section 3.4 - High Pressure Injection Termination Criteria - The four loop plant maximum safeguards with + 10 percent of the design head added uniformly over the entire curve yields the maximum possible high head flow rates and thus the maximum limiting break size for HPI termination criteria to be met for all plant types. Therefore, this section is applicable for all plant types with safety grade charging pumps part of the SIS.

Section 4.1 - RCP Trip Study -The important plant input parameters are given in Section 3.1. The steam generator safety valve setpoint is also an important parameter, since this determines the RCS pressure at which the system will start to drain. The steam generator safety valve opening setpoint for the plant considered is 1190 psia. The steam generator safety valve opening setpoints for all plant types are less than 1250 psia. The conclusions of this section are applicable to all plant types.

Section 4.2 - Available Operator Action Time for a Full Loss of Feedwater Transient - A two loop plant was analyzed for this case. Cases with charging SI pumps (shutoff head >~1600 psia) included and not included are considered. The important input parameters of this analysis are given in the text. To evaluate the effects of minimum operator action time for other plant types the key parameters are RCS volume above the top of the core, core power rating and steam generators secondary inventory. The core power rating and the steam generator secondary inventory determine PORV opening time (due to the dryout of the secondary). The core power level and the RCS liquid inventory above the top of the core determine the core uncovery time following the PORV setpoints being reached. The ratios of these parameters are about the same for all Westinghouse plants and therefore the minimum operator action times resulting from the analysis of a specific two loop plant gives the general magnitude of time available for other plant types and power levels as well.

The effectiveness of the two operator actions simulated is expected for other plant designs.

Section 4.3 - Isolated Steam Generator Analysis - A two loop plant was chosen since isolation of a steam generator for such a plant deprives the system of 50 percent of the steam generator heat removal capability. The results are applicable to all plant designs.

1071 141

Section 4.4 - Small Break Isolation - The analysis considered the maximum size breaks that could be isolated bounding all plant types. Important plant parameters for these cases are included in Section 3.1. The conclusions are applicable for all plant types.

Section 4.5 - Challenges to PORV.

The analysis provided peak pressurizer pressure and PORV response for a typical high power density plant. Although peak pressures very slightly from plant to plant the conclusions regarding whether the PORV or safety valves open for the transients analyzed are applicable to all plant types.

ADDITIONAL NRC CONCERNS ON WCAP-9600

1. Pressurizer Drain

Section 2.3 of WCAP-9600 states that the present evaluation model representation of the surge line does not allow counter-current 2-phase flow.

During small break events in which the pressurizer is calculated to drain (e.g., closure of a stuck-open PORV), it is unclear how draining takes place since this modeling does not appear to let steam enter the pressurizer to replace the liquid draining out.

Discuss how the present model allows pressurizer draining and if it has been compared to experimental data.

Response

The pressurizer liquid drain behavior during a small break LOCA is manifested in one of two ways. For all breaks not located in the pressurizer or for situations where the RCS is being cooled down, the drain behavior is single phase, saturated or two phase co-current flow from the pressurizer to the hot leg. As the RCS looses mass to the break or contracts, the pressurizer will drain thus feeding the system in a simple mass depletion/system depressurization process. This behavior is predicted in WFLASH runs with cold leg, hot leg, and pump suction leg breaks or during cooldown transients (e.g., delayed initiation of auxiliary feedwater).

Pressurizer vapor space breaks on the other hand cause an initial swelling of the mixture level and as the upper portions of the RCS drain, steam is pulled through the surge line holding the mixture level up in the pressurizer. Unlike break locations elsewhere, the pressurizer will only drain if the break is isolated or if the break is much smaller than the area of one PORV. In such cases, there are several possible modes of two phase counter-current flow possible including: 1)non-homogeneous bubbly flow in which steam bubbles up through a draining liquid, 2) slug flow where large slugs of steam flow up through a draining liquid, 3)semi-annular flow, 4) annular flow in which the liquid drains down in a film along the walls and steam flows up through the inner portions of the pipe, and 5)chugging flow in which there are alternate periods of homogeneous liquid flow down into the RCS and homogeneous steam flow up into the pressurizer vapor space.

The WFLASH ECCS evaluation model does not represent the surge line as a two phase counter-current flow path. This however does not pose a problem for the WFLASH analysis of pressurizer steam space breaks because the code will adequately model surge line flow and the pressurizer water is not important to keeping the core cooled. In the case analyzed in Section 4.4 of WCAP-9600, the vapor space break is isolated after major draining of the RCS leaves the surge line filled with steam and a certain liquid level in the pressurizer. Subsequently steam would be expected to flow up into the pressurizer until an equilibrium is reached. The draining by one of the previously mentioned two phase counter-current flow processes will occur.

WFLASH is forced to predict the chugging flow type of drain to occur because the surge line is modelled as a simple flow path rather than a counter-current flow path. Analysis performed in Section 4.4 of WCAP-9600 indicate that the initial flow to the pressurizer after break isolation remains as steam flow for about 2 minutes as the pressures equilibriate. Then there are periods of alternating steam flow into and liquid flow out of the pressurizer.

Simple drift flux calculations have been performed indicating that for breaks in the pressurizer vapor space less than .86 inches in diameters, counter-current flow can occur in the pressurizer surge line. This was reported in WCAP-9600, Section 2. Thus if a stuck open PORV is isolated, draining can be expected.

The pressurizer surge line screen is not calculated to impede the draining process. Steam bubbles in the screen holes provide resistance to draining but have an associated maximum Δp of 0.02 psi due to surface tension. The screen itself has a static pressure head of 0.5 psi from the top of the hemisphere to the base. Therefore, the extra resistance due to the screen is small and it is impossible for the entire screen to be in equilibrium at the same time such that no flow is occurring. Probably liquid will drain through the peripheral holes and steam will flow up through the center holes.

Even if one assumes that the pressurizer does not drain after the stuck open PORV is isolated, this will not lead to inadequate core cooling. The ECCS is now adding water to the system and there is no break. The core will remain covered in the case reported in Section 4.4 of WCAP-9600.

2. Level Calculation (Verification)

According to Section 2.10 of WCAP-9600, verification of the drift velocity correlation was demonstrated by comparing the overall level model (which utilizes the drift velocity correlation) to the tests from which the correlation was derived. This does not appear to be a valid verification method due to a lack of independence. Has the level model been compared against data other than that from which it was derived?

Response

The level model in WFLASH has not been compared against data other than the Westinghouse Uncovery Tests data. However, this is true of many other mathematical models which are part of the LOCA evaluation models for all vendors. For example, the reflood heat transfer correlation is derived from the FLECHT tests; the two phase pump model used by most vendors in their original Appendix K computer codes were derived from the ANC steam/water pump test data; the fuel rod burst and blockage models were derived from the Westinghouse Single-Rod and Multi-Rod Burst Tests, respectively; etc. 10CFR50.46 encourages the use of new experimental data to improve ECCS models and it is felt that all of the above examples including the level model in WFLASH meet the intent of the rule.

3. Level Calculation (Drift Velocity)

Provide additional information regarding the drift velocity correlation and its applicability over the indicated pressure range.

Response

As discussed in WCAP-9600, the drift velocity, Vgj, was correlated as a function of pressure from the Westinghouse Core Uncovery Tests. The test data between 400 and 1200 psia was used to derive the correlation. This is the interesting range of pressure, since above 1200 psia the system still has not drained and below 600 psia the accumulators are injecting leading to rapid recovery of the core.