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DYNAMIC PERFORMANCE OF THE PRESSURIZER
DURING REACTOR TRIPS AT DAVIS BESSE 1

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Q.A. Statement

The information contained in this report, and the calculations supporting this request have been checked for accuracy and completeness.

RMHarrington 9/1/78
Signature Date

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Approved: [signature]
Control Analysis Manager

7909190463

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INTRODUCTION

A concern exists with NRC (Region 3) that the pressurizer will empty completely during a reactor trip from full power with simultaneous loss of station power. This premise is founded upon actual pressurizer performance recorded during several reactor trip transients at Davis-Besse 1. The reactor trip transients have occurred at partial power levels with either all RC pumps running or all four RC pumps tripped.

The extent of reactor coolant volume contraction following a reactor trip is primarily governed by the wetted surface area of the tube bundle and by the steam pressure maintained within both Once Through Steam Generators. It is also affected by the flowrate of reactor coolant through both steam generators, that is, all pumps running versus all pumps tripped.

An effort to properly adjust the blowdown on all the main steam safety relief valves has been performed by Toledo Edison Company at the Davis-Besse 1 plant early in 1978. The values of minimum steam pressure after a recent reactor trip transient indicate that the performance of the steam pressure relief system is greatly improved over that observed during earlier reactor trip transients.

The purpose of this report will be to develop a calculational technique for predicting minimum pressurizer levels following a reactor trip transient and account for either tripped or running RC pumps. Actual reactor trip transient test data from Davis-Besse 1 will be used to support the calculational technique. A second purpose will be to predict the minimum pressurizer level that will occur for two specific reactor trip transients and to disclose values of minimum steam pressure that will cause the pressurizer to become empty for these two transients.

SUMMARY

A calculational technique has been developed for predicting changes in pressurizer level during reactor trips which agrees very well with observed reactor trip transients at Davis-Besse 1.

The method has been used to predict the final minimum pressurizer level for two possible transients (both from 100% power): a reactor trip with simultaneous trip of all RC pumps, and a manual trip of the reactor with all RC pumps operating.

For the first transient above, the pressurizer level will decrease only 100 inches, provided that steam pressure will not decrease below 950 psig. If steam pressure decreases to 700 psig the pressurizer would become empty and could cause a steam bubble to enter into the hot leg piping.

For the manual trip of the reactor transient, the pressurizer level will decrease below the lower level tap when steam pressure drops to 950 psig. Since a minimum steam pressure of 980 psig is anticipated on future reactor trip transients, the predicted minimum pressurizer level will be a few inches above the zero indication and nearly 80 inches above the bottom of the pressurizer. If steam pressure decreases to 840 psig on this transient, then the water level would drop completely to the bottom of the pressurizer.

The maximum filling rate for the Once Through Steam Generators should be only 850 gpm rather than the 1200 gpm rate determined from the November 29, 1977 test data. In order to maintain steam generator pressure above 800 psig and prevent possible emptying of the pressurizer during the loss of RC pump-reactor trip transient, the rate

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of fill must be controlled by the Operator using manual control on the emergency feedwater pump speed as required.

Two graphs have been developed (Figures 2 and 3) which relate minimum T_{ave} to minimum pressurizer level for the two different reactor trip transients. These graphs can be used to predict pressurizer performance during any large transients at Davis-Besse 1.

RECOMMENDATIONS AND CONCLUSIONS

The information included in this report is to replace that plant transient information used previously to develop the concept that the pressurizer will empty on a reactor trip from full power simultaneous with loss of all RC pumps.[1]

With proper operation of the adjusted steam pressure relief system and minimum steam pressures above 980 psig, pressurizer level will not drop below the lower level tap for a normal reactor trip transient at any power level up to 100%.

The minimum pressurizer level that occurred on the Nov. 29, 1977 reactor trip transient with loss of all four RC pumps is calculated to have been 32 inches below the low level tap. A fluid reserve equivalent to 43 inches of level existed in the pressurizer before makeup flow increased the volume of reactor coolant. Minimum steam pressures were 610 and 730 psig for the two steam generators. The decrease in steam pressure over a 200 second interval was a result of using an excessive emergency feedwater flowrate to increase the water level in each steam generator as required to induce a natural circulation flowrate.

The maximum flowrate of emergency feedwater to each steam generator should be limited to only 850 gpm. The limit on the jet impingement velocity on the OTSG tube bundle (5 ft/second) is equivalent to 850 gpm. Tech Spec 3/4.7.1.2 (Bases) requires 850 gpm for decay heat removal. From the test data of the upcoming Natural Circulation test at Davis-Besse 1, the steam generators should be filled to the new required water level at a rate not to exceed 20 inches per

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minute, which is compatible with maintaining steam pressures above 800 psig in order to keep pressurizer level above zero.

If, after initiation of either kind of reactor trip, the SFRCS were to be actuated and steam pressure decreases below 850 psig, then the predicted final pressurizer levels (i.e. from Figures 2 and 3) could be 20 inches or a completely empty pressurizer depending on the operation of the RC pumps. This analysis does not include the effect of SFRCS operation on primary system contraction due to any overcooling.

DISCUSSION OF DAVIS-BESSE 1 TRANSIENTS

Four recent reactor trip transients were selected to determine a realistic primary system cooldown profile for analyzing and predicting pressurizer performance. None of these transients were initiated from full power and each transient had a unique sequence of operations either before or following the trip of the reactor. The table below briefly describes each of the four reactor trip transients:

Table 1

Date	Initial Power Level	RC Pumps Running	Comments
2/24/78	74	yes	trip initiated by the failure of a flowmeter ΔP transmitter.
4/2/78	75	yes	turbine trip test with unsuccessful runback of reactor power.
8/2/78	40	yes	reactor trip due to divergent oscillations while in tracking mode.
11/29/77	40	no	reactor trip and station blackout causing loss of RC pumps.

The response of the ICS and plant was adequately similar for these four transients to be able to characterize the T_{ave}-RC pressure relationship following the trip of the reactor. Figure 1 displays this relationship. This curve was utilized in predicting minimum conditions in the reactor coolant system for calculating minimum values of level in the pressurizer.

The following paragraphs present a critique of each of the selected reactor trip transients.

Reactor Trip on February 24, 1978 (Site Problem Report 431)

Due to flowmeter instrumentation failure the reactor was tripped from 74% power level and that action automatically tripped the turbine. Feedwater flow decreased to nearly zero 60 seconds after the transient was initiated.

Minimum steam generator pressure was 952 psig and minimum T_{ave} was 547.7F. The minimum values for RC pressure and pressurizer level were 1734 psig and 12 inches respectively. The change in pressurizer level for this reactor trip transient was 191 inches where the initial level was not 180 inches, but 203 inches.

If the initial pressurizer level had been at 180 inches, the final minimum level would have been 11 inches below the lower level tap. A fluid reserve equivalent to 64 inches of pressurizer level would have existed below that minimum level and no adverse affect on the primary system would have resulted.

Reactor Trip Transient on April 2, 1978 (Site Problem Report 435)

A turbine trip transient occurred on April 2, 1978 from 75% power leve . A runback in reactor power proceeded for about 50 seconds before the reactor was tripped.

Immediately after tripping the turbine, a very large reduction in feedwater flow to both steam generators occurred (due to high steam pressure) followed by too much feedwater flowrate in each loop. (This was prior to adding feedwater pump speed kicker circuits to the ICS at Davis-Besse 1). The excess feedwater flow reduced pressurizer level from a peak value of 238 inches to 170 inches and a peak RC pressure value of 2250 psig to about 1960 psig before the reactor was tripped.

After the reactor was tripped, minimum values of steam pressure and T_{ave} were 943 psig and 546F respectively. Minimum values of RC pressure and pressurizer level were 1650 psig and 6 inches. The change in pressurizer level following the reactor trip was 162 inches, and the level remained above the lower level tap during the entire transient.

Reactor Trip Transient on August 2, 1978

The initial reactor power level was 40% and the operator had placed the Diamond station in manual. The ICS therefore was in a tracking mode. Oscillations in generated power were being reinforced every two minutes and after 8 or 9 minutes, the reactor tripped. From the Post Trip Review log, hot and cold leg temperatures were 6 to 8F higher than normal. Also, pressurizer level was 230 inches rather than 180 inches.

After the reactor trip steam pressure decreased to only 980 psig and about 5 minutes after the trip T_{ave} reached a minimum value of 552F.(The values on this transient are excellent minimum values). About 90 seconds after reactor trip, a minimum pressurizer level of 34 inches was reached. This is a 196 inch level change and is greater than the normal operating point of 180 inches. Thus, the pressurizer level would have dropped to 16 inches below the lower level tap on this transient.

The unusually large contraction of the RC system fluid was caused by the higher than normal T_{ave} and pressurizer level prior to reactor trip. The change in T_{ave} was from 589.3F to 555F, or 34.3F. If the same ΔT occurred from 582F, then the minimum T_{ave} would have been 547.7F and the minimum pressurizer level would have been 18 inches below the lower tap in accordance with Figure 3.

Note: The information on temperatures and pressures during this reactor trip transient were derived from the Post Trip Review

Log only. Since some channels only update every 15 seconds, while others only update every 30 seconds, this data cannot adequately describe this kind of a transient.

Reactor Trip on November 29, 1977 (Site Problem Report 396)

At 40% power level, the reactor was tripped by high flux indications. (This was caused by spurious signals through improper patch panel connections). Automatically after the reactor trip, the turbine was tripped. The operators decided to open the main circuit breakers. The backup diesel power was started, but one of the two units tripped and shutdown.

The station experienced a 7 second blackout and the RC pumps were de-energized so that natural circulation flowrate of reactor coolant lasted for 15 minutes.

About 5 minutes after the reactor trip, RC pressure reached a minimum value of 1625 psig with a ± 50 psig oscillation. One minute earlier, pressurizer level had decreased below the low level tap and remained off scale for 6½ minutes.

One minute after the trip of the reactor, water level in each steam generator was 29 to 34 inches (startup level). After a rapid rate of fill of emergency feedwater, the levels increased to 80 inches in Steam Generator #1 and 120 inches in Steam Generator #2. During the three minute filling operation, steam generator pressures decreased from 920 psig to 610 in Steam Generator #2. The excessive contraction in the primary system is due to the cold leg temperatures produced by the rapid fill rate (and level) of each steam generator by the emergency feedwater system.

From References 1 through 4, detailed profiles of RC pressure, T_{ave}, and other related plant parameters were prepared from the test data to create a characteristic relationship of T_{ave} and RC pressure for reactor trip transients at Davis-Besse 1. This is displayed as Figure 1 which is part of Reference 5.

In general, there is a difference in the cooldown of T_{ave} and the decrease in RC pressure following a reactor trip depending on whether or not the RC pumps are running. The cooldown of the primary system is considerably faster with all four pumps running than when natural circulation exists: about 1 minute compared to 5 minutes to reach minimum T_{ave}.

Figure 1 also shows that for minimum values of T_{ave} below 540F, the final RC pressure will be approximately the same regardless of whether the pumps are running or not.

For this study of pressurizer level change following reactor trip transients, the most conservative (lowest) relationship of T_{ave} and RC pressure was used. That relationship utilizes data from the August 2, 1978 and April 2, 1978 transients.

ANALYSIS

The objective of Reference 5 was to compare the predicted change in pressurizer level with measured changes in level and verify that the mathematical model was sufficiently accurate to predict pressurizer level changes that dropped below the lower level tap or would occur during hypothetical transients.

The mathematical model used to represent the contraction of the RC system during these transients utilizes the following equation:

Total mass of fluid in the RC system = M_o =

$$\frac{\text{Equivalent Volume of Hot Fluid}}{\text{Specific Volume of Hot Fluid}}$$

$$+ \quad \frac{\text{Equivalent Volume of Cold Fluid}}{\text{Specific Volume of Cold Fluid}}$$

$$+ \quad \frac{\text{Liquid Volume of the Pressurizer}}{\text{Specific Volume of Pressurizer Fluid}}$$

Initially, no attempt was made to account for variable makeup flowrates and pressurizer vent valve flowrates during the cooldown interval. After evaluating the agreement between calculated and measured changes in pressurizer level, it was decided to not account for slight additions or deletions of reactor coolant mass during the cooldown transient.

The calculational technique requires the determination of the initial and final pressures and temperatures of the reactor coolant system, an evaluation of the specific volumes for those conditions plus saturated conditions within the pressurizer, and the difference in pressurizer volume due to the calculated contraction of the constant mass in the RC system.

Table 2 below, presents a comparison of calculated pressurizer level changes with measured level changes at selected time intervals in the four reactor trip transients.

Table 2

Comparison of Measured and Calculated Changes
In Pressurizer Levels During Reactor Trip
Transients at Davis-Besse 1

Date of Rx Trip	Measured Δ Level - inches	Calculated Δ Level - inches	Time Elapsed - seconds
2/24/78	191	184	60
4/2/78	162	167	45
8/2/78	196	206	90
11/29/77	139	132	170
11/29/77	184	181	240

The equivalent volume of hot fluid consists of upper half of each steam generator, one half of the reactor vessel and all the hot leg piping.

Similarly the equivalent volume of cold fluid consists of the other half of both steam generators, the lower half of the reactor vessel, and all the cold leg piping. The sum of the hot and cold fluid volumes is equivalent to the total reactor coolant system volume excluding the pressurizer.

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A reference volume of 800 ft^3 for a normal pressurizer level of 180 inches was often adjusted to account for different initial levels as measured in the selected reactor trip transients.

The test data from the November 29, 1977 reactor trip was examined to find the minimum RC pressure and temperatures that probably occurred while the pressurizer level was off scale and the values were determined to be the following:

> At clock time 22:48:50, minimum RC pressure was 1625 psig (± 50 psig due to oscillations). The corresponding value of hot leg temperature was 562.5F whereas the cold leg temperature was off-scale (below 520F) and was calculated to be 508.5F. T_{ave} for Loop 2 was determined to be 535.5F and the Loop 1 and 2 steam pressures indicated 610 and 760 psig respectively.

These values were used to specify the final specific volumes required in the equation and revealed that the change in pressurizer level was 224 inches. Since the initial pressurizer level at instant of reactor trip was only 192 inches, then the final pressurizer level was 32 inches below the lower level tap. There was another 43 inches of water remaining in the pressurizer at this time.

Figure 2 was developed for the situation of a reactor trip from full power plus loss of all RC pumps. The minimum T_{ave} will be controlled by the steam pressure in each steam generator. By selecting decreasing values of T_{ave} and corresponding values of steam pressure, minimum pressurizer levels were predicted.

The intent is for the user to be able to predict the total change in pressurizer level that will occur as T_{ave} changes from a normal 582F to a known or anticipated minimum temperature.

Figure 2 shows that T_{ave} has to decrease to 534F to empty the pressurizer for this reactor trip transient (no RC pumps running) and that this requires a minimum steam pressure in each steam generator to be equal to 665 psig.

By controlling steam pressure above 800 psig during this transient, (via limiting the fill rate and water level in each steam generator) the pressurizer level can remain above the lower level tap.

If the initial power level had been 100% on the November 29, 1977 transient, then the calculated minimum pressurizer level would have been 58 inches below the lower level tap. Since the initial power level was only 40%, the amount of contraction in the RC system was only -32 inches and less than predicted (by application of Figure 2). The dependence of the contraction of reactor coolant on initial power level is exhibited in Table 3 below:

Table 3

RC Contractions for Reactor Trips
(With Station Blackout) From 40% and 100% Power Levels

Power Level: - %	40	100
Initial RC Pressure - psia	2138	2138
Initial T_{hot} - F	592	605.5
Initial T_{cold} - F	567	558.5
Initial Level - Inches	192	192
Initial RC Volume - Ft^3	11,264	11,264
Initial RC Mass - Lbs.	496,969	493,437
Final RC Pressure - psia	1640	1640
Final T_{hot} - F	562.5	562.5
Final T_{cold} - F	508.5	508.5
Final RC Mass - Lbs	496,969	493,437
Final Pzr. Volume - Ft^3	122	37
Final Pzr. Level - Inches	-32	-58

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Figure 3 was similarly developed for a regular reactor trip from full power (all pumps running). This transient is more severe than the previous situation in that the forced convection of reactor coolant quickly removes all stored heat in the primary system. Below a T_{ave} value of 550F, T_{ave}, cold leg temperature, and saturation temperature in the steam generators are almost all equal. Thus, much greater care must be exercised on maintaining steam pressure to avoid emptying the pressurizer. Without the steam generator fill rate occurring in the previous type of reactor trip, good pressure control will occur as has been demonstrated on the August 2, 1978 reactor trip. An expected pressure of 980 psig will not cause the pressurizer level to go below the lower level tap.

The investigation of the cause for the final contraction of RC volume on the November 29, 1977 transient revealed that the rate of fill in both steam generators by the emergency feedwater system was too large for proper control of the steam pressure and the primary system cold leg temperature.

Figure 4 displays the rate of change in full range level and steam pressure in the interval of time between the reactor trip (0 seconds) and the time of minimum pressurizer level (315 seconds).

By calculating true levels of water in each steam generator from the indicated levels, and converting the volumetric rate of change in the steam generator to inlet conditions at the auxiliary nozzles, it was determined that an emergency feedwater flowrate of 1200 gpm was delivered to each steam generator during this transient.

The emergency feedwater flowrate of 1200 gpm should be reduced under all operating conditions to only 850 gpm. With this adjustment, the following advantages can be realized:

1. The limit of 5 feet per second impingement velocity on the tube bundle from the auxiliary feedwater nozzles is satisfied with a flowrate no greater than 850 gpm. At 1200 gpm, there is a high probability that tubes are vibrating excessively opposite the nozzles whenever the emergency system is utilized. This is an undesirable condition that can contribute to tube failure or leakage.
2. By filling each steam generator at two-thirds the previous rate (and to a lower liquid level setpoint) the ability of the operators to maintain steam pressure above the desired minimum value of 800 psig for a reactor trip-station blackout transient will be enhanced.

The basis for Technical Specification 3/4.7.1.2 states that the emergency feedwater system should have the capability to flow 850 gpm into each steam generator at an existing steam pressure of 1035 psig. The concern is to provide adequate flow for cooling the plant down to 280F. Comparison of Davis-Besse 1 fill rates with those measured and recorded at the Crystal River-3 plant reveal that the emergency feedwater flowrate for each steam generator was approximately two-thirds that shown in Figure 4 for Davis-Besse 1.

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REFERENCES:

1. Site Problem Report #431, Report including test data on the reactor trip transient of February 24, 1978.

2. Site Problem Report #435, Report including test data on the turbine trip test (and reactor trip) of April 2, 1978.

3. Site Problem Report #396, Report including test data on the reactor trip and station blackout transient of November 29, 1977.

4. Copies of test data for the reactor trip on August 2, 1978.

5. B&W Calculational File: 32-9538-00, "Davis-Besse 1 Pressurizer Levels During Reactor Trips", by R.W. Winks, dated August 31, 1978.

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R C SYSTEM PRESSURE AND TEMPERATURE DURING SPECIFIC REACTOR TRIPS AT DAVIS-BESSE 1

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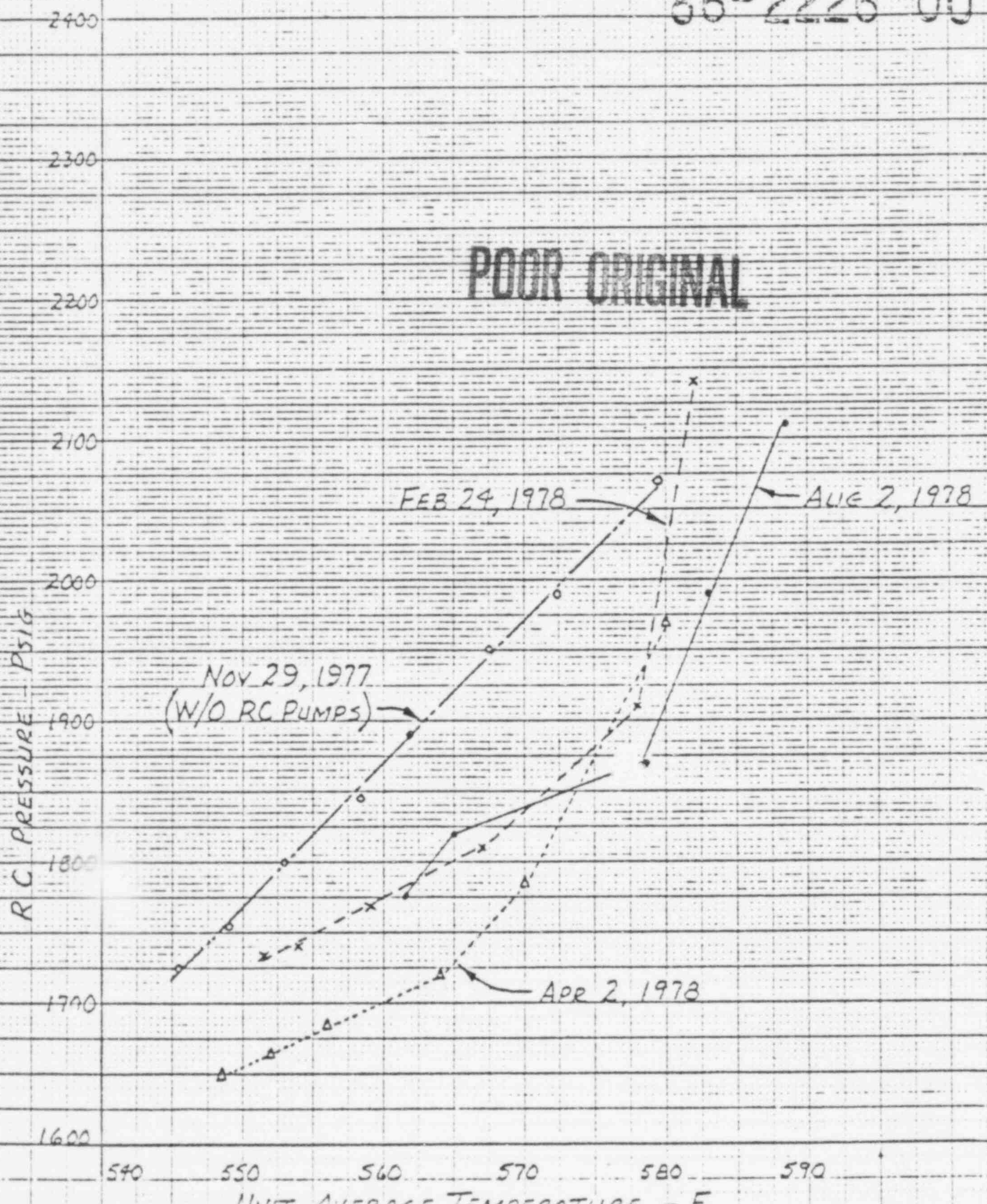

FIG 1

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PREDICTED PRESSURIZER LEVELS FOR A REACTOR TRIP AND LOSS OF RC PUMPS AT DAVIS-BESSE 1

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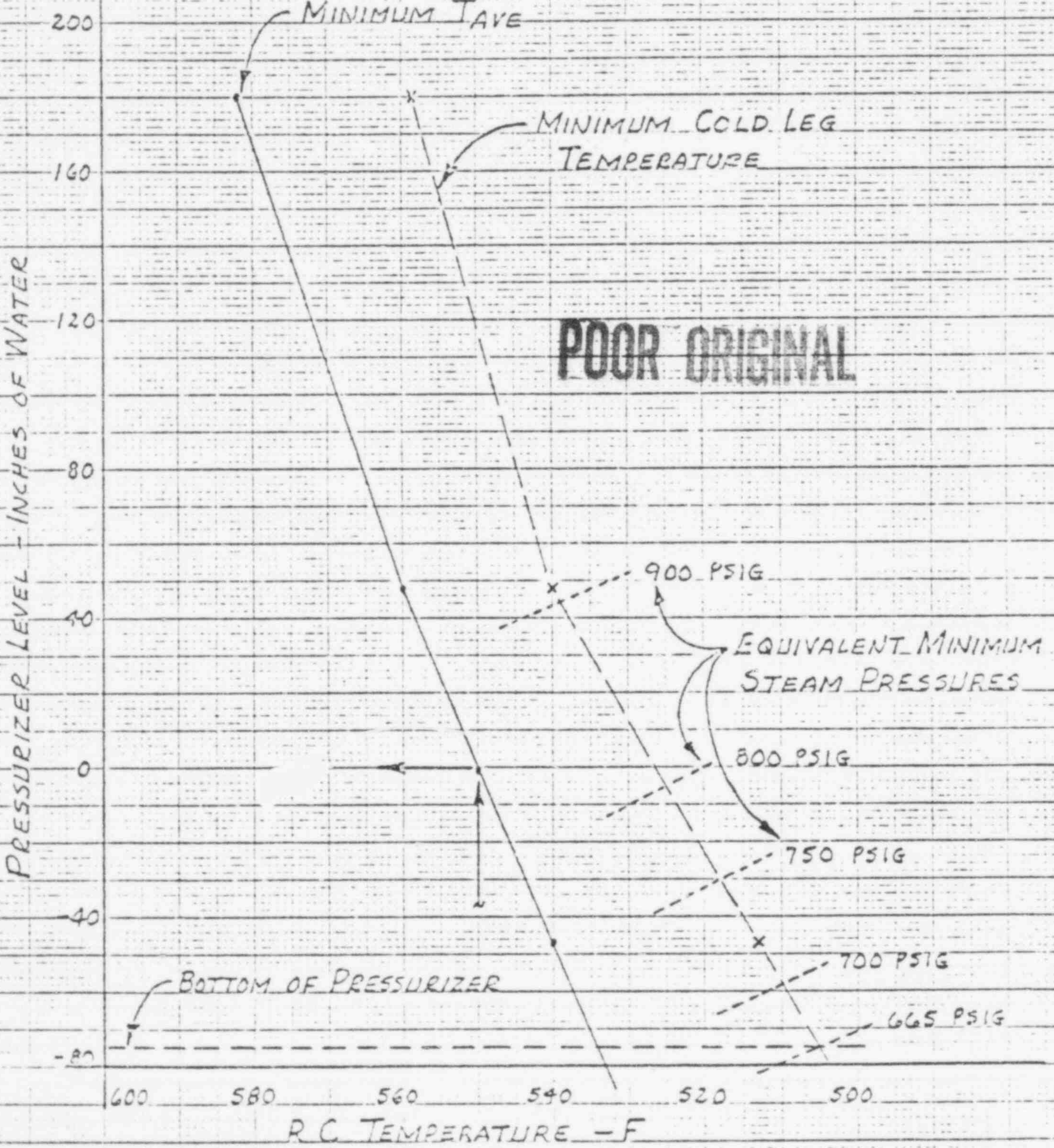

FIG 2

PREDICTED PRESSURIZER LEVELS FOR A REACTOR TRIP FROM FULL POWER AT DAVIS-BESSE 1

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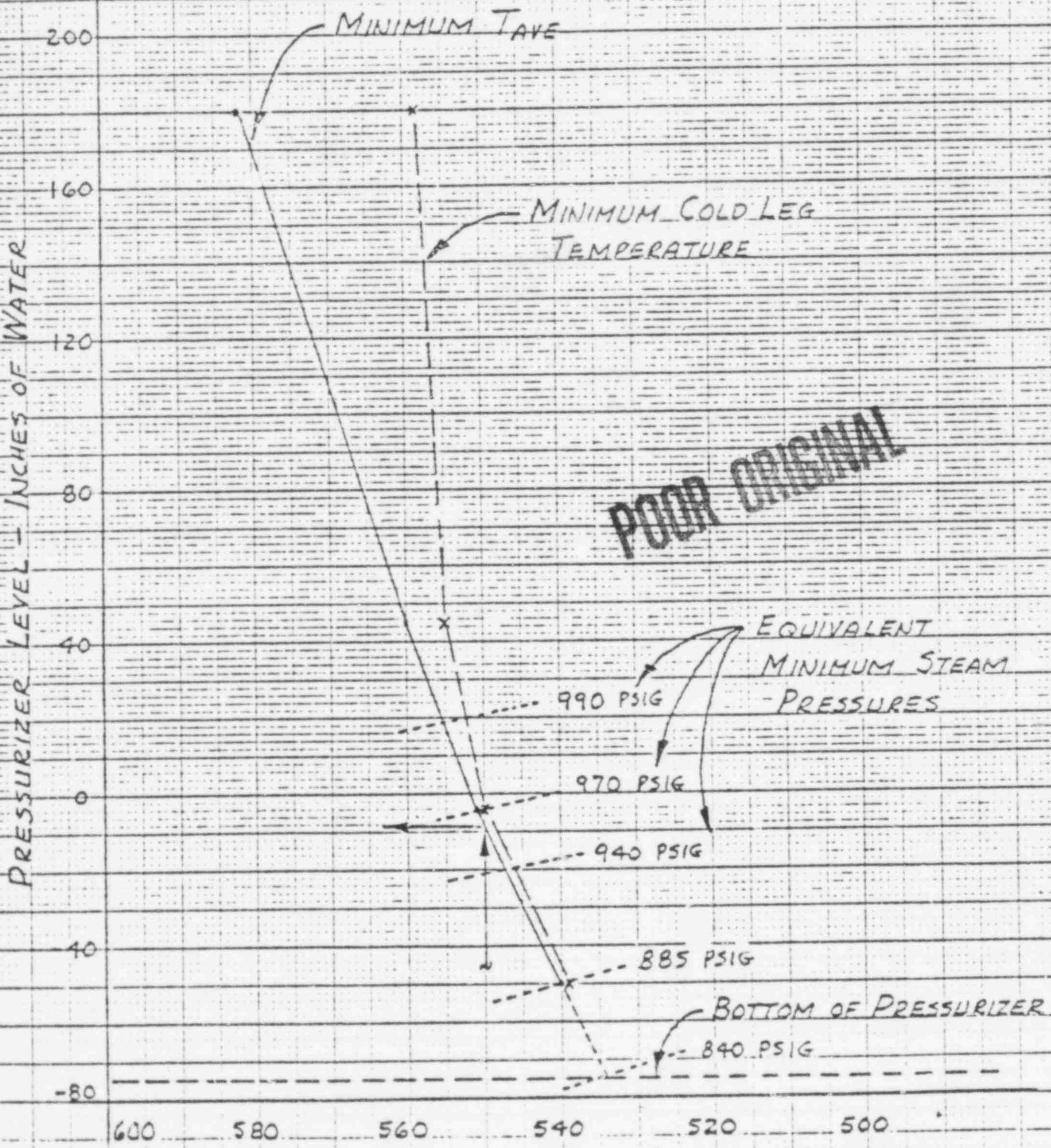

FIG 3

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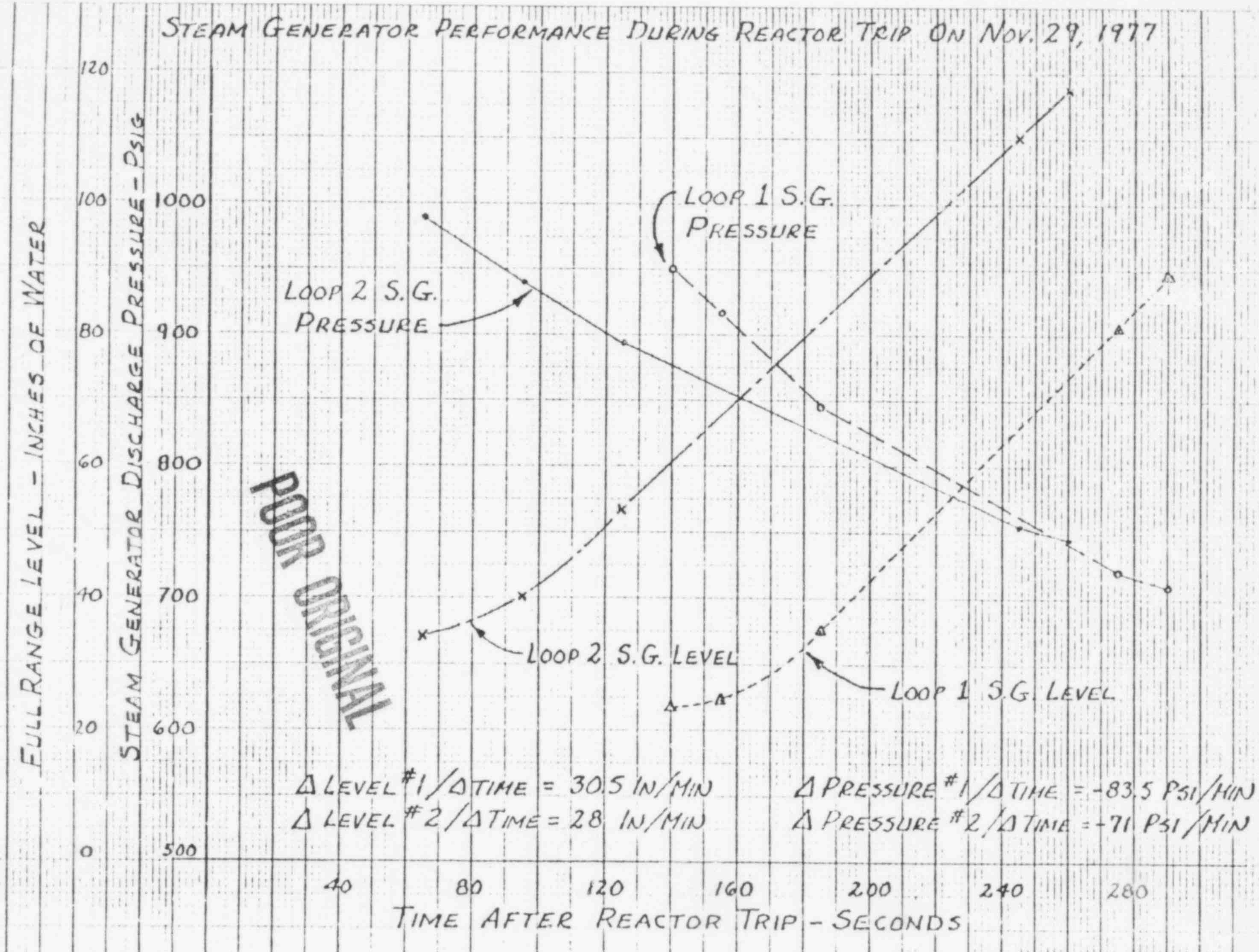
STEAM GENERATOR PERFORMANCE DURING REACTOR TRIP ON NOV. 29, 1977
FULL RANGE LEVEL - INCHES OF WATER
STEAM GENERATOR DISCHARGE PRESSURE - PSIG
120
100
80
60
40
20
0
1000
900
800
700
600
500
LOOP 1 S.G. PRESSURE
LOOP 2 S.G. PRESSURE
LOOP 2 S.G. LEVEL
LOOP 1 S.G. LEVEL
Δ LEVEL #1 / Δ TIME = 30.5 IN/MIN
Δ LEVEL #2 / Δ TIME = 28 IN/MIN
Δ PRESSURE #1 / Δ TIME = -83.5 PSI/MIN
Δ PRESSURE #2 / Δ TIME = -71 PSI/MIN
40
80
120
160
200
240
280
TIME AFTER REACTOR TRIP - SECONDS
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FIG 4

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32-9538 00 BWNP-20032A-3(10-76)

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TITLE DB-1 Pressurizer Levels During Reactor Trips

PREPARED BY R. W. Winks REVIEWED BY RM Harrington

TITLE Principal Engineer DATE 8/18/78 TITLE Sr Engr DATE 8/31/78

PURPOSE:

To review actual plant operating data and show that pressurizer level will not go below a zero indication when the reactor is tripped from full power and station blackout occurs simultaneously and all RC pumps trip.

SUMMARY OF RESULTS (INCLUDE DOC. ID'S OF PREVIOUS TRANSMITTALS & SOURCE CALCULATIONAL PACKAGES FOR THIS TRANSMITTAL)

Minimum Pressurizer Levels will provide sufficient margin above bottom of vessel for both kinds of reactor trips from full power: trip of all RC pumps or all RC pumps operating. The requirements are that proper control of OTSG steam pressure and water inventory be established after each reactor trip.

Site Problem Reports # 396, 431, and 435 from Davis-Besse 1 were used as source of actual plant performance.

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C. W. Tally
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J. R. Burris
Linda Page

1 MU Pump Operation:
k_1 = 0.010 and 0.0050
= (psid / gpm^2)

Prc psig	Q_{mu} gpm	Q_{RE+SI} gpm	Q_{pump} gpm	Pd psig	ΔP_{sys} psi	k_1	Q_{mu}' gpm
2200	142	70	212	2400	200	0.010	141
2000	169	70	239	2290	290	.010	170
1800	192	70	262	2169	369	.010	192
1700	203	70	273	2108	408	.010	202
2200	160	70	230	2325	125	.0050	158
2000	190	70	260	2180	180	.0050	190
1800	215	70	285	2036	236	.0050	217
1700	227	70	297	1960	260	.0050	228

2 MU Pump Operation with same system Resistance
$k_2 = k_1$ = 0.010 and 0.0050 psi/gpm^2

Prc	Q_{MU}	Q_{PUMP}	Q_{TOT}	Pd	ΔP_{sys}	k_1	Q_{TOT}'
2200	95	165	190	2562	362	.010	190
2000	112.5	182.5	225	2508	508	.010	225
1800	127.5	197.5	255	2456	656	.010	256
1700	135	205	270	2430	730	.010	270
2200	119	189	238	2485	285	.0050	239
2000	142	212	284	2402	402	.0050	284
1800	161	231	322	2322	522	.0050	323
1700	170	240	340	2280	580	.0050	340

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CALCULATED MAKEUP FLOWRATES FOR EITHER 1 OR 2 MAKE UP PUMPS VERSUS RC PRESSURE AT DAVIS-BESSE 1

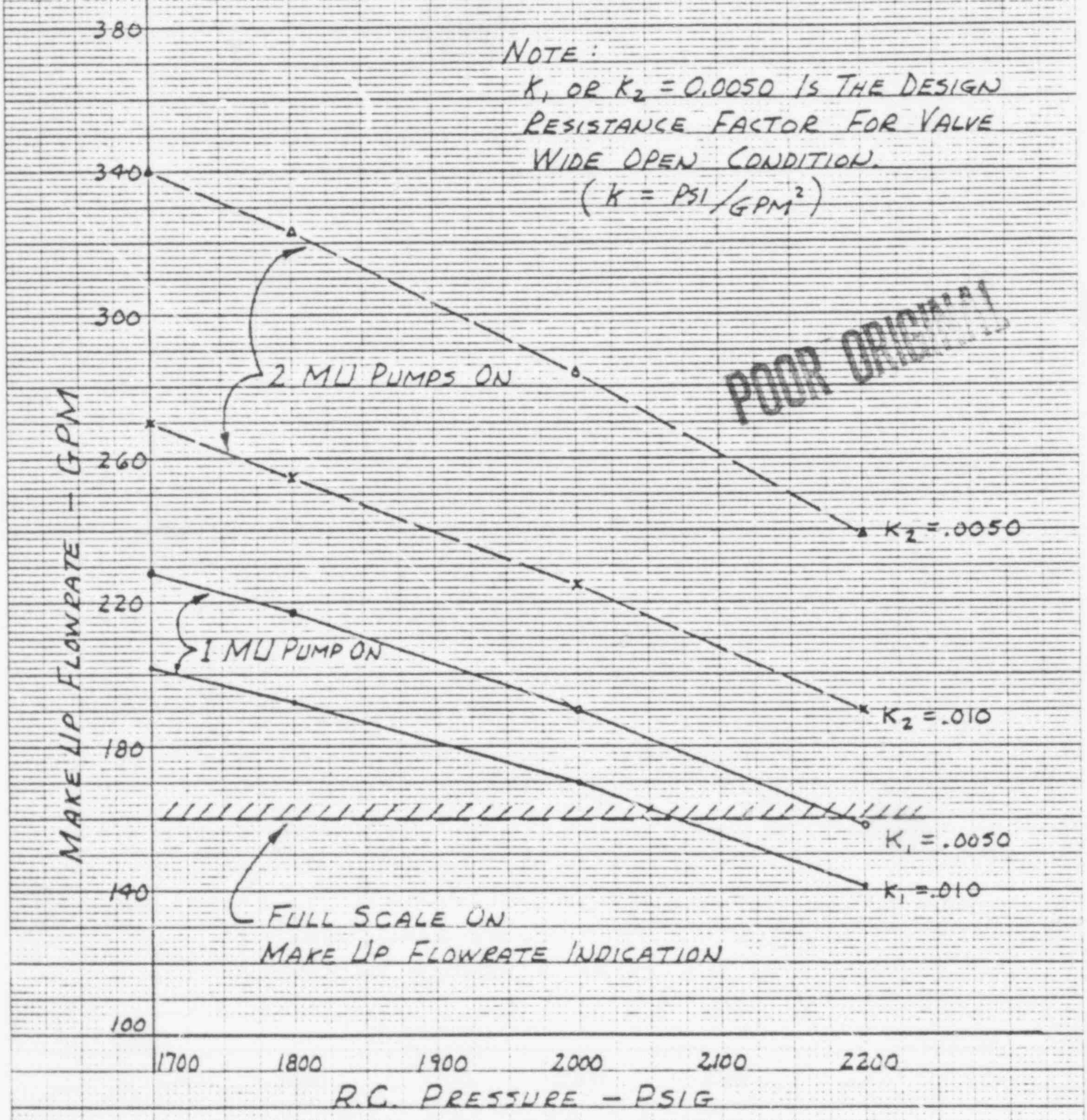

FIG 6

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CALCULATED M.U. SYSTEM FLOWRATE VERSUS RC PRESSURE FOR VALVE WIDE OPEN CONDITIONS

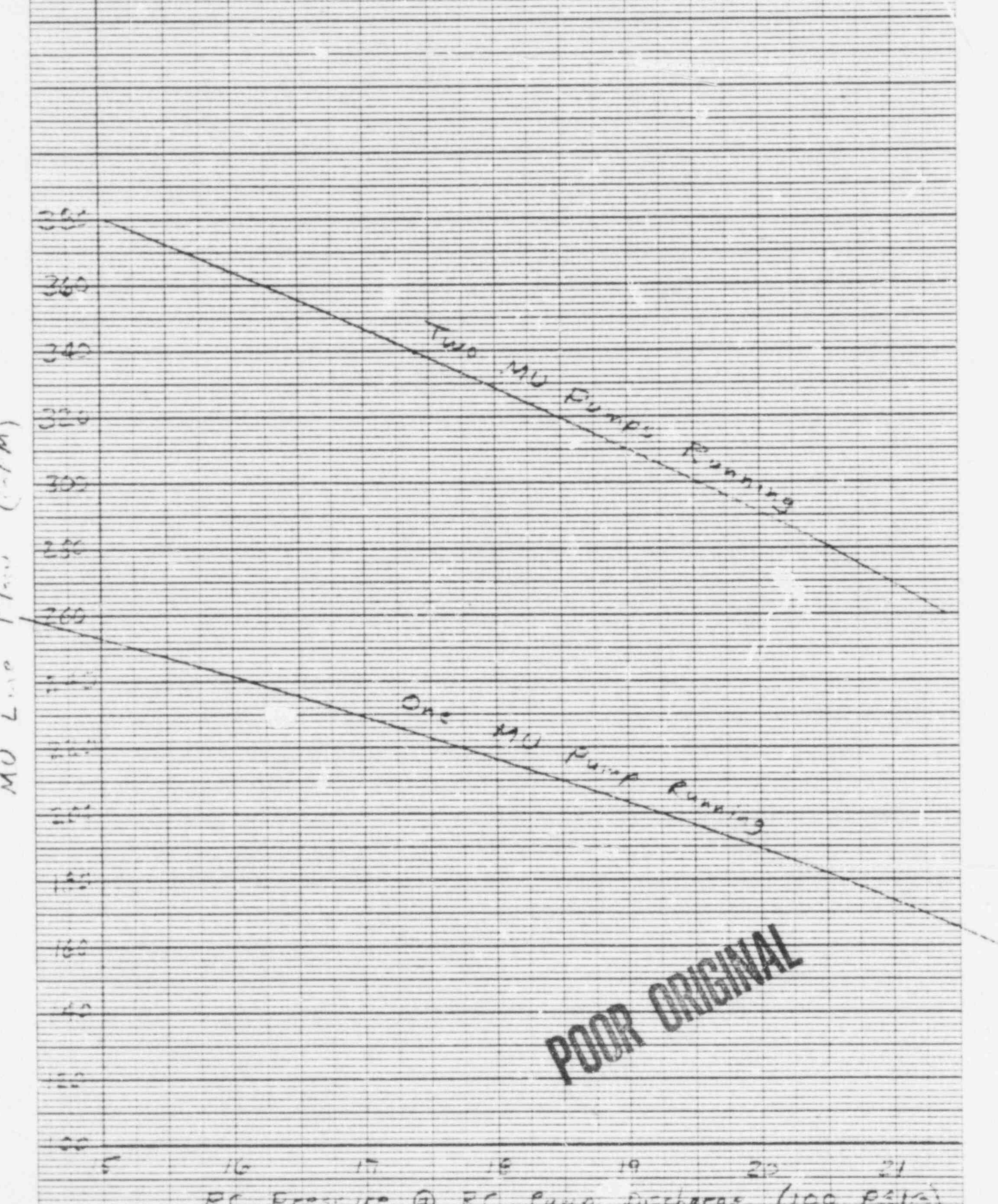

FIG 7

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1	2	3	4	5	
[illegible] Flow (GPM)	MU Line Flow (GPM)	1 + 2 GPM	MU Line ΔP (PSI)	MU Pump TDH (PSI)	RC Press @ HPI Nozzle 5 - 4 (PSIG)
One Pump					
32	[illegible]	[illegible]	102	[illegible]	[illegible]
32	150	182	117	2355	2235
32	160	192	133	2315	2182
32	[illegible]	212	166	[illegible]	2062
[illegible]	[illegible]	[illegible]	208	2130	[illegible]
[illegible]	[illegible]	252	[illegible]	[illegible]	1774
[illegible]	[illegible]	[illegible]	299	1915	[illegible]
[illegible]	[illegible]	[illegible]	351	1790	1439

MU Line ΔP = 67.44 PSI @ 114 GPM (valve wide open)

$k_1 = .0052$ psi/gpm^2

Two Pump

		(1 + 2)/2				
32	[illegible]	96	133	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	206	[illegible]	2372	
[illegible]	[illegible]	136	299	2520	[illegible]	
[illegible]	[illegible]	[illegible]	407	2460	[illegible]	✓
[illegible]	[illegible]	176	531	[illegible]	[illegible]	✓
[illegible]	[illegible]	[illegible]	673	2300	[illegible]	✓
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[illegible]	[illegible]	[illegible]	[illegible]	2490	2139	

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TECO

Appendix to 32-9745-00

14

J.R. Merchent for R W Winks

10/3/78

750127

TOLEDO EDISON COMPANY

TOLEDO, OHIO 43652

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DATE September 25, 1978 Monday

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Post Trip Review Data for 11/29/77 Event
for the range of interest (~6 min after Reactor Trip)

L761 MU TK LVL (in H_2O)
F717 LETDOWN FLOW (gpm)
F740 MU FLOW (HI RANGE) (gpm)
F782 RCP SEAL IN FLOW (range 0 to 100.0 gpm)

POOR ORIGINAL

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:13:40
30/77
T TRIP REVIEW

REACTOR TRIP AT 22:43:23

TIME		L761 MU TK LVL (IN.)	F740 MU FLOW (GPM)	F717 LTDN FLOW (GPM)	F182 SEAL INJ
:42:00	-85	59·47	44·71	50·78	34·78
2:42:15	-70	59·47	44·71	50·75	34·78
:42·30	-55	59·33	27·29	50·75	35·75
2:42:45	-40	59·33	27·29	50·84	35·75
2:43:00	-25	59·31	26·95	50·84	35·63
2:43:15 Rtrip	-10	59·31	26·95	50·79	35·63
2:43:30	+5	58.62	125·6	50·79	24·84
2:43:45	+20	58·62	125·6	50·66	24·84
:44:00	+35	56·78	119·1	50·66	-$$$$
2:44:15	+50	56·78	119·1	·0000	
2:44:30	+65	56·86	16·09	·0000	
2:44:45	+80	56·86	16·09	·0000	
22:45:00	+95	56·93	16·04	·0000	
2:45 15	110	56·93	16·04	·0000	
22:45·30	125	56·99	16·00	LETDOWN FLOW ZERO IN THIS PERIOD	
22:45 :45	140	56·99	16·00		$$$$
22:46 :00	155	57·04	15·92		
22:46 :15	170	57·04	15·92		
22:46 :30	185	57·05	15·82		
22:46 :45	200	57·05	15·82		
:47 :00	215	57·05	15·67		
22:47 :15	230	57·05	15·67		
22:47 :30	245	56·87	17·96		
22:47 :45	260	56·87	17·96		-$$$$

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		L 761	F 740	F 717	F 782
22:48:00	275	56.38	18.04	0	26.55
22 48:15	290	56.38	18.04	0	26.55
22 49:15	350	55.23	17.99	0	27.21
22:52:15			112.		
22:53:15			(-1)		

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86-2226 00

BWNP-20032A-3(10-76)

CONTRACT/STANDARD NO.	DOCUMENT RELEASE NOTICE (DRN)
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PART/TASK-GROUP-SEQ.	B&W DOCUMENT NO.	DOCUMENT TITLE	PUL STAT.	RRL NO.
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NAME DATE

Principal Engineer

REVIEWED BY

R M Harrington 9/1/78
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CALCULATION DATA/TRANSMITTAL SHEET

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TYPE: ___RESEARCH & DEVELOPMENT ___SAFETY ANALYSIS REPORT ___NUC. SERV. INPUT ___DESIGN RQMT. ___DESIGN VERIF. X OTHER

TITLE Dynamic Performance of the Pressurizer During Reactor Trips at Davis-Besse 1

PREPARED BY Robert Winks REVIEWED BY RM Harrington

TITLE Principal Engineer DATE 8/31/78 TITLE Sr. Engineer DATE 9/1/78

PURPOSE:

To report on the success of a mathematical technique of calculating minimum pressurizer level when initial and final RC hot leg and cold leg temperatures and RC pressures are known relative to large upset transients such as reactor trip from full power.

SUMMARY OF RESULTS (INCLUDE DOC. ID'S OF PREVIOUS TRANSMITTALS & SOURCE CALCULATIONAL PACKAGES FOR THIS TRANSMITTAL)

The minimum level of water in the pressurizer will remain above the bottom provided the lowest value of Tave and steam pressure are above certain specified values for either a reactor trip with all RC pumps running or without the pumps running. Field data from Davis-Besse 1 plant contained in SPR # 396, 431, 435, and 476, was used to verify the accuracy of calculated minimum pressurizer levels during transients.

The Calculational File used to prepare this report is 32-9538-00.

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86-2226 00

DYNAMIC PERFORMANCE OF THE PRESSURIZER
DURING REACTOR TRIPS AT DAVIS BESSE 1

By: Robert W. Winks
Principal Engineer
Babcock & Wilcox Co.
Lynchburg, Virginia

August 31, 1978

Q.A. Statement

The information contained in this report, and the calculations supporting this request have been checked for accuracy and completeness.

RMHarrington 9/1/78
Signature Date

Approved: LBDavis
Control Analysis Manager

86-2226 00

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INTRODUCTION

A concern exists with NRC (Region 3) that the pressurizer will empty completely during a reactor trip from full power with simultaneous loss of station power. This premise is founded upon actual pressurizer performance recorded during several reactor trip transients at Davis-Besse 1. The reactor trip transients have occurred at partial power levels with either all RC pumps running or all four RC pumps tripped.

The extent of reactor coolant volume contraction following a reactor trip is primarily governed by the wetted surface area of the tube bundle and by the steam pressure maintained within both Once Through Steam Generators. It is also affected by the flowrate of reactor coolant through both steam generators, that is, all pumps running versus all pumps tripped.

An effort to properly adjust the blowdown on all the main steam safety relief valves has been performed by Toledo Edison Company at the Davis-Besse 1 plant early in 1978. The values of minimum steam pressure after a recent reactor trip transient indicate that the performance of the steam pressure relief system is greatly improved over that observed during earlier reactor trip transients.

The purpose of this report will be to develop a calculational technique for predicting minimum pressurizer levels following a reactor trip transient and account for either tripped or running RC pumps. Actual reactor trip transient test data from Davis-Besse 1 will be used to support the calculational technique. A second purpose will be to predict the minimum pressurizer level that will occur for two specific reactor trip transients and to disclose values of minimum steam pressure that will cause the pressurizer to become empty for these two transients.

SUMMARY

A calculational technique has been developed for predicting changes in pressurizer level during reactor trips which agrees very well with observed reactor trip transients at Davis-Besse 1.

The method has been used to predict the final minimum pressurizer level for two possible transients (both from 100% power): a reactor trip with simultaneous trip of all RC pumps, and a manual trip of the reactor with all RC pumps operating.

For the first transient above, the pressurizer level will decrease only 100 inches, provided that steam pressure will not decrease below 950 psig. If steam pressure decreases to 700 psig the pressurizer would become empty and could cause a steam bubble to enter into the hot leg piping.

For the manual trip of the reactor transient, the pressurizer level will decrease below the lower level tap when steam pressure drops to 950 psig. Since a minimum steam pressure of 980 psig is anticipated on future reactor trip transients, the predicted minimum pressurizer level will be a few inches above the zero indication and nearly 80 inches above the bottom of the pressurizer. If steam pressure decreases to 840 psig on this transient, then the water level would drop completely to the bottom of the pressurizer.

The maximum filling rate for the Once Through Steam Generators should be only 850 gpm rather than the 1200 gpm rate determined from the November 29, 1977 test data. In order to maintain steam generator pressure above 800 psig and prevent possible emptying of the pressurizer during the loss of RC pump-reactor trip transient, the rate

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of fill must be controlled by the Operator using manual control on the emergency feedwater pump speed as required.

Two graphs have been developed (Figures 2 and 3) which relate minimum T_{ave} to minimum pressurizer level for the two different reactor trip transients. These graphs can be used to predict pressurizer performance during any large transients at Davis-Besse 1.

RECOMMENDATIONS AND CONCLUSIONS

The information included in this report is to replace that plant transient information used previously to develop the concept that the pressurizer will empty on a reactor trip from full power simultaneous with loss of all RC pumps.[1]

With proper operation of the adjusted steam pressure relief system and minimum steam pressures above 980 psig, pressurizer level will not drop below the lower level tap for a normal reactor trip transient at any power level up to 100%.

The minimum pressurizer level that occurred on the Nov. 29, 1977 reactor trip transient with loss of all four RC pumps is calculated to have been 32 inches below the low level tap. A fluid reserve equivalent to 43 inches of level existed in the pressurizer before makeup flow increased the volume of reactor coolant. Minimum steam pressures were 610 and 730 psig for the two steam generators. The decrease in steam pressure over a 200 second interval was a result of using an excessive emergency feedwater flowrate to increase the water level in each steam generator as required to induce a natural circulation flowrate.

The maximum flowrate of emergency feedwater to each steam generator should be limited to only 850 gpm. The limit on the jet impingement velocity on the OTSG tube bundle (5 ft/second) is equivalent to 850 gpm. Tech Spec 3/4.7.1.2 (Bases) requires 850 gpm for decay heat removal. From the test data of the upcoming Natural Circulation test at Davis-Besse 1, the steam generators should be filled to the new required water level at a rate not to exceed 20 inches per minute, which is compatible with maintaining steam pressures above 800 psig in order to keep pressurizer level above zero.

If, after initiation of either kind of reactor trip, the SFRCS were to be actuated and steam pressure decreases below 850 psig, then the predicted final pressurizer levels (i.e. from Figures 2 and 3) could be 20 inches or a completely empty pressurizer depending on the operation of the RC pumps. This analysis does not include the effect of SFRCS operation on primary system contraction due to any overcooling.

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DISCUSSION OF DAVIS-BESSE 1 TRANSIENTS

Four recent reactor trip transients were selected to determine a realistic primary system cooldown profile for analyzing and predicting pressurizer performance. None of these transients were initiated from full power and each transient had a unique sequence of operations either before or following the trip of the reactor. The table below briefly describes each of the four reactor trip transients:

Table 1

Date	Initial Power Level	RC Pumps Running	Comments
2/24/78	74	yes	trip initiated by the failure of a flowmeter ΔP transmitter.
4/2/78	75	yes	turbine trip test with unsuccessful runback of reactor power.
8/2/78	40	yes	reactor trip due to divergent oscillations while in tracking mode.
11/29/77	40	no	reactor trip and station blackout causing loss of RC pumps.

The response of the ICS and plant was adequately similar for these four transients to be able to characterize the T_{ave}-RC pressure relationship following the trip of the reactor. Figure 1 displays this relationship. This curve was utilized in predicting minimum conditions in the reactor coolant system for calculating minimum values of level in the pressurizer.

The following paragraphs present a critique of each of the selected reactor trip transients.

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Reactor Trip on February 24, 1978 (Site Problem Report 431)

Due to flowmeter instrumentation failure the reactor was tripped from 74% power level and that action automatically tripped the turbine. Feedwater flow decreased to nearly zero 60 seconds after the transient was initiated.

Minimum steam generator pressure was 952 psig and minimum T_{ave} was 547.7F. The minimum values for RC pressure and pressurizer level were 1734 psig and 12 inches respectively. The change in pressurizer level for this reactor trip transient was 191 inches where the initial level was not 180 inches, but 203 inches.

If the initial pressurizer level had been at 180 inches, the final minimum level would have been 11 inches below the lower level tap. A fluid reserve equivalent to 64 inches of pressurizer level would have existed below that minimum level and no adverse affect on the primary system would have resulted.

Reactor Trip Transient on April 2, 1978 (Site Problem Report 435)

A turbine trip transient occurred on April 2, 1978 from 75% power level. A runback in reactor power proceeded for about 50 seconds before the reactor was tripped.

Immediately after tripping the turbine, a very large reduction in feedwater flow to both steam generators occurred (due to high steam pressure) followed by too much feedwater flowrate in each loop. (This was prior to adding feedwater pump speed kicker circuits to the ICS at Davis-Besse 1). The excess feedwater flow reduced pressurizer level from a peak value of 238 inches to 170 inches and a peak RC pressure value of 2250 psig to about 1960 psig before the reactor was tripped.

After the reactor was tripped, minimum values of steam pressure and T_{ave} were 943 psig and 546F respectively. Minimum values of RC pressure and pressurizer level were 1650 psig and 6 inches. The change in pressurizer level following the reactor trip was 162 inches, and the level remained above the lower level tap during the entire transient.

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Reactor Trip Transient on August 2, 1978

The initial reactor power level was 40% and the operator had placed the Diamond station in manual. The ICS therefore was in a tracking mode. Oscillations in generated power were being reinforced every two minutes and after 8 or 9 minutes, the reactor tripped. From the Post Trip Review log, hot and cold leg temperatures were 6 to 8F higher than normal. Also, pressurizer level was 230 inches rather than 180 inches.

After the reactor trip steam pressure decreased to only 980 psig and about 5 minutes after the trip T_{ave} reached a minimum value of 552F.(The values on this transient are excellent minimum values). About 90 seconds after reactor trip, a minimum pressurizer level of 34 inches was reached. This is a 196 inch level change and is greater than the normal operating point of 180 inches. Thus, the pressurizer level would have dropped to 16 inches below the lower level tap on this transient.

The unusually large contraction of the RC system fluid was caused by the higher than normal T_{ave} and pressurizer level prior to reactor trip. The change in T_{ave} was from 589.3F to 555F, or 34.3F. If the same ΔT occurred from 582F, then the minimum T_{ave} would have been 547.7F and the minimum pressurizer level would have been 18 inches below the lower tap in accordance with Figure 3.

Note: The information on temperatures and pressures during this reactor trip transient were derived from the Post Trip Review

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Log only. Since some channels only update every 15 seconds, while others only update every 30 seconds, this data cannot adequately describe this kind of a transient.

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Reactor Trip on November 29, 1977 (Site Problem Report 396)

At 40% power level, the reactor was tripped by high flux indications. (This was caused by spurious signals through improper patch panel connections). [illegible]omatically after the reactor trip, the turbine was tripped. The operators decided to open the main circuit breakers. The backup diesel power was started, but one of the two units tripped and shutdown.

The station experienced a 7 second blackout and the RC pumps were de-energized so that natural circulation flowrate of reactor coolant lasted for 15 minutes.

About 5 minutes after the reactor trip, RC pressure reached a minimum value of 1625 psig with a $\pm$ 50 psig oscillation. One minute earlier, pressurizer level had decreased below the low level tap and remained off scale for 6½ minutes.

One minute after the trip of the reactor, water level in each steam generator was 29 to 34 inches (startup level). After a rapid rate of fill of emergency feedwater, the levels increased to 80 inches in Steam Generator #1 and 120 inches in Steam Generator #2. During the three minute filling operation, steam generator pressures decreased from 920 psig to 610 in Steam Generator #2. The excessive contraction in the primary system is due to the cold leg temperatures produced by the rapid fill rate (and level) of each steam generator by the emergency feedwater system.

From References 1 through 4, detailed profiles of RC pressure, T_{ave}, and other related plant parameters were prepared from the test data to create a characteristic relationship of T_{ave} and RC pressure for reactor trip transients at Davis-Besse 1. This is displayed as Figure 1 which is part of Reference 5.

In general, there is a difference in the cooldown of T_{ave} and the decrease in RC pressure following a reactor trip depending on whether or not the RC pumps are running. The cooldown of the primary system is considerably faster with all four pumps running than when natural circulation exists: about 1 minute compared to 5 minutes to reach minimum T_{ave}.

Figure 1 also shows that for minimum values of T_{ave} below 540F, the final RC pressure will be approximately the same regardless of whether the pumps are running or not.

For this study of pressurizer level change following reactor trip transients, the most conservative (lowest) relationship of T_{ave} and RC pressure was used. That relationship utilizes data from the August 2, 1978 and April 2, 1978 transients.

ANALYSIS

The objective of Reference 5 was to compare the predicted change in pressurizer level with measured changes in level and verify that the mathematical model was sufficiently accurate to predict pressurizer level changes that dropped below the lower level tap or would occur during hypothetical transients.

The mathematical model used to represent the contraction of the RC system during these transients utilizes the following equation:

Total mass of fluid in the RC system = M_o =

$$\frac{\text{Equivalent Volume of Hot Fluid}}{\text{Specific Volume of Hot Fluid}}$$

$$+ \quad \frac{\text{Equivalent Volume of Cold Fluid}}{\text{Specific Volume of Cold Fluid}}$$

$$+ \quad \frac{\text{Liquid Volume of the Pressurizer}}{\text{Specific Volume of Pressurizer Fluid}}$$

Initially, no attempt was made to account for variable makeup flowrates and pressurizer vent valve flowrates during the cooldown interval. After evaluating the agreement between calculated and measured changes in pressurizer level, it was decided to not account for slight additions or deletions of reactor coolant mass during the cooldown transient.

The calculational technique requires the determination of the initial and final pressures and temperatures of the reactor coolant system, an evaluation of the specific volumes for those conditions plus saturated conditions within the pressurizer, and the difference in pressurizer volume due to the calculated contraction of the constant mass in the RC system.

Table 2 below, presents a comparison of calculated pressurizer level changes with measured level changes at selected time intervals in the four reactor trip transients.

Table 2

Comparison of Measured and Calculated Changes
In Pressurizer Levels During Reactor Trip
Transients at Davis-Besse 1

Date of Rx Trip	Measured Δ Level - inches	Calculated Δ Level - inches	Time Elapsed - seconds
2/24/78	191	184	60
4/2/78	162	167	45
8/2/78	196	206	90
11/29/77	139	132	170
11/29/77	184	181	240

The equivalent volume of hot fluid consists of upper half of each steam generator, one half of the reactor vessel and all the hot leg piping.

Similarly the equivalent volume of cold fluid consists of the other half of both steam generators, the lower half of the reactor vessel, and all the cold leg piping. The sum of the hot and cold fluid volumes is equivalent to the total reactor coolant system volume excluding the pressurizer.

A reference volume of 800 ft^3 for a normal pressurizer level of 180 inches was often adjusted to account for different initial levels as measured in the selected reactor trip transients.

The test data from the November 29, 1977 reactor trip was examined to find the minimum RC pressure and temperatures that probably occurred while the pressurizer level was off scale and the values were determined to be the following:

> At clock time 22:48:50, minimum RC pressure was 1625 psig (± 50 psig due to oscillations). The corresponding value of hot leg temperature was 562.5F whereas the cold leg temperature was off-scale (below 520F) and was calculated to be 508.5F. T_{ave} for Loop 2 was determined to be 535.5F and the Loop 1 and 2 steam pressures indicated 610 and 760 psig respectively.

These values were used to specify the final specific volumes required in the equation and revealed that the change in pressurizer level was 224 inches. Since the initial pressurizer level at instant of reactor trip was only 192 inches, then the final pressurizer level was 32 inches below the lower level tap. There was another 43 inches of water remaining in the pressurizer at this time.

Figure 2 was developed for the situation of a reactor trip from full power plus loss of all RC pumps. The minimum T_{ave} will be controlled by the steam pressure in each steam generator. By selecting decreasing values of T_{ave} and corresponding values of steam pressure, minimum pressurizer levels were predicted.

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The intent is for the user to be able to predict the total change in pressurizer level that will occur as T_{ave} changes from a normal 582F to a known or anticipated minimum temperature.

Figure 2 shows that T_{ave} has to decrease to 534F to empty the pressurizer for this reactor trip transient (no RC pumps running) and that this requires a minimum steam pressure in each steam generator to be equal to 665 psig.

By controlling steam pressure above 800 psig during this transient, (via limiting the fill rate and water level in each steam generator) the pressurizer level can remain above the lower level tap.

If the initial power level had been 100% on the November 29, 1977 transient, then the calculated minimum pressurizer level would have been 58 inches below the lower level tap. Since the initial power level was only 40%, the amount of contraction in the RC system was only -32 inches and less than predicted (by application of Figure 2). The dependence of the contraction of reactor coolant on initial power level is exhibited in Table 3 below:

Table 3

RC Contractions for Reactor Trips
(With Station Blackout) From 40% and 100% Power Levels

Power Level: - %	40	100
Initial RC Pressure psia	2138	2138
Initial T_{hot} - F	592	605.5
Initial T_{cold} - F	567	558.5
Initial Level - Inches	192	192
Initial RC Volume - Ft^3	11,264	11,264
Initial RC Mass - Lbs.	496,969	493,437
Final RC Pressure - psia	1640	1640
Final T_{hot} - F	562.5	562.5
Final T_{cold} - F	508.5	508.5
Final RC Mass - Lbs	496,969	493,437
Final Pzr. Volume - Ft^3	122	37
Final Pzr. Level - Inches	-32	-58

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Figure 3 was similarly developed for a regular reactor trip from full power (all pumps running). This transient is more severe than the previous situation in that the forced convection of reactor coolant quickly removes all stored heat in the primary system. Below a T_{ave} value of 550F, T_{ave}, cold leg temperature, and saturation temperature in the steam generators are almost all equal. Thus, much greater care must be exercised on maintaining steam pressure to avoid emptying the pressurizer. Without the steam generator fill rate occurring in the previous type of reactor trip, good pressure control will occur as has been demonstrated on the August 2, 1978 reactor trip. An expected pressure of 980 psig will not cause the pressurizer level to go below the lower level tap.

The investigation of the cause for the final contraction of RC volume on the November 29, 1977 transient revealed that the rate of fill in both steam generators by the emergency feedwater system was too large for proper control of the steam pressure and the primary system cold leg temperature.

Figure 4 displays the rate of change in full range level and steam pressure in the interval of time between the reactor trip (0 seconds) and the time of minimum pressurizer level (315 seconds).

By calculating true levels of water in each steam generator from the indicated levels, and converting the volumetric rate of change in the steam generator to inlet conditions at the auxiliary nozzles, it was determined that an emergency feedwater flowrate of 1200 gpm was delivered to each steam generator during this transient.

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The emergency feedwater flowrate of 1200 gpm should be reduced under <u>all</u> operating conditions to only 850 gpm. With this adjustment, the following advantages can be realized:

1. The limit of 5 feet per second impingement velocity on the tube bundle from the auxiliary feedwater nozzles is satisfied with a flowrate no greater than 850 gpm. At 1200 gpm, there is a high probability that tubes are vibrating excessively opposite the nozzles whenever the emergency system is utilized. This is an undesirable condition that can contribute to tube failure or leakage.
2. By filling each steam generator at two-thirds the previous rate (and to a lower liquid level setpoint) the ability of the operators to maintain steam pressure above the desired minimum value of 800 psig for a reactor trip-station blackout transient will be enhanced.

The basis for Technical Specification 3/4.7.1.2 states that the emergency feedwater system should have the capability to flow 850 gpm into each steam generator at an existing steam pressure of 1035 psig. The concern is to provide adequate flow for cooling the plant down to 280F. Comparison of Davis-Besse 1 fill rates with those measured and recorded at the Crystal River-3 plant reveal that the emergency feedwater flowrate for each steam generator was approximately two-thirds that shown in Figure 4 for Davis-Besse 1.

750154

REFERENCES:

1. Site Problem Report #431, Report including test data on the reactor trip transient of February 24, 1978.

2. Site Problem Report #435, Report including test data on the turbine trip test (and reactor trip) of April 2, 1978.

3. Site Problem Report #396, Report including test data on the reactor trip and station blackout transient of November 29, 1977.

4. Copies of test data for the reactor trip on August 2, 1978.

5. B&W Calculational File: 32-9538-00, "Davis-Besse 1 Pressurizer Levels During Reactor Trips", by R.W. Winks, dated August 31, 1978.

52-9558 00

R.C. SYSTEM PRESSURE AND TEMPERATURE DURING SPECIFIC REACTOR TRIPS AT DAVIS-BESSE 1

86-2226 00

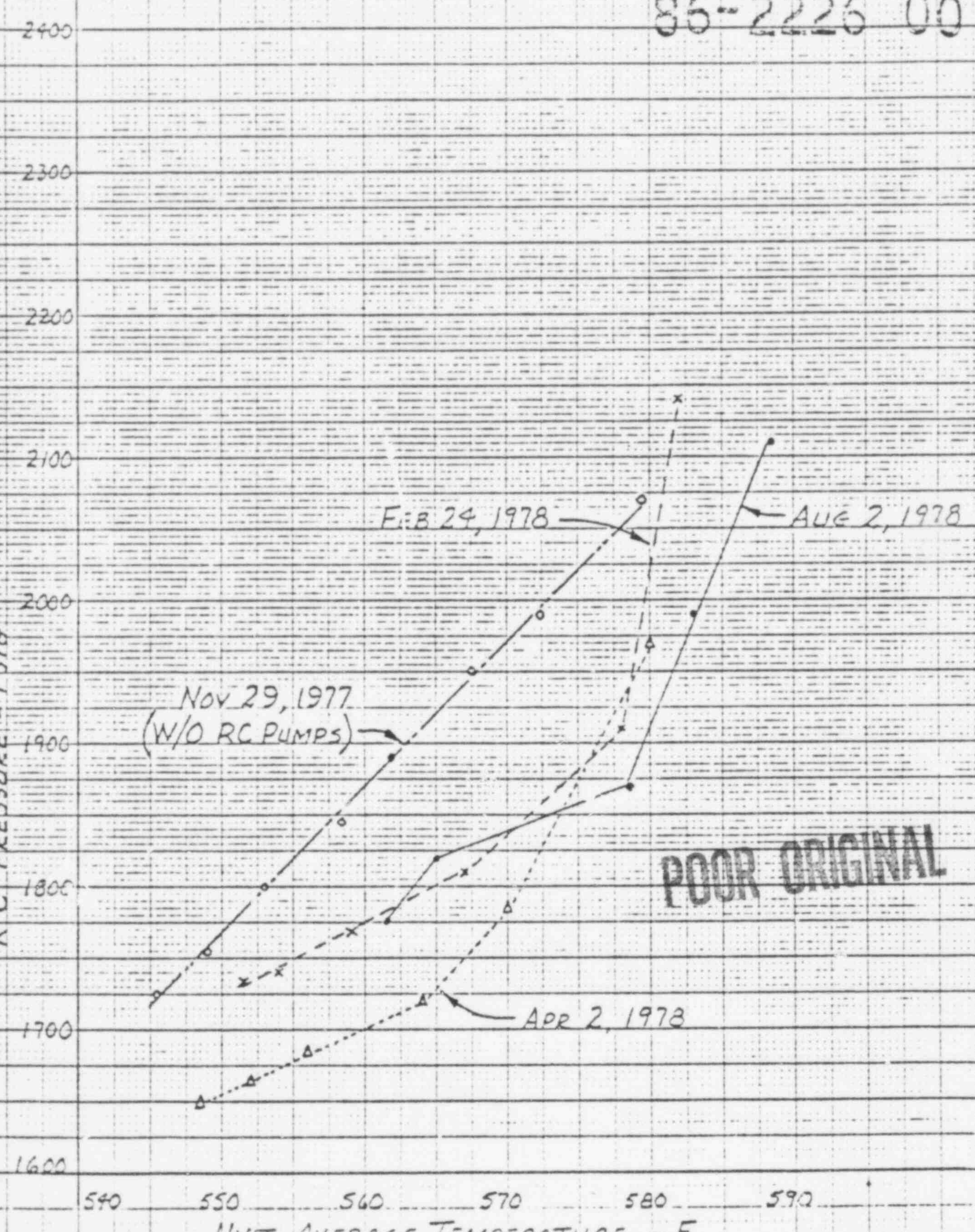

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FIG 1

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PREDICTED PRESSURIZER LEVELS FOR A REACTOR TRIP AND LOSS OF RC PUMPS AT DAVIS-BESSE 1

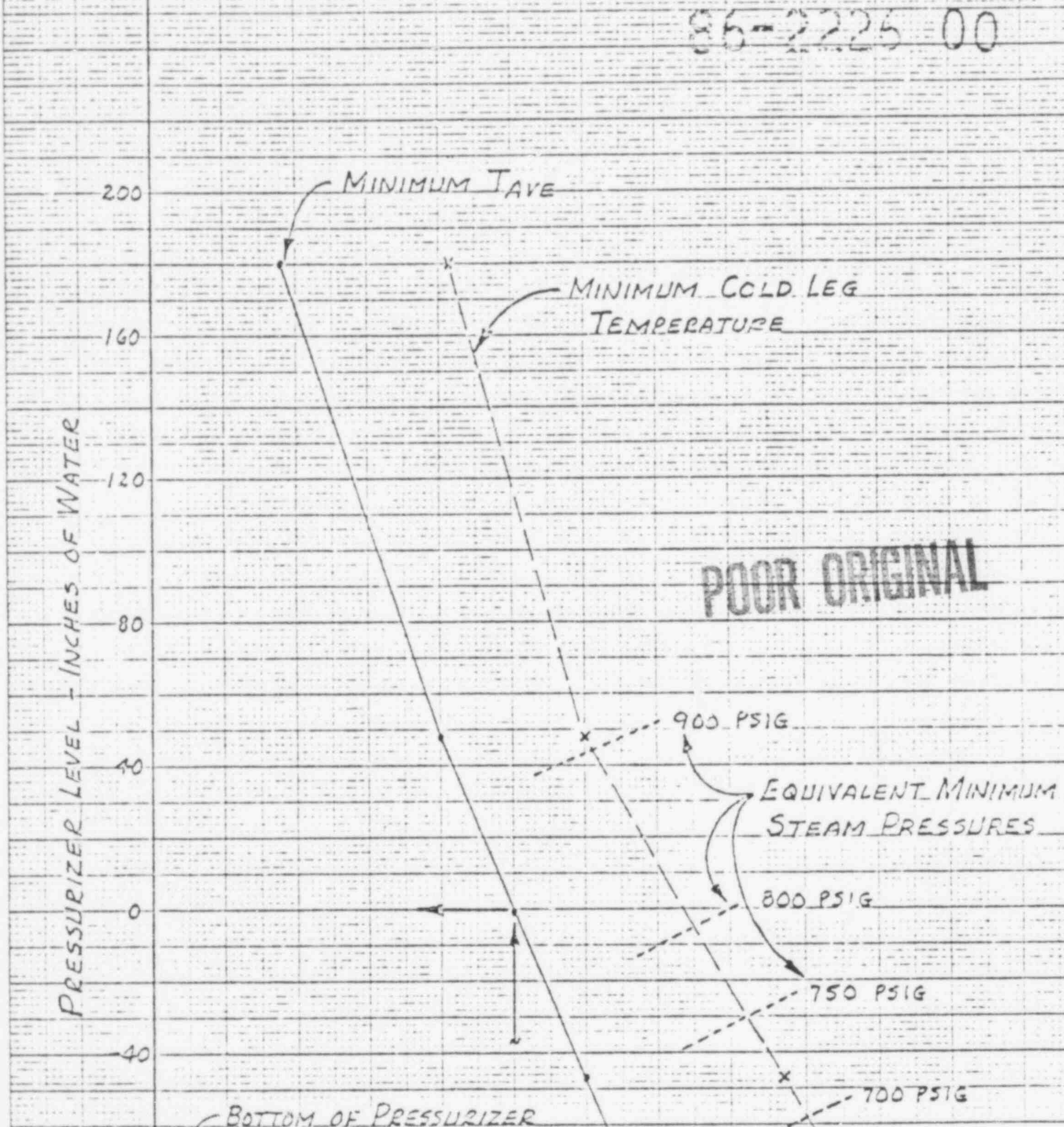

FIG 2

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PREDICTED PRESSURIZER LEVELS FOR A REACTOR TRIP FROM FULL POWER AT DAVIS-BESSE 1

86-2226 00

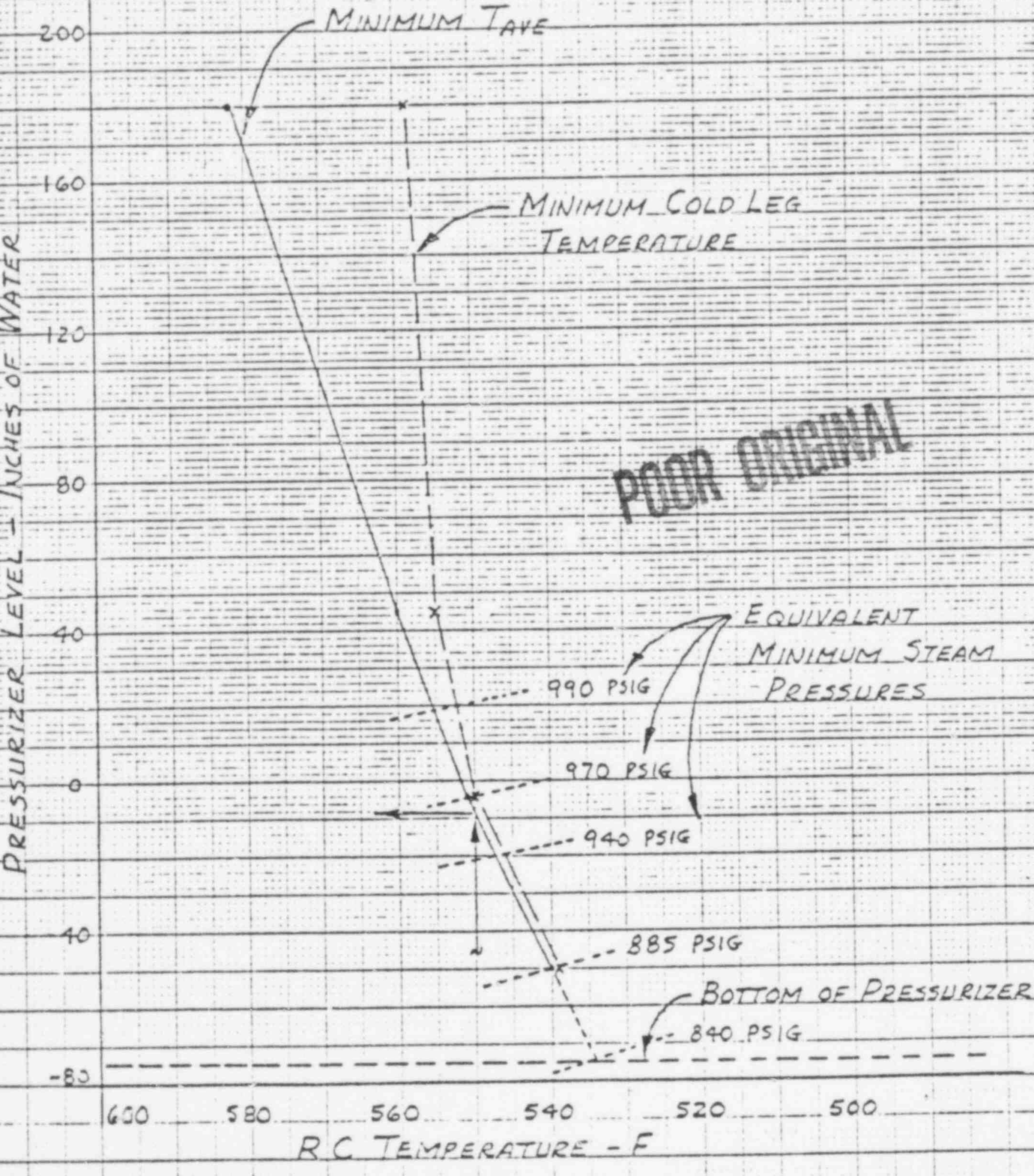

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FIG 3

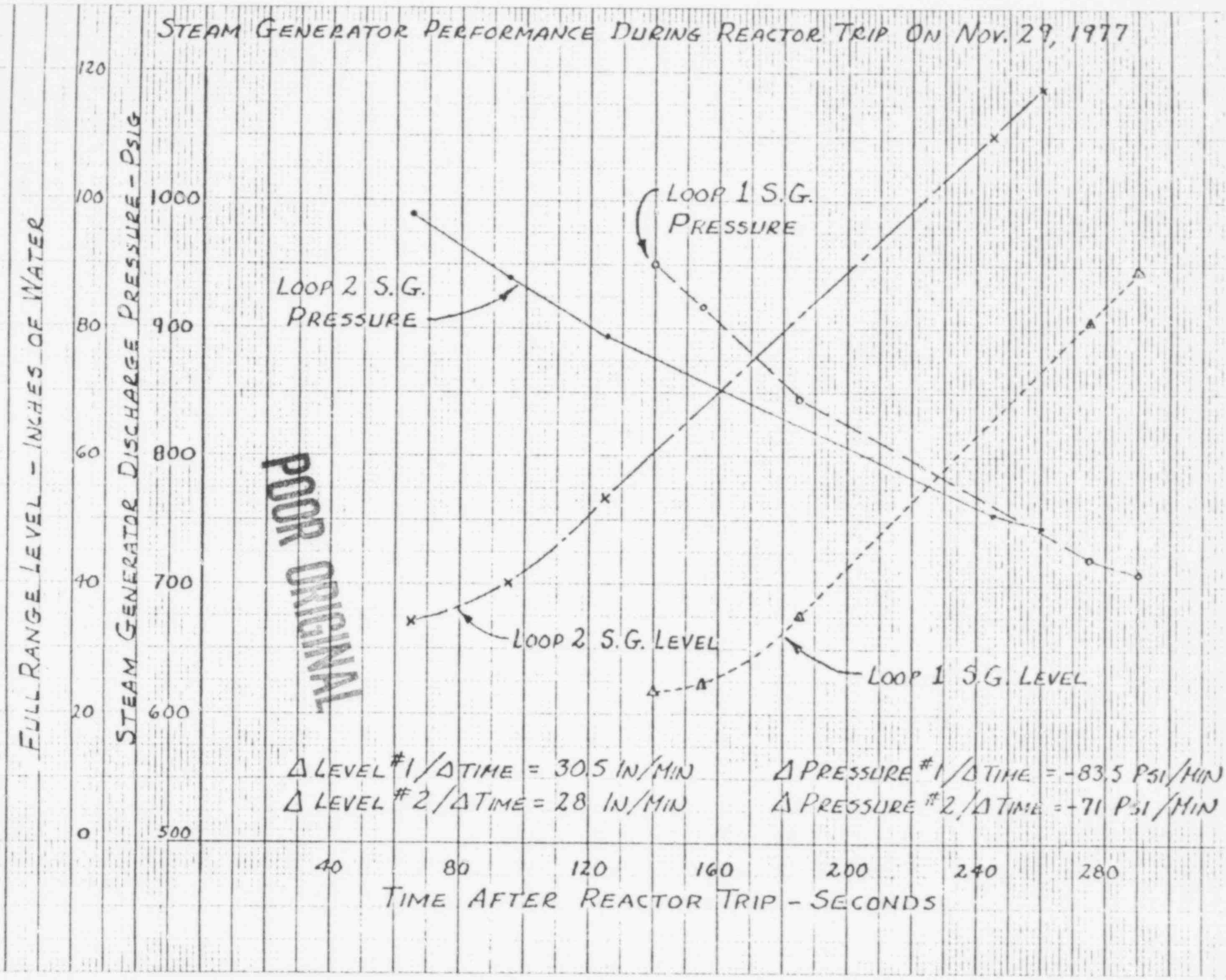

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FIG 4

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C.W. Tally	1	1			
Linda [illegible]	1				

RELEASED BY

Robert Winks 8/31/78

NAME DATE

Principal Engineer

REVIEWED BY

RM Harrington 9/1/78

NAME DATE

[illegible] 9/1/78

86-2226 00

CALCULATION DATA/TRANSMITTAL SHEET

DOCUMENT IDENTIFIER

CALC. 32 - ____ - ____

TRANS. 86 - 2226 - 00

TYPE: ___ RESEARCH & DEVELOPMENT ___ SAFETY ANALYSIS REPORT ___ NUC. SERV. INPUT ___ DESIGN RQMT. ___ DESIGN VERIF. X OTHER

TITLE Dynamic Performance of the Pressurizer During Reactor Trips at Davis-Besse 1

PREPARED BY Robert Winks REVIEWED BY RM Harrington

TITLE Principal Engineer DATE 8/31/78 TITLE Sr. Engineer DATE 9/1/78

PURPOSE:

To report on the success of a mathematical technique of calculating minimum pressurizer level when initial and final RC hot leg and cold leg temperatures and RC pressures are known relative to large upset transients such as reactor trip from full power.

SUMMARY OF RESULTS (INCLUDE DOC. ID'S OF PREVIOUS TRANSMITTALS & SOURCE CALCULATIONAL PACKAGES FOR THIS TRANSMITTAL)

The minimum level of water in the pressurizer will remain above the bottom provided the lowest value of Tave and steam pressure are above certain specified values for either a reactor trip with all RC pumps running or without the pumps running. Field data from Davis-Besse 1 plant contained in SPR # 396, 431, 435, and 476, was used to verify the accuracy of calculated minimum pressurizer levels during transients.

The Calculational File used to prepare this report is 32-9538-00.

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DISTRIBUTION

R. B. Davis
R. M. Harrington
R M Gribble
C. W. Tally
J. R. Burris
Linda Page
R. C. Lukan
R. W. Winks - Please Return Originals to me

Page ____ of ____

Babcock&Wilcox

Power Generation Group

P.O. Box 1260, Lynchburg, Va. 24505

Telephone: (804) 384-5111

December 22, 1978

BWT-1734
File: T1.2/[illegible]

Mr. C. R. Domeck
Nuclear Project Engineer
Toledo Edison Company
300 Madison Avenue
Toledo, OH 43652

Subject: Toledo Edison Company
Davis-Besse Unit 1
NSS-14
MINIMUM PRESSURIZER LEVEL REPORT

Dear Mr. Domeck:

Attached is a copy of a report, "Minimum Pressurizer Level for Various Reactor Trip Transients" prepared per your request.

Very truly yours,

R C Luken

R. C. Luken
Project Manager

For A. H. Lazar
Senior Project Manager

RCL/hj

Attachment

cc: JD Lenardson w/a
JC Lewis
DJ DeLaCroix
EC Novak/1 w/a
M Malcom/4 w/a

bcc: (all without attachment)
RW Winks
AHL/RED/FRF
Records Center T1.2
RC Luken
LB

POOR ORIGINAL

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86-2725 00

Minimum Pressurizer Level
for Various Reactor Trip
Transients

by

Robert Winks

Babcock & Wilcox Co.
Lynchburg, Virginia 24501

December 22, 1978

Reviewed by: Luther L Gaynes
Date: 12/22/78

Approved by: [illegible]
Title: [illegible]
Date: 12-22-78

POOR ORIGINAL

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86-2725 00

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1.0 Introduction:

Throughout the startup program for the Davis-Besse 1 plant a large number of reactor trip transients have occurred. These transients have revealed necessary adjustments in several of the auxiliary systems, such as higher reseating pressure of the steam relief valves and lower liquid levels in the steam generator. In the near future Toledo Edison Company plans to conduct three very significant "operational" transients in order to demonstrate proper operation of all related systems. They are: loss of electrical load from full power, loss of all offsite power with reactor at 15% power, and shutdown from outside the control room with the reactor at 15% power.

Previous reactor trip transients have revealed considerable overcooling of the reactor coolant system and a concern exists that excessive cooling of the primary system might occur during some of the planned reactor trip transients. A request for analysis and calculations of minimum pressurizer level during several types of reactor trip transients was made by Toledo Edison Company in order to understand the limits required to avoid emptying the pressurizer. The scope of this report will be to describe several typical reactor trip transients, and to predict the minimum pressurizer level, and to state any limitations on plant operation to prevent emptying the pressurizer.

2.0 Objectives of the Analysis:

Tabulate the specific reactor trip transient test data which was used to complete the study of minimum pressurizer level during selected reactor trip transients.

Show that RC pressure will remain higher than 1650 psig during these selected reactor trip transients by incorporating actual Davis-Besse 1 test data.

Show that the minimum pressurizer level for a normal reactor trip transient at any initial power level will be above a zero indicated level.

Show under what conditions minimum pressurizer level will remain above a zero indication on a reactor trip following a loss of main feedwater.

Show that minimum pressurizer level for a reactor trip coincident with loss of station power will remain above a zero indication provided the operator maintains a proper water level in the steam generator via the auxiliary feedwater system.

3.0 Conclusions

1. For a normal reactor trip from full power (Case 1) with main feedwater, pumps operating and the main feedwater system holding a 2 foot level in each steam generator, the pressurizer level will remain on scale provided steam generator pressure is no lower than 980 psig.

2. For a normal reactor trip from 15% power (Case 2) with main feedwater pumps operating the pressurizer level will remain on scale if steam pressure does not drop below 980 psig. At the same time the cold leg temperatures must not decrease below 545F in the first 60 to 90 seconds after the reactor trip.

3. For a reactor trip from low power levels with loss of main feedwater pumps (Case 4) the pressurizer level will just barely remain "on scale" if the auxiliary feedwater maintains only a 30" level in each steam generator and the control room operator uses the makeup pumps to simultaneously regain approximately 12" of pressurizer level.

4. For a reactor trip and loss of all RC pumps and main feedwater pumps (Case 5) the pressurizer level will not drop "off scale." If the auxiliary feedwater system was used to generate a 100" startup level in each steam generator, (and steam pressure decreased to 770 psig) then pressurizer level would decrease to a zero indication.

5. The 3 foot setpoint for startup level during auxiliary feedwater system operation appears to be satisfactory in keeping pressurizer level above a zero indication except for Case 3, the reactor trip transient from full power due to a loss of main feedwater flow.

6. The performance of the auxiliary feedwater system on the loss of offsite power transient of November 29, 1977, has been applied to both natural circulation and forced convection situations for this analysis. By comparing the test data of SPR #430, a reactor trip on March 1, 1978, with the data of November 29, 1977, it is clear that applying the November 29th auxiliary feedwater system performance to reactor trip transients with RC pumps operating is more conservative (lower pressurizer levels) than applying an appropriate auxiliary feedwater system performance corresponding to all RC pumps operating.

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4.0 Summary of Analytical Method

The work performed in this report was targeted toward preparing calculated RC pressurizer levels at Davis-Besse 1 for the following kinds of reactor trips. (Refer to available site problem reports which describe actual plant performance during reactor trip transients.)

Case No.	Reactor trip transient
1	Normal reactor trip (100%) with RC pumps and main feedwater system operating. Normal control of steam pressure and water level in both steam generators.
2	Normal reactor trip from 15%; other conditions same as 1 above.
3	Loss of feedwater with reactor power at 100%. RC pumps are operating and the operator manually controls final steam generator levels using the auxiliary feedwater system.
4	Loss of feedwater with reactor power at 15%. Other conditions same as 3 above.
5	Loss of offsite power with reactor power at 15%. RC pumps and main feedwater pumps shutdown. Operator manually controls the auxiliary feedwater system.

The procedure used to analyze these five cases was as follows:

1. Several recent site problem reports were studied to determine the relationship between RC pressure and T_{ave} following reactor trip at DB-1 (section 6.1). This relationship was used to determine proper specific volumes for the primary coolant following a reactor trip. An incidental use of this data was to verify that the reactor trips listed as Cases 1-5 previously will not actuate the Safety Features Actuation System.
2. Using the RC pressure — T_{ave} relationships just discussed, the contraction of the RC coolant after a reactor trip was determined, hence the level change in the pressurizer was calculated. The particular technique used is described in section 6.3.

4.1 Tabulated Description of Actual Reactor Trip Transients at DB-1

Table 1 presents recent reactor trip transients used to determine a T_{ave} — RC pressure relationships assumed in this report. Each event was reported by a site problem report (SPR) numbered as shown in Table 1.

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Table 1

SRP No.	Rx Trip Date	Brief Description of Transient
476	8/2/78	Following a control rod insertion test a large neutron power error drove feedwater to overfeed the steam generators and overcool the RC system. After the trip SG levels were held at 40 inches by main feedwater.
484	9/28/78	At 95% power a failed BY ΔP transmitter initiated a runback. Due to erroneous loop 1 and 2 RC flow indications, feedwater flow to each steam generator was re-ratioed. Operator over fed the steam generators and overcool RCS causing a low pressure trip. After the trip SG levels were held at 100 inches by main feedwater.
485	10/3/78	A turbine trip occurred at 70% power level. Runback proceeded for 30 seconds before low RC pressure tripped reactor. SG levels were held at approximately 4 feet by main feedwater following the trip.
431	2/24/78	Rx tripped by high reactor outlet temperature. Turbine tripped and main feedwater flows reduced to zero in about 1 minute. Steam generator startup levels maintained above 50 and 75 inches in loops #1 and #2.
435	4/2/78	A planned turbine trip test from 75% power level. Reactor power runback proceeded for approximately 30 seconds. Reactor tripped on low RC pressure due to main feedwater overcooling primary side.
396	11/29/77	At 40% power level all station power was lost and the reactor and RC pumps were shutdown. Loss of main feedwater pumps set up the auxiliary feedwater system and 10 foot and 8foot levels were maintained, respectively, in the two steam generators.

4.2 Relationship Between RC Pressure and T_{ave} Following Rx Trips at DB-1

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The relationship of minimum RC pressure for a minimum T_{ave} following a reactor trip at Davis-Besse 1 is shown in Figures 1 and 2. Figure 1 displays the most recent reactor trip transients and indicates a slightly higher RC pressure due to the improved operation of the steam relief valves. Figure 2 shows that there have been instances of RC pressure decreasing to 1650 psig on some reactor trip transients. This information has been included to verify the minimum T_{ave} values used in the following analysis. Figure 2 shows a loss

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of RC pumps cooldown as well as a normal RC pump operating cooldown of the RC system.

4.3 Method of Analysis — An Example Calculation

The initial mass of reactor coolant immediately prior to a reactor trip transient is determined by knowing three RC system volumes and evaluating the proper specific volumes of the fluid at reactor outlet and inlet temperatures and at saturation temperature within the pressurizer.

For example: At 100% power level we know the following information:

Tave	582F
RC pressure	2170 psia
T hot leg	605.5F
T cold leg	559F
Hot leg volume	5471 ft^3
Cold leg volume	4955 ft^3
Pressurizer level	200 inches
Pressurizer volume	864 ft^3

The specific volume of the hot leg reactor coolant at 605.5F is 0.023491 ft^3/lb whereas the specific volume of the cold leg coolant at 559F is 0.021641 ft^3/lb. The fluid contained in the pressurizer is at saturation temperature at 2170 psia pressure so its specific volume is 0.026525 ft^3/lb. The initial (and final) mass of the reactor coolant is:

$$Mo = \frac{V_{hot}}{\nu_{hot}} + \frac{V_{cold}}{\nu_{cold}} + \frac{V_{pzr}}{\nu_{pzr}}$$

$$= \frac{5471}{0.023491} + \frac{4955}{0.021641} + \frac{864}{0.026525}$$

$$Mo = 494{,}435 \text{ lbs.}$$

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It is conservative to predict a minimum pressurizer level based on a contraction of the fluid in the primary system by [illegible] no net addition of mass to the RC system (via makeup flow) during the initial 60 seconds or so of the reactor trip transient.

Now, by reversing the application of the above equation, it is possible to find the amount of reactor coolant remaining in the pressurizer at [illegible] or "minimum" values of RC pressure and temperatures.

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For example, what is the minimum pressurizer level corresponding to a reactor outlet temperature of 551F, a reactor inlet temperature of 550F and a minimum RC pressure of 1735 psia?

The proper specific volume values are:

$$\nu_{hot} = 0.021538 \ ft^3/lb$$
$$\nu_{cold} = 0.021506 \ ft^3/lb$$
$$\nu_{pzr} = 0.02443 \ ft^3/lb$$

Solving for the final pressurizer volume;

$$V_{pzr} = \left\{Mo - \frac{V_{hot}}{\nu_{hot}} - \frac{V_{cold}}{\nu_{cold}}\right\} \times \nu_{pzr}$$

$$= \left[494,435 - \frac{5471}{0.021538} - \frac{4955}{0.021506}\right] \times 0.02443$$

$$V_{pzr} = 245 \ ft^3$$

The final pressurizer level is:

$$\Delta V_{pzr} = 864 - 245 = 619 \ ft^3$$
$$V_{pzr} \text{ level} = 619/3.2 \ ft^3/inch$$
$$= 193 \text{ inches}$$

Final pressurizer level = 200" - 193" or 7 in. (above the zero indication).

Whenever a reactor trip transient starts at 100% power and the primary fluid temperature drops below 550F (and 1720 psig), then the minimum pressurizer level will nearly equal a zero indication of level which is 75 inches above the bottom of the pressurizer. No operator action involving makeup flowrate was assumed. Also, the corresponding pressure in each steam generator to generate a 550F RC system temperature would be approximately 980 psig assuming a 6F difference between T_{cold} and saturation temperature.

On the following pages are displayed tables of calculated pressurizer levels for the different cases described on page 6.

750171

THE TOLEDO EDISON COMPANY
TELEPHONE CALL DOCUMENTATION
ED 6650

ORIGINATOR: Terry Murray	COMPANY/ORGANIZATION: Toledo Edison Company		FILE: TT 3.3
CALL MADE TO: Bill Spangler	COMPANY/ORGANIZATION: B&W Lynchburg		ROUTE TO: 1. 2.
CONFERENCE CALL PARTIES: Fred Faist, Chuck Domeck, Ed Kane, Dick DeMars, Bob Winks, Ray Luken, Al Lazar			3. 4.
STATION/UNIT: D-B #1	DATE: July 25, 19 78	TIME: 1430 a.m. p.m.	5.

SUBJECT:

Terry Murray reviewed the question that was discussed, i.e., on the November 29th Event 1977 when the pressurizer level dropped below indicated range, how can we, Toledo Edison, rationaliz continued operation given the fact that during this event pressurizer level did go off scale. We must also consider that the second auxiliary feedpump did not start until later. The transient analysis indicates that we should not lose levels but in actual experience we did. What is the difference between the two? What have we done to correct the situation? Bob Winks of B&W reminded us that the main steam safety valves had a very large effect on the transient that was observed in the November 29th Event. During that event, steam pressure was allowed to drop to somewhere between 940-950 pounds. Based on the data observed during the 75% turbine trip in April of this year, we know that the adjustments that we made in the interim now prevented steam pressure from going below 975. Since the April 2nd turbine trip test, we have in fact made further adjustments to better refine the steam pressure control transient. Now we expect that steam pressure will be maintained even ~~either~~ higher than the 975 because there were several valves that had to have their setpoint adjusted upward. The improvements that were made as a result of these upward setpoint adjustments can be demonstrated by the fact that during the turbine trip test, we did in fact maintain pressurizer level on scale.

Another significant item that was brought out in the discussion with those people was that if in fact both auxiliary feedpumps did come on simultaneously as designed, and if there was a significant difference as a result of the second feedpump coming on, that the expansion of

COPIES TO: F. Faist, C. Domeck, Section Heads, L. E. Roe, J. S. Grant, Don Lee , TOM 7/27/78

PREPARED BY: TD Murray 750172 DATE 7/26/78 the pressurizer steam bubble into the No. 2 Loop, i.e., the Loop that is connected to the pressurizer, that this would only give you a vapor lock or affect the natural circulation in the No. 2 Loop. The No. 1 Loop would still be available for natural circulation and one loop is sufficient to remove the decay heat.

Third item directly related to this is that the review of the strip charts and plots for the November 29th Event indicate that there was only approximately a minute difference in the time that the two pumps were actuated and that during this period of time the pressurizer level was still falling and that pressurizer decrease effect was a result of both auxiliary feedpumps feeding steam generators.

It was agreed that our position is one that we have made adjustments to the main steam safety valves which would greatly reduce the shrinkage that we see in the pressurizer in an event like this. Second point is that if both aux feedpumps do come on and you get steam blockage, it would only affect one loop. The other loop would be available for decay heat removal. The third point is that the actual difference in time between the two auxiliary feedpumps in the November 29th Event was so slight that in fact the effect that we saw was a result of both auxiliary feedpumps.

TDM/daw

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

To R.P. WILLIAMSON - NUCLEAR SERVICE	FEB 17 1978 NUCLEAR SERVICE
From C.W. TALLY - CONTROL ANALYSIS (EXT. 2883)	SPR 396 BDS 663-5
Cust. TECO	File No. or Ref.
Subj. SPR 396	Date FEBRUARY 10, 1978

This letter to cover one customer and one subject only.

Reference: 1. Letter BWT-1609, J.A. Lauer to C.R. Domeck, T1.2/12B, dated December 5, 1977.

Engineering has evaluated the transient described in SPR 396 resulting in the following comments:

1. The classification of the transient in Reference 1 was correct and no further comment on this aspect is required.

2. The decrease in pressurizer level (off-scale low) is indicative of rapid steam generator level increases following the initiation of AFW. This undesirable effect is symptomatic of high level setpoints. Conversations with Fred Miller of TECO Engineering have confirmed TECO's awareness of this problem and their desire to have it rectified. In view of the fact that Davis-Besse I has elevated loops. there should be little difficulty in decreasing the level setpoint with appropriate analysis. The funding for this work will be pursued through Project Management.

3. Engineering has been unable to satisfactorily resolve the dissimilar behavior of the two OTSG's during the transient. During the 5 to 15 minute period of the transient, the two steam pressures moved in opposite directions and were considerably apart. The plant computer printout says a main steam line warm up isolation valve was open during this time ("22:55:56 Z688 MN STM Line 2 WU ISO VLV CLOS"), but TECO Engineering says the valve indicator is wired backwards, indicating that it actually was closed until 22:55:56, when an operator opened it. If indeed it was closed until this time, there appears to be no logical explanation for the steam pressure differences. This should be passed on to TECO Engineering, since Plant Design has no further information with which to investigate this anomaly.

CW Tally
C.W. Tally

7550174

cc: J.R. Burris
R.B. Davis
J.A. Lauer
R.W. Winks

POOR ORIGINAL

22:5[illegible]:49 SR's energized NI's NI-1,2

22:51:[illegible]1 MU #1 Pump on

22:56:25 AFPT 2 trouble

22:5[illegible]:32 AFPT 1 trouble

22:57:16 AFPT's normal

NOTES: NI-1 failed low at some later time - preamplifier problem - preamp has now been replaced.

Electrical problems 1) 34560, 61 should not have been opened manually - the 30 sec. time sequence should have been allowed to time out for anti-motoring. 2) The transfer of A Bus to 01 was successful out later tripped - cause unknown as yet. 3) Gr 7 dropped rod problem not identified as yet.

4) Reactimeter data shows RCS pressure dropped to ~1500 psig.
5) Evaluation of computer printouts has uncovered several computer points and alarms in error - MWR's have been written to correct these.
6) Turb. trip procedure modification made to correct the operation of 34560, 61.
7) Cause of DG #1 tripping after ira start sequence is unknown.
8) Discovered leads lifted frr ICS 11A,B that prevented switchover from Turbine Bypass Valves during a Circ Water lineup change. Problem corrected by tying down these leads.
9) Circ Water Valve problem - Maint. preparing to repair.

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To		From
[illegible]	BABCOCK & WILCOX	LYNCHBURG, VA.
[illegible]	1/31/78	Fred R. Faist, Site Operations Manager

~~FP 800.04~~

Attached is the reactimeter data obtained during the 11/29/77 transient at Davis-Besse I.

BWT-1509 is the conclusion reached from this data.

SPR 396

Yours truly,

Fred R. Faist

FRF:mlf
encl.
cc: J. A. Lauer

IDG

File 800 04

to Mackall McAlpine

POOR ORIGINAL

750176

[illegible] TELECOPY

Power Generation Group

P.O. Box 1260, Lynchburg, Va. 24505
Telephone: (804) 384-5111

December 5, 1977

BWT-1609
File: T1.2/12B

Mr. C. R. Domeck
Nuclear Project Engineer
Toledo Edison Company
300 Madison Avenue
Toledo, Ohio 43652

cc: [illegible]
Halsted
[illegible]
R. Faist
C. Luken

Subject: Toledo Edison Company
EVALUATION OF NOVEMBER 29 TRANSIENT
Davis-Besse Unit 1
NSS-14

Dear Mr. Domeck:

B&W has evaluated the November 29 reactor trip at Davis-Besse and found no harmful effects were incurred in the reactor coolant boundary. The reactor coolant pressure dropped about 410 psi in 7-1/2 minutes. The temperature in the #1 cold leg dropped approximately 56°F in 3-1/4 minutes.

The design specification for Davis-Besse components required evaluation of 40 cycles of loss of station power. This transient includes a pressure drop of 420 psi and a temperature drop of 20°F in 20 seconds. The effect of the actual pressure drop is about the same as the design transient, since pressure stress is not time dependent. The actual temperature drop was greater than the design transient but the rate of temperature drop was much less severe, and they tend to offset each other. The net result is that the fatigue usage of this reactor-trip transient is about the same as that predicted for one cycle of loss of station power.

B&W has no objection to continued operation of Davis-Besse.

Very truly yours,

A. H. Lazar
Senior Project Manager

J. A. Lauer

By: J. A. Lauer
Project Manager

JAL/hj

POOR ORIGINAL

cc: J. D. Lenardson
J. C. Lewis
[illegible]
P. P. Anas/4c
E. C. Novak/1c

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7501?8

NOT CERTIFIED **** NOT CERTIFIED **** NOT CERTIFIED **** NOT CERTIFIED ****

REPRINT MONITORED VARIABLES

DASEY NUMBER	UNITS	----TITLE----
2	SEC	TIME ([illegible])
6??	DEGF	UNIT OUTLET TP (DEGF)
6??	DEGF	RC INLET TP 1A2-?? (DEGF)
6??	DEGF	RC INLET TP 1A1-N? (DEGF)
900?		----------------------(4) RCS FLOW LP1
900?		----------------------(4) RCS FLOW LP2
900?		----------------------(5) SU FW FLOW LP2
900?		----------------------(5) SU FW FLOW LP1
1???	PCT	OTSG B OPER LVL (PCT) LP2
???	PCT	OTSG A OPER LVL (PCT) LP1
?3?	PSIG	OTSG B OUTLET SP (PSIG) LP2
9??	PSIG	OTSG A OUTLET SP (PSIG) LP1

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**** NOT CERTIFIED **** NOT CERTIFIED **** NOT CERTIFIED **** NOT CERTIFIED ****

RPRINT MONITORED VARIABLES

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CHANNEL 27	T_h Lp2 CHANNEL 6	T_c Lp2 CHANNEL 7	T_c Lp1 CHANNEL 8	CHANNEL 9	CHANNEL 10	CHANNEL 13	CHANNEL 14	OTSG op level #2 CHANNEL 15	#1 CHANNEL 17
.000	592.571	567.546	567.464	75.789	75.019	1.264	1.095	21.625	22.[illegible]
3.000	592.890	567.351	557.262	74.929	74.591	1.104	1.017	18.336	20.[illegible]
6.000	590.610	569.139	569.259	74.947	73.830	.607	.745	15.517	18.[illegible]
9.000	[illegible]	572.255	572.207	74.874	74.250	.104	.129	11.911	14.[illegible]
12.000	584.595	572.157	572.640	74.154	74.017	.083	.053	7.181	8.[illegible]
15.000	581.651	569.939	570.116	73.066	73.198	.072	.058	3.639	4.[illegible]
18.000	577.801	569.373	567.383	71.366	71.223	.070	.054	3.308	3.[illegible]
21.000	575.870	568.956	567.375	69.410	69.551	.068	.053	3.244	3.[illegible]
24.000	576.021	568.479	566.667	68.900	68.875	.067	.053	3.134	3.[illegible]
27.000	577.609	567.491	565.413	67.422	67.051	.066	.051	3.079	3.[illegible]
30.000	[illegible]	567.067	564.318	64.177	53.370	.066	.051	3.125	3.[illegible]
33.000	[illegible]	566.339	564.772	49.911	50.134	.065	.050	3.099	3.[illegible]
36.000	[illegible]	566.490	564.265	41.454	41.264	.065	.050	3.095	3.[illegible]
39.000	[illegible]	565.926	563.551	35.353	34.612	.065	.050	3.095	3.[illegible]
42.000	[illegible]	565.474	562.340	30.073	29.539	.065	.050	3.049	3.[illegible]
45.000	[illegible]	565.939	562.199	25.654	25.122	.065	.051	2.982	3.[illegible]
48.000	[illegible]	564.451	561.693	24.026	21.705	.064	.050	2.933	3.[illegible]
51.000	[illegible]	564.082	561.519	21.625	18.442	.064	.049	2.919	3.[illegible]
54.000	[illegible]	563.753	561.696	19.078	16.055	.064	.049	2.939	3.[illegible]
57.000	569.493	563.515	561.964	17.821	13.921	.065	.049	2.916	3.[illegible]
60.000	[illegible]	563.592	562.224	16.23[illegible]	11.860	.063	.049	2.939	3.[illegible]
63.000	567.651	563.603	562.498	14.326	9.333	.063	.049	2.930	3.[illegible]
66.000	567.717	563.719	562.709	13.978	6.430	.063	.047	2.925	3.[illegible]
69.000	567.607	563.595	562.383	13.058	5.576	.063	.047	2.890	3.[illegible]
72.000	567.757	563.908	562.559	11.945	2.480	.063	.049	2.893	4.[illegible]
75.000	[illegible]	563.790	563.042	11.373	-.003	.063	.049	2.890	3.[illegible]
78.000	[illegible]	563.725	563.103	10.320	-.003	.063	.049	2.915	3.[illegible]
81.000	568.671	563.663	563.130	9.051	-.003	.062	.049	2.810	3.[illegible]
84.000	[illegible]	563.399	563.103	9.023	-.003	.062	.049	2.893	3.[illegible]
87.000	570.[illegible]	562.559	562.767	8.762	-.003	.062	.048	2.912	3.[illegible]
90.000	[illegible]	562.068	562.092	8.227	-.003	.061	.049	2.896	3.[illegible]
93.000	[illegible]	560.975	561.431	7.669	-.003	.061	.048	2.912	3.[illegible]
96.000	[illegible]	559.633	560.592	7.154	-.003	.061	.049	2.899	4.[illegible]
99.000	[illegible]	558.223	560.454	6.66[illegible]	-.003	.061	.047	2.866	3.[illegible]
102.000	[illegible]	557.132	560.257	6.213	-.003	.061	.047	2.935	3.[illegible]
105.000	[illegible]	555.997	560.066	5.735	-.003	.061	.047	2.777	3.[illegible]
108.000	[illegible]	554.879	559.990	5.513	-.003	.063	.046	2.854	3.[illegible]
111.000	[illegible]	553.889	560.002	5.169	-.003	.060	.045	2.814	3.[illegible]
114.000	[illegible]	553.065	560.081	4.551	-.003	.060	.046	2.805	3.[illegible]
117.000	[illegible]	552.051	560.139	4.34[illegible]	-.003	.060	.046	2.789	3.[illegible]
120.000	[illegible]	551.156	560.219	3.703	-.003	.051	.047	2.733	3.[illegible]
123.000	[illegible]	550.397	560.319	3.532	-.003	.060	.047	2.725	3.[illegible]
126.000	[illegible]	549.732	560.432	3.071	-.003	.062	.046	2.693	3.[illegible]
129.000	[illegible]	549.123	560.527	2.571	-.003	.061	.048	2.738	3.[illegible]
132.000	[illegible]	548.323	560.627	2.120	-.003	.060	.047	2.629	3.[illegible]
135.000	[illegible]	547.455	560.716	1.980	-.003	.060	.045	2.557	3.[illegible]
138.000	571.453	546.772	560.762	1.500	-.003	.060	.046	2.558	3.[illegible]
141.000	570.922	546.122	560.737	.071	-.003	.059	.047	2.538	3.[illegible]
144.000	569.914	545.575	560.722	-.003	-.003	.060	.045	2.537	3.[illegible]
147.000	569.982	544.763	560.658	-.003	-.003	.060	.046	2.716	3.[illegible]
150.000	571.355	544.019	560.524	.052	-.003	.060	.046	2.524	3.2[illegible]

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RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 6 (Th Loop2)	CHANNEL 7 (Tc Loop2)	CHANNEL 8 (Tc Loop1)	CHANNEL 9	CHANNEL 10	CHANNEL 13	CHANNEL 14	CHANNEL 15 (Loop 1)	CHANNEL 17 (Loop 2)
153.000	571.899	543.235	560.389	.163	-.003	.060	.045	2.505	3.137
156.000	571.973	542.557	560.246	-.003	-.003	.060	.045	2.493	3.128
159.000	570.666	541.974	560.145	.022	-.003	.060	.045	2.478	3.055
162.000	572.342	541.235	560.055	.003	-.003	.060	.047	2.475	2.979
165.000	571.757	540.726	559.950	.005	-.003	.060	.045	2.280	2.855
168.000	570.599	540.339	559.938	-.003	-.003	.060	.046	2.411	2.843
171.000	570.046	539.425	559.831	-.003	-.003	.060	.045	2.435	2.832
174.000	570.449	538.865	559.514	.003	-.003	.060	.044	2.347	2.731
177.000	570.501	538.257	558.909	.000	-.003	.060	.045	2.374	2.755
180.000	569.466	537.378	557.206	.000	-.003	.060	.045	2.353	2.755
183.000	570.134	536.693	555.137	.009	-.003	.060	.045	2.377	2.713
186.000	571.914	535.791	553.541	-.003	-.003	.060	.045	2.316	2.657
189.000	571.529	535.325	551.520	-.003	-.003	.060	.045	2.232	2.717
192.000	570.513	534.781	549.781	-.003	-.003	.059	.045	2.296	2.677
195.000	570.653	533.945	547.864	-.003	-.003	.059	.045	2.271	2.649
198.000	570.925	532.319	545.798	.005	-.003	.060	.046	2.277	2.643
201.000	571.422	532.312	543.939	.014	-.003	.060	.045	2.259	2.622
204.000	571.471	531.902	542.667	.009	-.003	.060	.045	2.237	2.616
207.000	571.477	531.372	541.358	.022	-.003	.059	.045	2.402	2.603
210.000	571.675	530.819	540.274	-.003	-.003	.060	.045	3.116	2.631
213.000	571.169	530.657	539.249	.003	-.003	.060	.045	3.741	2.593
216.000	571.221	530.234	537.[illegible]10	.003	-.003	.060	.045	4.330	2.5[illegible]
219.000	571.662	529.942	536.[illegible]	.011	-.003	.060	.045	5.[illegible]33	[illegible]
222.000	571.635	529.625	535.[illegible]2	-.003	-.003	.060	.045	5.664	[illegible]
225.000	571.461	528.946	535.153	.004	-.003	.059	.045	6.354	[illegible]
228.000	571.874	528.596	534.81[illegible]	-.003	-.003	.060	.045	6.953	[illegible]
231.000	571.511	528.103	534.277	.005	-.003	.059	.045	7.551	[illegible]
234.000	571.055	527.361	533.523	-.003	-.003	.060	.045	8.121	[illegible]
237.000	570.537	526.934	533.029	.019	-.003	.060	.044	8.693	[illegible]
240.000	571.727	526.367	532.254	.033	-.003	.060	.045	9.311	[illegible]
243.000	571.221	525.805	531.079	-.003	-.003	.059	.047	9.955	[illegible]
246.000	570.606	525.237	529.921	.000	-.003	.060	.045	10.532	[illegible]
249.000	569.856	524.669	528.783	.011	-.003	.060	.045	11.223	[illegible]
252.000	569.634	524.[illegible]	527.767	.016	-.003	.058	.044	11.832	[illegible]
255.000	569.764	523.515	527.131	.009	-.003	.060	.043	12.445	[illegible]
258.000	569.729	523.232	526.260	.005	-.003	.062	.045	13.093	[illegible]
261.000	569.829	522.826	525.609	.003	-.003	.060	.045	13.746	[illegible]
264.000	568.822	522.544	525.017	-.003	-.003	.059	.045	13.981	[illegible]
267.000	569.069	522.318	524.465	.027	-.003	.059	.044	14.112	[illegible]
270.000	568.200	521.801	523.579	-.003	-.003	.058	.045	14.535	[illegible]
273.000	569.035	520.964	523.208	.065	-.003	.059	.045	14.811	[illegible]
276.000	568.468	520.570	522.591	.000	-.003	.059	.045	14.933	[illegible]
279.000	567.933	520.163	521.907	-.003	-.003	.060	.045	14.979	[illegible]
282.000	567.342	519.997	521.337	.000	-.003	.059	.045	15.019	[illegible]
285.000	566.139	519.597	520.732	-.003	-.003	.062	.044	14.948	4.[illegible]
288.000	566.029	519.997	520.281	-.003	-.003	.059	.044	14.982	4.7[illegible]
291.000	565.934	519.997	520.076	-.003	-.003	.061	.045	14.973	5.[illegible]
294.000	565.645	519.997	519.597	.055	-.003	.059	.045	14.921	6.[illegible]
297.000	565.373	519.997	519.997	-.003	-.003	.059	.044	14.893	6.4[illegible]
300.000	564.247	519.997	519.997	-.003	-.003	.050	.038	14.253	2.653

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RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 5	CHANNEL 7	CHANNEL 8	CHANNEL 9	CHANNEL 10	CHANNEL 13	CHANNEL 14	CHANNEL 15	CHANNEL 17
	Tc loop2	Tc loop2	Tc loop1						
[illegible]3.000	5[illegible].597	519.997	519.997	-.003	-.003	.050	.038	14.177	3.[illegible]42
306.000	5[illegible]7.614	519.997	519.997	-.003	-.003	.051	.038	14.137	4.[illegible]
309.000	5[illegible].5[illegible]5	519.997	519.997	-.003	-.003	.052	.039	14.1[illegible]3	4.[illegible]
312.000	563.650	519.997	519.997	-.003	-.003	.051	.039	14.059	5.[illegible]41
315.000	5[illegible].759	519.997	519.997	-.003	-.003	.052	.039	13.9[illegible]	6.[illegible]
318.000	5[illegible].295	519.997	519.997	-.003	-.003	.052	.038	13.969	6.651
321.000	5[illegible].333	519.997	519.997	-.003	-.003	.052	.040	13.917	7.[illegible]
324.000	563.6[illegible]4	519.997	519.997	-.003	-.003	.052	.039	13.8[illegible]3	7.[illegible]
327.000	5[illegible]	519.997	519.997	-.003	-.003	.052	.038	13.[illegible]1	[illegible]
330.000	562.623	519.997	519.997	-.003	-.003	.050	.037	13.[illegible]1	9.151
333.000	5[illegible].221	519.997	519.997	-.003	-.003	.051	.037	13.7[illegible]	9.[illegible]
336.000	562.172	519.997	519.997	-.003	-.003	.051	.037	13.7[illegible]	9.[illegible]
339.000	562.634	519.997	519.997	-.003	-.003	.051	.038	13.7[illegible]	9.[illegible]
342.000	563.127	519.997	519.997	-.003	-.003	.051	.039	13.6[illegible]	9.759
345.000	562.739	519.997	519.997	-.003	-.003	.051	.037	13.62[illegible]	9.[illegible]
348.000	562.327	519.997	519.997	-.003	-.003	.051	.039	13.5[illegible]	9.[illegible]
351.000	562.356	519.997	519.997	-.003	-.003	.051	.039	13.5[illegible]0	9.[illegible]
354.000	562.439	519.997	519.997	-.003	-.003	.050	.039	13.5[illegible]5	9.[illegible]
357.000	562.556	519.997	519.997	-.003	-.003	.051	.037	13.[illegible]0	9.[illegible]
360.000	562.495	519.997	519.997	-.003	-.003	.052	.037	13.[illegible]4	9.515
363.000	562.755	519.997	519.997	-.003	-.003	.052	.037	13.[illegible]1	9.[illegible]7
366.000	562.282	519.997	519.997	-.003	-.003	.050	.037	13.[illegible]	[illegible]
369.000	562.163	519.997	519.997	-.003	-.003	.051	.037	13.[illegible]	[illegible]
372.000	562.233	519.997	519.997	-.003	-.003	.051	.037	13.[illegible]23	9.31[illegible]
375.000	562.221	519.997	519.997	-.003	-.003	.051	.037	13.439	9.3[illegible]
378.000	562.041	519.997	519.997	-.003	-.003	.051	.037	13.335	[illegible]
381.000	561.986	519.997	519.997	-.003	-.003	.051	.037	13.421	9.7[illegible]
384.000	561.983	519.997	519.997	-.003	-.003	.051	.037	13.37[illegible]	9.7[illegible]
387.000	561.951	519.997	519.997	-.003	-.003	.051	.037	13.383	9.7[illegible]2
390.000	561.987	519.997	519.997	-.003	-.003	.052	.037	13.371	9.7[illegible]
393.000	561.745	519.997	519.997	-.003	-.003	.051	.035	13.[illegible]58	[illegible]
396.000	561.624	519.997	519.997	-.003	-.003	.052	.037	13.371	[illegible]
399.000	561.110	519.997	519.997	-.003	-.003	.051	.037	13.340	[illegible]
402.000	560.9[illegible]0	519.997	519.997	-.003	-.003	.053	.037	13.[illegible]46	9.[illegible]11
405.000	560.732	519.997	519.997	-.003	-.003	.051	.037	13.313	[illegible]
408.000	5[illegible].493	519.997	519.997	-.003	-.003	.051	.037	13.306	[illegible]
411.000	560.573	519.997	519.997	-.003	-.003	.051	.036	13.255	[illegible]
414.000	560.291	519.997	519.997	-.003	-.003	.051	.037	13.279	9.775
417.000	560.159	519.997	519.997	-.003	-.003	.052	.037	13.257	9.[illegible]
4[illegible].000	5[illegible]0.369	519.997	519.997	-.003	-.003	.051	.037	13.224	[illegible]
4[illegible].000	5[illegible]	519.997	519.997	-.003	-.003	.051	.037	13.236	[illegible]
4[illegible].000	5[illegible].730	519.997	519.997	-.003	-.003	.051	.040	13.245	[illegible]
4[illegible].000	5[illegible].511	519.997	519.997	-.003	-.003	.051	.037	13.250	[illegible]
4[illegible].000	559.[illegible]	519.997	519.997	-.003	-.003	.051	.037	13.215	[illegible]
4[illegible].000	559.125	519.997	519.997	-.003	-.003	.050	.036	13.218	9.4[illegible]
4[illegible].000	558.979	519.997	519.997	-.003	-.003	.051	.036	13.200	9.4[illegible]
441.000	55[illegible].757	519.997	519.997	-.003	-.003	.050	.037	13.184	9.4[illegible]
444.000	558.677	519.997	519.997	-.003	-.003	.051	.037	13.172	9.4[illegible]2
447.000	558.564	519.997	519.997	-.003	-.003	.051	.037	13.16[illegible]	[illegible]
450.000	558.390	519.997	519.997	-.003	-.003	.051	.037	13.145	9.431

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RPRINT MONITORED VARIABLES

Loop 2 Loop 2 Loop 1

CHANNEL 27	CHANNEL 6	CHANNEL 7	CHANNEL 8	CHANNEL 9	CHANNEL 10	CHANNEL 13	CHANNEL 14	CHANNEL 15	CHANNEL 17
[illegible]	558.378	519.997	519.997	-.003	-.003	.048	.037	13.151	9.415
[illegible]	558.482	519.997	519.997	-.003	-.003	.051	.037	13.136	9.[illegible]
[illegible]	558.357	[illegible]19.997	519.997	-.003	-.003	.051	.037	13.087	9.403
[illegible]	558.290	[illegible]19.997	519.997	-.003	-.003	.051	.036	13.102	9.385
[illegible]	558.290	[illegible]19.997	519.997	-.003	-.003	.051	.037	13.071	9.[illegible]
[illegible]	558.308	519.997	519.997	-.003	-.003	.051	.035	13.075	9.4[illegible]
[illegible]	558.232	519.997	519.997	-.003	-.003	.051	.037	13.078	9.[illegible]
[illegible]	558.165	519.997	519.997	-.003	-.003	.051	.035	13.065	9.376
[illegible]	558.073	520.494	519.997	-.003	-.003	.051	.036	13.032	9.3[illegible]1
[illegible]	558.033	519.997	519.997	-.003	-.003	.051	.037	13.017	9.[illegible]
[illegible]	558.070	519.997	519.997	-.003	-.003	.053	.035	13.037	9.[illegible]
[illegible]	558.036	519.997	519.997	-.003	-.003	.051	.037	12.[illegible]	9.[illegible]
[illegible]	557.994	519.997	519.997	-.003	-.003	.050	.036	12.9[illegible]	9.[illegible]
[illegible]	558.027	519.997	519.997	-.003	-.003	.051	.037	12.92[illegible]	9.[illegible]
[illegible]	557.807	519.997	519.997	-.003	-.003	.050	.036	12.9[illegible]	9.[illegible]
[illegible]	557.814	519.997	519.997	-.003	-.003	.050	.036	12.94[illegible]	9.330
[illegible]	557.783	519.997	519.997	-.003	-.003	.051	.036	12.917	9.373
[illegible]	557.710	519.997	519.997	-.003	-.003	.049	.037	12.9[illegible]	9.[illegible]
[illegible]	557.[illegible]	519.997	519.997	-.003	-.003	.050	.034	[illegible]	9.[illegible]
[illegible]	557.636	519.997	519.997	-.003	-.003	.050	.037	[illegible]	9.33[illegible]
[illegible]	557.576	519.997	519.997	-.003	-.003	.051	.037	[illegible]	9.2[illegible]
[illegible]	557.630	519.997	519.997	-.003	-.003	.050	.036	[illegible]	9.315
[illegible]	557.619	519.997	519.997	-.003	-.003	.051	.035	[illegible]	9.[illegible]
[illegible]	557.503	519.997	519.997	-.003	-.003	.050	.035	[illegible]	9.[illegible]
[illegible]	557.417	519.997	519.997	-.003	-.003	.050	.037	12.[illegible]73	9.220
[illegible]	557.435	519.997	519.997	-.003	-.003	.051	.036	12.[illegible]32	9.[illegible]
[illegible]	557.402	519.997	519.997	-.003	-.003	.050	.036	12.[illegible]35	9.[illegible]45
[illegible]	557.359	519.997	519.997	-.003	-.003	.050	.035	12.731	9.2[illegible]
[illegible]	557.377	519.997	520.324	-.003	-.003	.051	.036	12.7[illegible]	9.[illegible]
[illegible]	557.322	519.997	520.830	-.003	-.003	.051	.035	12.775	9.[illegible]
[illegible]	557.262	519.997	521.033	-.003	-.003	.050	.036	12.7[illegible]	9.[illegible]
[illegible]	557.209	519.997	521.251	-.003	-.003	.050	.035	12.752	9.1[illegible]3
[illegible]	557.167	519.997	521.776	-.003	-.003	.050	.035	12.7[illegible]	9.[illegible]
[illegible]	557.102	519.997	522.158	-.003	-.003	.051	.036	12.739	9.421
[illegible]	557.164	519.997	522.473	-.003	-.003	.050	.035	12.727	9.[illegible]
[illegible]	557.173	519.997	522.643	-.003	-.003	.051	.035	12.711	9.[illegible]
[illegible]	557.160	519.997	522.988	-.003	-.003	.051	.036	12.702	9.[illegible]
[illegible]	557.135	519.997	523.342	-.003	-.003	.050	.036	12.675	9.[illegible]
[illegible]	557.093	519.997	523.583	-.003	-.003	.050	.035	12.678	9.311
[illegible]	557.014	519.997	523.867	-.003	-.003	.050	.036	12.665	9.[illegible]
[illegible]	557.081	519.997	524.163	-.003	-.003	.051	.035	12.647	9.[illegible]
[illegible]	557.069	519.997	524.468	-.003	-.003	.051	.035	12.[illegible]	9.[illegible]
[illegible]	557.154	519.997	524.727	-.003	-.003	.050	.036	12.623	9.[illegible]
[illegible]	557.044	519.997	524.938	-.003	-.003	.051	.035	12.620	9.[illegible]
[illegible]	556.959	519.997	525.222	-.003	-.003	.051	.035	12.611	9.[illegible]
[illegible]	555.977	519.997	525.487	-.003	-.003	.050	.035	12.562	9.211
[illegible]	556.745	519.997	525.545	-.003	-.003	.050	.035	12.510	9.2[illegible]7
[illegible]	556.958	519.997	525.967	-.003	-.003	.050	.035	12.540	9.[illegible]
[illegible]	556.907	519.997	526.107	-.003	-.003	.050	.035	12.556	9.27[illegible]
[illegible]	556.779	519.997	526.260	-.003	-.003	.050	.036	12.498	9.311

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RPRINT MONITORED VARIABLES

POOR ORIGINAL

CHANNEL 27	CHANNEL 6	CHANNEL 7	CHANNEL 8	CHANNEL 9	CHANNEL 10	CHANNEL 13	CHANNEL 14	CHANNEL 15	CHANNEL 17
603.000	556.238	519.997	525.629	-.003	-.003	.049	.036	12.431	9.139
606.000	551.098	519.997	525.081	-.003	-.003	.044	.025	11.903	[illegible]
609.000	554.741	519.997	524.230	-.003	-.003	.031	.000	10.819	8.472
612.000	555.942	519.997	526.327	-.003	-.003	.050	.034	12.345	9.174
615.000	556.632	519.997	527.295	-.003	-.003	.050	.035	12.473	9.311
618.000	555.665	519.997	526.559	-.003	-.003	.048	.032	12.247	9.128
621.000	554.237	519.997	525.277	-.003	-.003	.041	.025	11.655	7.654
[illegible]	553.730	519.997	523.778	-.003	-.003	.033	.021	12.644	[illegible]
[illegible]	556.379	519.997	525.344	-.003	-.003	.055	.000	11.373	[illegible]
[illegible]	554.817	519.997	524.374	-.003	-.003	.014	.022	11.384	[illegible]
633.000	555.110	519.997	526.763	-.003	-.003	.054	.031	12.085	[illegible]
636.000	556.266	519.997	527.764	-.003	-.003	.050	.036	12.373	9.237
639.000	556.232	519.997	529.014	-.003	-.003	.050	.035	12.339	9.335
642.000	554.455	519.997	526.574	-.003	-.003	.045	.030	11.755	8.648
645.000	554.325	519.997	526.861	-.003	-.003	.043	.027	11.500	9.829
648.000	553.373	519.997	525.628	-.003	-.003	.038	.022	11.320	8.455
651.000	554.612	519.997	527.107	-.003	-.003	.045	.030	11.835	9.013
[illegible]	555.725	519.997	529.121	-.003	-.003	.051	.035	12.239	[illegible]
[illegible]	554.550	519.997	527.108	-.003	-.003	.045	.030	11.774	[illegible]
[illegible]	553.187	519.997	526.125	-.003	-.003	.037	.023	11.243	[illegible]
[illegible]	553.358	519.997	526.491	-.003	-.003	.040	.024	11.298	[illegible]
[illegible]	555.775	519.997	528.732	-.003	-.003	.050	.035	12.125	9.333
[illegible]	555.677	519.997	528.825	-.003	-.003	.049	.035	12.124	[illegible]
[illegible]	555.552	519.997	528.990	-.003	-.003	.049	.035	12.077	9.357
[illegible]	555.464	519.997	529.006	-.003	-.003	.049	.035	12.085	9.351
[illegible]	555.418	519.997	529.138	-.003	-.003	.050	.035	12.040	[illegible]
[illegible]	555.454	519.997	529.230	-.003	-.003	.049	.035	12.022	9.351
[illegible]	555.418	519.997	529.406	-.003	-.003	.049	.035	12.022	[illegible]
[illegible]	551.725	519.997	525.566	-.003	-.003	.053	.030	10.828	[illegible]
[illegible]	555.910	519.997	525.553	-.003	-.003	.036	.011	9.342	8.371
[illegible]	552.295	519.997	529.778	-.003	-.003	.035	.020	10.862	[illegible]
[illegible]	552.241	519.997	526.733	-.003	-.003	.036	.021	10.072	[illegible]
[illegible]	552.140	519.997	526.742	-.003	-.003	.029	.020	10.865	[illegible]
[illegible]	552.167	519.997	527.523	-.003	-.003	.035	.020	11.950	[illegible]
[illegible]	552.467	519.997	526.379	-.003	-.003	.037	.022	10.947	[illegible]
[illegible]	552.409	519.997	527.053	-.003	-.003	.037	.022	10.874	[illegible]
[illegible]	552.419	519.997	527.288	-.003	-.003	.035	.023	10.877	8.573
[illegible]	552.275	519.997	527.325	-.003	-.003	.035	.021	10.834	[illegible]
[illegible]	552.493	519.997	527.053	-.003	-.003	.039	.023	11.003	[illegible]
[illegible]	554.916	519.997	529.552	-.003	-.003	.048	.035	11.781	[illegible]
[illegible]	554.978	519.997	529.922	-.003	-.003	.048	.035	11.814	[illegible]
[illegible]	555.701	519.997	529.739	-.003	-.003	.049	.037	11.750	[illegible]
[illegible]	554.820	519.997	529.775	-.003	-.003	.048	.035	[illegible]	[illegible]
[illegible]	554.917	519.997	529.760	-.003	-.003	.049	.035	[illegible]	[illegible]
[illegible]	554.780	519.997	529.955	-.003	-.003	.048	.035	[illegible]	[illegible]
[illegible]	554.673	519.997	530.209	-.003	-.003	.048	.035	11.835	[illegible]
[illegible]	553.797	519.997	529.257	-.003	-.003	.044	.031	11.311	[illegible]
[illegible]	552.192	519.997	527.591	-.003	-.003	.035	.035	[illegible]	[illegible]
[illegible]	551.655	519.997	527.523	-.003	-.003	.036	.020	[illegible]	[illegible]
[illegible]	551.270	519.997	528.097	-.003	-.003	.031	.027	10.725	8.625

CHK 1

750184

RPRINT MONITORED VARIABLES

POOR ORIGINAL

CHANNEL 27	CHANNEL 6	Loop 2 CHANNEL 7	Loop 1 CHANNEL 8	CHANNEL 9	CHANNEL 10	CHANNEL 13	CHANNEL 14	Loop 2 CHANNEL 15	CHANNEL 17
[illegible]	551.645	519.997	525.327	-.003	-.003	.035	.021	10.439	9.479
[illegible]	551.831	519.997	527.618	-.003	-.003	.035	.021	10.541	8.573
[illegible]	554.33[illegible]	519.997	530.884	-.003	-.003	.047	.035	11.518	9.445
[illegible]	554.447	519.997	530.749	-.003	-.003	.048	.031	11.494	9.534
[illegible]	554.139	519.997	530.444	-.003	-.003	.048	.035	11.448	9.5[illegible]
[illegible]	554.339	519.997	530.319	-.003	-.003	.048	.035	11.460	9.522
[illegible]	554.481	519.997	530.995	-.003	-.003	.047	.035	11.442	9.531
[illegible]	553.516	519.997	530.096	-.003	-.003	.044	.032	11.188	9.321
[illegible]	552.851	519.997	529.705	-.003	-.003	.041	.028	10.889	9.055
[illegible]	553.567	519.997	527.931	-.003	-.003	.040	.027	10.804	9.012
[illegible]	553.144	519.997	530.093	-.003	-.003	.042	.030	11.069	9.273
[illegible]	554.363	519.997	531.454	-.003	-.003	.046	.035	11.414	9.519
[illegible]	554.255	519.997	531.445	-.003	-.003	.046	.035	11.349	9.540
[illegible]	554.353	519.997	531.509	-.003	-.003	.046	.035	11.533	9.537
[illegible]	552.854	519.997	530.371	-.003	-.003	.041	.015	11.372	9.174
[illegible]	553.309	519.997	530.328	-.003	-.003	.044	.032	12.153	9.302
[illegible]	551.5[illegible]	519.997	532.519	-.003	-.003	.034	.021	12.028	8.979
[illegible]	554.219	519.997	531.979	-.003	-.003	.046	.035	12.949	9.519
[illegible]	554.2[illegible]	519.997	532.275	-.003	-.003	.047	.035	12.672	9.5[illegible]
[illegible]	554.0[illegible]	519.997	532.421	-.003	-.003	.046	.035	12.636	9.4[illegible]
[illegible]	[illegible]	519.997	532.547	-.003	-.003	.046	.034	13.764	9.[illegible]
[illegible]	[illegible]	519.997	532.576	-.003	-.003	.046	.034	15.077	9.[illegible]
[illegible]	[illegible]	520.009	532.590	-.003	-.003	.046	.035	16.154	9.[illegible]
[illegible]	553.695	520.663	532.736	-.003	-.003	.047	.034	16.757	10.[illegible]
[illegible]	553.729	521.161	532.931	-.003	-.003	.046	.034	17.355	11.7[illegible]
[illegible]	553.653	521.502	533.194	-.003	-.003	.047	.035	17.973	12.[illegible]
[illegible]	553.409	521.838	533.136	-.003	-.003	.048	.034	13.589	13.[illegible]
[illegible]	553.043	521.396	533.273	-.003	-.003	.048	.035	19.181	15.[illegible]
[illegible]	552.500	522.170	533.215	-.003	-.003	.048	.035	18.968	15.[illegible]
[illegible]	551.[illegible]	522.570	533.224	-.003	-.003	.048	.035	18.995	15.[illegible]
[illegible]	551.619	522.591	533.404	-.003	-.003	.048	.034	18.974	[illegible]
[illegible]	551.[illegible]	522.432	533.532	-.003	-.003	.046	.035	19.[illegible]	[illegible]
[illegible]	551.647	522.073	533.790	-.003	-.003	.045	.035	19.172	[illegible]
[illegible]	551.[illegible]	521.193	533.657	-.003	-.003	.046	.034	19.155	[illegible]
[illegible]	551.[illegible]	520.634	533.929	-.003	-.003	.046	.034	19.120	[illegible]
[illegible]	552.[illegible]	519.997	534.179	-.003	-.003	.046	[illegible]	19.183	[illegible]
[illegible]	552.143	519.997	534.292	-.003	-.003	.047	.035	19.156	[illegible]
[illegible]	552.253	519.997	534.262	-.003	-.003	.046	.035	19.178	[illegible].470
[illegible]	552.[illegible]	519.997	533.941	-.003	-.003	.046	.034	19.151	[illegible]
[illegible]	[illegible]	519.997	533.630	-.003	-.003	.047	.034	19.282	[illegible]
[illegible]	[illegible]	519.997	533.923	-.003	-.003	.047	.035	19.1[illegible]3	[illegible]
[illegible]	552.[illegible]	519.997	533.386	-.003	-.003	.046	.034	19.111	[illegible]
[illegible]	552.143	519.997	532.721	-.003	-.003	.048	.034	19.142	[illegible]
[illegible]	552.143	519.997	532.077	-.003	-.003	.048	.034	19.584	[illegible]
[illegible]	551.872	519.997	531.762	-.003	-.003	.048	.034	19.093	[illegible]
[illegible]	552.[illegible]1	519.997	531.329	-.003	-.003	.048	.034	19.081	[illegible]
[illegible]	551.[illegible]	519.997	530.654	3.697	-.003	.047	.034	19.056	[illegible].409
[illegible]	551.673	519.997	531.695	18.789	-.003	.048	.034	19.032	[illegible]
[illegible]	551.[illegible]63	519.997	532.965	35.823	-.003	.048	.034	19.017	[illegible]
[illegible]	547.609	519.997	527.679	38.026	-.003	.020	.034	17.854	14.710

1

Notes: 1. Tc|Loop 2 is increasing when Tc comes on scale; at T ≈ 310 sec level begins increasing

**** NOT CERTIFIED **** NOT CERTIFIED **** NOT CERTIFIED **** NOT CERTIFIED ****

RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 5	CHANNEL 7	CHANNEL 8	CHANNEL 9	CHANNEL 10	CHANNEL 13	CHANNEL 14	CHANNEL 15	CHANNEL 17
[illegible]	549.662	519.997	529.765	37.489	-.003	.035	.119	17.945	14.743
[illegible]	559.850	519.317	532.717	38.781	-.003	.035	.020	17.857	14.955
[illegible]	554.475	519.397	537.967	38.393	-.003	.048	.034	19.020	[illegible]
[illegible]	559.312	519.917	539.001	38.724	-.003	.048	.034	19.212	[illegible]
[illegible]	[illegible]	521.798	538.988	38.411	-.003	.048	.034	19.420	[illegible]
[illegible]	563.756	526.76[illegible]	538.251	39.069	-.003	.048	.034	19.627	14.945
[illegible]	[illegible]	524.474	537.521	39.218	-.003	.048	.034	19.655	[illegible]
[illegible]	562.695	525.591	536.944	38.100	-.003	.049	.034	19.691	[illegible]
[illegible]	561.346	524.953	536.761	39.394	-.003	.048	.033	19.819	[illegible]
[illegible]	553.491	524.997	536.838	38.765	-.003	.048	.034	19.859	14.741
[illegible]	555.461	523.934	537.240	38.787	-.003	.049	.034	19.869	[illegible]
[illegible]	[illegible]	521.602	537.802	39.051	-.003	.048	.034	19.695	14.725
[illegible]	546.537	522.799	539.516	38.847	-.003	.049	.035	19.511	[illegible]
[illegible]	539.265	521.059	539.221	38.290	-.003	.051	.034	19.133	[illegible]
[illegible]	532.199	525.316	539.807	39.567	-.003	.049	.034	19.026	[illegible]
[illegible]	[illegible]	526.591	540.237	38.422	-.003	.049	.034	19.239	[illegible]
[illegible]	524.731	527.038	540.524	38.345	-.003	.049	.034	19.224	14.840
[illegible]	522.564	527.843	540.723	38.641	-.003	.049	.034	19.105	14.906
557.010	520.685	528.649	540.924	38.133	-.003	.048	.034	19.050	14.826

— OTSG Pressure —

RPRINT MONITORED VARIABLES

	Loop 2	Loop 1
CHANNEL 27	CHANNEL 19	CHANNEL 20
[illegible]	894.449	[illegible]
[illegible]	953.671	933.419
[illegible]	1043.829	1032.192
[illegible]	1064.939	1052.957
[illegible]	983.913	1023.917
[illegible]	[illegible]	1007.932

← OTSG Pressure →

RPRINT MONITORED VARIABLES

	Loop 2	Loop 1
CHANNEL 27	CHANNEL 19	CHANNEL 20
.000	883.445	892.950
[illegible]	953.671	933.419
[illegible]	104[illegible].[illegible]29	1032.192
9.000	1054.935	1052.957
[illegible]	998.913	1028.017
15.000	930.368	1097.932
[illegible]	913.190	991.027
21.000	975.862	979.381
[illegible]	968.394	968.687
[illegible]	973.082	959.996
[illegible]	958.541	965.794
[illegible]	973.245	959.798
[illegible]	979.834	953.571
[illegible]	976.932	947.226
[illegible]	973.554	939.698
[illegible]	962.608	944.369
[illegible]	966.272	968.762
[illegible]	951.475	969.127
[illegible]	974.403	932.797
[illegible]	983.570	964.775
[illegible]	987.475	1004.065
[illegible]	933.772	1012.912
[illegible]	990.[illegible]	1018.568
[illegible]	936.230	1024.721
[illegible]	992.238	1029.665
[illegible]	973.978	992.139
[illegible]	975.603	964.182
[illegible]	959.473	957.554
[illegible]	951.[illegible]33	949.716
[illegible]	947.[illegible]04	942.977
[illegible]	951.1[illegible]	950.[illegible]5
[illegible]	95[illegible].[illegible]	961.143
[illegible]	963.[illegible]	968.930
[illegible]	935.[illegible]47	975.023
[illegible]	92[illegible].[illegible]	930.946
[illegible]	925.[illegible]91	935.827
[illegible]	970.[illegible]57	958.[illegible]
[illegible]	91[illegible].[illegible]	954.[illegible]7
[illegible]	912.753	966.667
[illegible]	[illegible]	987.[illegible]8
[illegible]	[illegible].[illegible]53	974.474
[illegible]	[illegible].[illegible]1	951.[illegible]9
[illegible]	8[illegible].[illegible]	955.636
[illegible]	832.291	957.630
[illegible]	8[illegible].[illegible]16	958.752
[illegible]	843.2[illegible]1	955.418
[illegible]	879.[illegible]76	955.393
[illegible]	874.[illegible]79	946.567
[illegible]	870.179	939.755
[illegible]	865.[illegible]	934.627
[illegible]	861.034	930.452

POOR ORIGINAL

7950186

RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 19	CHANNEL 20
153.000	858.533	924.922
[illegible]	852.4.5	917.195
[illegible]	846.695	909.161
[illegible]	834.169	901.227
[illegible]	840.253	893.932
168.000	835.477	886.504
171.000	832.131	879.253
174.000	828.676	872.661
177.000	825.150	865.739
[illegible]	820.065	859.257
[illegible]	817.469	852.633
[illegible]	817.697	846.475
[illegible]	815.213	840.432
[illegible]	816.432	834.243
[illegible]	813.657	820.251
[illegible]	799.927	823.952
201.000	796.521	819.038
[illegible]	793.491	813.880
[illegible]	790.331	809.376
213.000	787.568	804.541
[illegible]	784.115	799.437
[illegible]	780.556	794.943
[illegible]	777.403	790.361
[illegible]	775.672	785.977
[illegible]	772.129	781.615
[illegible]	770.335	776.534
[illegible]	767.911	772.972
[illegible]	765.238	770.408
[illegible]	761.845	764.595
[illegible]	760.995	761.672
[illegible]	758.965	757.353
[illegible]	755.979	754.401
[illegible]	754.697	750.925
[illegible]	752.156	747.249
[illegible]	750.127	744.113
[illegible]	748.251	741.073
261.000	745.210	737.704
[illegible]	749.387	734.791
[illegible]	755.190	731.515
[illegible]	765.171	725.292
[illegible]	770.143	725.142
[illegible]	774.146	722.432
[illegible]	779.618	718.949
[illegible]	785.671	716.426
[illegible]	790.133	713.789
[illegible]	791.723	710.532
[illegible]	794.177	707.525
294.000	796.701	704.962
297.000	798.242	702.059
300.000	735.103	635.330

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RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 19	CHANNEL 20
[illegible]	779.143	634.170
[illegible]	741.[illegible]	631.165
[illegible]	754.259	628.530
[illegible]	767.161	625.536
[illegible]	750.[illegible]	623.473

POOR ORIGINAL

7501870

RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 19	CHANNEL 20
[illegible]	733.[illegible]	634.170
[illegible]	741.659	631.165
[illegible]	744.259	628.530
[illegible]	747.183	625.536
[illegible]	750.333	623.0[illegible]
[illegible]	753.[illegible]	620.546
[illegible]	755.613	617.[illegible]
[illegible]	758.353	614.696
[illegible]	760.776	612.415
[illegible]	763.194	611.756
[illegible]	765.[illegible]1	614.649
[illegible]	767.359	627.065
[illegible]	769.565	632.595
[illegible]	771.231	636.477
[illegible]	772.243	641.371
[illegible]	773.799	647.391
[illegible]	775.535	652.394
[illegible]	776.315	657.316
[illegible]	777.[illegible]	659.879
[illegible]	778.193	662.553
[illegible]	778.319	663.798
[illegible]	778.266	665.471
[illegible]	777.[illegible]	669.183
[illegible]	777.[illegible]	671.672
[illegible]	777.220	674.971
[illegible]	777.416	678.227
[illegible]	776.[illegible]	681.194
[illegible]	775.425	684.9[illegible]
[illegible]	774.40[illegible]	688.115
[illegible]	774.0[illegible]	692.7[illegible]
[illegible]	773.511	696.393
[illegible]	77[illegible]	700.311
[illegible]	77[illegible].[illegible]9	703.934
[illegible]	771.397	706.9[illegible]3
[illegible]	771.214	710.676
[illegible]	770.285	713.752
[illegible]	769.[illegible]	717.085
[illegible]	768.[illegible]	720.[illegible]
[illegible]	762.191	723.[illegible]
[illegible]	767.[illegible]	726.[illegible]
[illegible]	766.[illegible]	728.914
[illegible]	766.270	731.075
[illegible]	765.[illegible]1	734.591
[illegible]	765.171	737.[illegible]
[illegible]	764.[illegible]	739.5[illegible]
[illegible]	763.[illegible]	742.035
[illegible]	76[illegible]	744.[illegible]2
[illegible]	760.763	746.868
[illegible]	761.215	748.374
[illegible]	761.[illegible]16	751.550

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POOR ORIGINAL

7501188

RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 19	CHANNEL 20
[illegible]	760.227	754.221
[illegible]	759.934	756.294
[illegible]	759.149	759.669
[illegible]	758.759	761.309
[illegible]	757.790	763.450
[illegible]	756.931	765.340
[illegible]	756.309	768.138
[illegible]	755.776	770.518
[illegible]	754.667	772.716
[illegible]	754.234	775.316
[illegible]	753.662	777.477
[illegible]	752.573	780.297
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[illegible]	751.323	784.559
[illegible]	750.169	786.423
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[illegible]	747.771	800.220
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[illegible]	745.724	804.431
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[illegible]	743.437	812.525
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[illegible]	737.191	832.113
[illegible]	735.397	833.240
[illegible]	736.715	835.661
[illegible]	735.543	837.629
[illegible]	735.556	837.549
[illegible]	735.177	839.557
[illegible]	734.437	840.236
[illegible]	734.296	841.695
[illegible]	733.675	842.263
[illegible]	733.748	843.472
[illegible]	733.746	844.571
[illegible]	732.760	843.838

1

RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 19	CHANNEL 20
[illegible]	731.551	845.010
[illegible]	727.155	841.013
[illegible]	731.736	835.164
[illegible]	725.855	849.222
[illegible]	731.930	850.320
[illegible]	728.494	847.664

POOR ORIGINAL

750189

POOR ORIGINAL

RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 19	CHANNEL 20
[illegible]	731.551	845.010
[illegible]	727.156	841.019
[illegible]	721.736	835.184
812.000	729.855	840.222
815.010	731.[illegible]30	850.320
[illegible]	728.894	847.584
[illegible]	720.271	841.558
[illegible]	719.279	839.187
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[illegible]	717.150	839.333
[illegible]	725.638	850.101
[illegible]	722.438	855.484
[illegible]	728.145	855.559
842.000	722.532	848.453
845.010	722.139	849.195
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872.000	725.325	861.564
[illegible]	726.069	862.040
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[illegible]	723.454	863.065
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[illegible]	714.[illegible]	851.459
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[illegible]	711.684	865.000
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[illegible]	713.259	855.381
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[illegible]	[illegible]	870.463
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[illegible]	721.143	871.452
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[illegible]	722.067	872.917
[illegible]	717.451	865.255
[illegible]	[illegible]	859.659
[illegible]	[illegible]	865.575
[illegible]	710.786	863.903

1

RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 19 Loop 2	CHANNEL 20 Loop 1
[illegible]	729.101	862.553
[illegible]	684.482	850.760
[illegible]	723.015	877.641
762.010	719.968	877.275
765.010	719.427	877.532
768.010	720.193	878.411
771.010	713.644	879.070
[illegible]	717.512	876.505
[illegible]	713.[illegible]	874.459
[illegible]	713.[illegible]	872.771
[illegible]	715.[illegible]	879.180
[illegible]	712.[illegible]	882.256
[illegible]	717.[illegible]	882.659
[illegible]	715.450	883.291
[illegible]	713.637	877.334
[illegible]	702.765	880.935
[illegible]	691.155	870.924
[illegible]	689.114	880.718
[illegible]	687.[illegible]	877.202
[illegible]	695.[illegible]	865.263
[illegible]	692.[illegible]	852.731
[illegible]	687.[illegible]	841.571
[illegible]	692.732	831.276
[illegible]	677.653	820.912
[illegible]	672.258	810.071
[illegible]	667.[illegible]	800.952
[illegible]	662.[illegible]	792.916
[illegible]	657.[illegible]	783.625
[illegible]	665.[illegible]	776.961
[illegible]	660.172	787.336
[illegible]	667.[illegible]	794.595
[illegible]	672.[illegible]	785.130
[illegible]	676.[illegible]	790.331
[illegible]	679.[illegible]	794.590
[illegible]	691.707	796.694
[illegible]	685.[illegible]	792.335
[illegible]	684.[illegible]	799.927
[illegible]	615.[illegible]	801.025
[illegible]	645.[illegible]	801.395
[illegible]	[illegible]	802.344
[illegible]	641.[illegible]	802.930
[illegible]	647.[illegible]	802.564
[illegible]	687.[illegible]	804.138
[illegible]	684.[illegible]	804.761
[illegible]	658.[illegible]	806.043
[illegible]	619.[illegible]	805.530
[illegible]	692.621	806.970
[illegible]	632.[illegible]	809.778
[illegible]	693.[illegible]	827.930
[illegible]	610.388	850.467

1

RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 19	CHANNEL 20
[illegible]	639.[illegible]	865.215
[illegible]	675.[illegible]	852.296
[illegible]	632.938	865.263
[illegible]	640.571	858.304
[illegible]	679.[illegible]	857.273

POOR ORIGINAL

7501 92

RPRINT MONITORED VARIABLES

CHANNEL 27	CHANNEL 19	CHANNEL 20
[illegible]	659.[illegible]	866.215
[illegible]	675.664	862.296
[illegible]	632.[illegible]	865.26[illegible]
912.000	680.671	858.304
915.000	679.[illegible]	857.279
[illegible]	680.132	861.637
[illegible]	681.[illegible]	869.041
[illegible]	684.234	877.795
[illegible]	637.017	837.576
[illegible]	690.359	866.504
[illegible]	694.159	886.944
[illegible]	696.[illegible]	885.992
[illegible]	732.545	885.662
[illegible]	734.743	886.431
[illegible]	738.112	887.420
[illegible]	711.[illegible]	888.738
[illegible]	718.792	890.396
[illegible]	719.575	892.437
997.000	723.677	893.756

PRINT COMPLETED

TECO DECAY HEAT BLK5

TEP	TIME(SEC)	P(BTU/HR)	E(BTU)
1	.1[illegible]0E+00	.510[illegible]E+09	.14242E+05
2	.12[illegible]E+00	.5099[illegible]E+09	.17911E+05
3	.15849E+00	.50814E+09	.22518E+05
4	.1[illegible]53E+00	.5064[illegible]E+09	.28301E+05
5	.25119E+00	.5034[illegible]E+09	.35554E+05
6	.31623E+00	.50152E+09	.44643E+05
7	.39811E+00	.49861E+09	.56026E+05
8	.50119E+00	.49487E+09	.70244E+05
9	.63096E+00	.4902[illegible]E+09	.88002E+05
[illegible]	.7943[illegible]E+00	.484[illegible]E+09	.11012E+06
[illegible]	.1[illegible]E+01	.47[illegible]E+09	.1376[illegible]E+06
[illegible]	.12[illegible]E+01	.471[illegible]E+09	.17174E+06
[illegible]	.1[illegible]E+01	.46[illegible]E+09	.21404E+06
[illegible]	.1[illegible]5[illegible]E+01	.45[illegible]E+09	.2662[illegible]E+06
[illegible]	.2[illegible]E+01	.4[illegible]E+09	.33095E+06
[illegible]	.31623E+01	.432[illegible]E+09	.40968E+06
17	.39811E+01	.42252E+09	.50592E+06
[illegible]	.50119E+01	.41223E+09	.626[illegible]E+06
[illegible]	.6[illegible]E+01	.402[illegible]E+09	.77304E+06
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[illegible]	.251[illegible]E+02	.334[illegible]E+09	.25721E+07
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27	[illegible]11E+02	.3045[illegible]E+09	.39728E+07
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[illegible]	.7[illegible]E+02	.2[illegible]E+09	.7[illegible]E+07
[illegible]	.1[illegible]E+03	.2[illegible]E+09	.8[illegible]E+07
[illegible]	.1[illegible]E+03	.2[illegible]E+09	.1[illegible]E+08
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[illegible]	.31623E+03	.19277E+09	.21[illegible]E+08
37	.39811E+03	.18017E+09	.25804E+08
[illegible]	.5[illegible]E+03	.1[illegible]E+09	.3[illegible]E+08
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[illegible]	.1[illegible]E+04	.11[illegible]E+09	.86404E+08
45	.25119E+04	.10548E+09	.10257E+09
46	.31623E+04	.10035E+09	.12141E+09

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[illegible]	.8[illegible]E+08	.15[illegible]43E+09
.8[illegible]+04	.76[illegible]E+08	.197[illegible]2E+09
.73[illegible]53[illegible]+04	.699[illegible]+08	.23[illegible]49E+09
.100[illegible]E+05	.64276E+08	.26873E+09
.120[illegible]E+05	.59342E+08	.31316[illegible]+09
.15[illegible]46E+05	.55025E+08	.364[illegible]5E+09
.15[illegible]3E+05	.50695E+08	.42[illegible]66E+09
.2511[illegible]+05	.46796E+08	.49525E+09
.31623E+05	.4267[illegible]E+08	.57573E+09
.39811E+05	.38[illegible]E+08	.65799E+09
.50[illegible]E+05	.34[illegible]26E+08	.77285E+09
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.19952E+06	.18197E+08	.17743E+10
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.31[illegible]23E+06	.1328[illegible]E+08	.2277[illegible]E+10
.39811E+06	.11341E+08	.25531E+10
.5[illegible]1[illegible]E+06	.9[illegible]12[illegible]E+07	.2839[illegible]E+10
[illegible]+06	.74[illegible]E+07	.31352E+10
.79[illegible]3E+06	.61404E+07	.34412E+10
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.1[illegible]E+07	.4[illegible]49[illegible]E+07	.40343E+10
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.2[illegible]1[illegible]E+07	.22360E+07	.51515E+10
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.3[illegible]11E+07	.11957E+07	.5920[illegible]E+10
.5[illegible]1[illegible]E+07	.84975E+06	.61150E+10
.6[illegible]9[illegible]E+07	.6133[illegible]E+06	.63740E+10
.79433E+07	.46410E+06	.66145E+10

[illegible] SCOPE OPERATION SYSTEM / V2 **** 12/09/77 77343

[illegible] IFES #19/ 4/PF FLS=200K FLL=764K MXS=160K MXL=453K MXB=4530

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[illegible]        CH[illegible].[illegible],CORADAZZI DA,366,P,DEHEZ.
[illegible]        -ATT[illegible]DEHE.[illegible]
[illegible]        [illegible]6 - P[illegible]O - ATTACH - PFLIST - PFLIST
[illegible]        P[illegible]244 - CYC[illegible] 251 ATTACHED FROM SN=SYSTEM
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750194

[illegible] DECAY HEAT BLK2

TIME(SEC)	P(BTU/HR)	E(BTU)
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.1[illegible]E+00	.24627E+09	.83392E+04
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.1[illegible]E+00	.23475E+09	.13120E+05
.251[illegible]E+00	.23371E+09	.16407E+05
.316[illegible]E+00	.23247E+09	.20699E+05
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.50113E+05	.43444E+07	.17407E+09
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.79633E+07	.88239E+04	.41174E+09

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SCOPE OPERATION SYSTEM 3 V2 ****        12/09/77      77343
DEVICES 8127 4270 FLS=200K FLL=764K MXS=160K MXL=453K MXD=4530
CLASS CPU SECOND ORIGIN
                           20PPU CDR73 B+W LYN ECS-2CPUS 08/24/77
                          -DEHE,T10,CR70.COR[illegible]
                           CHARGE.[illegible]14,COR[illegible] ,DEHE2.
                          -ATTACH(DEHE,2)
                             PF[illegible] - PFDACRO - ATTACH - [illegible] - RELIST
                             PF254 - CYCLE 250 ATTACHED FROM SN=SYSTEM
                             PF646 - PFDACRO - ATTACH - [illegible] - DEHE
                             PF254 - CYCLE   1 ATTACHED FROM SN=SYSTEM
                          -DEHE.
                             FORTRAN LIBRARY 217-MODIFIED 03/16/76
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POOR ORIGINAL

7501?7

[illegible] DECAY HEAT BLK3

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POOR ORIGINAL

7501138

1000 DECAY HEAT 3.41

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POOR ORIGINAL

7501??

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FCCO DECAY HEAT 3LK1

750200

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4	.19[illegible]E+00	.4995[illegible]E+03	.2791[illegible]E+05
5	[illegible]	.497[illegible]E+03	.3502[illegible]E+05
6	[illegible]	.494[illegible]E+03	.44[illegible]E+05
7	[illegible]	.4917[illegible]E+03	.552[illegible]E+05
8	.501[illegible]E+00	.487995E+03	.692[illegible]E+05
9	[illegible]	.483376E+03	.867[illegible]E+05
10	[illegible]	.477791E+03	.108[illegible]E+06
11	.1[illegible]E+01	.471[illegible]E+03	.1357[illegible]E+06
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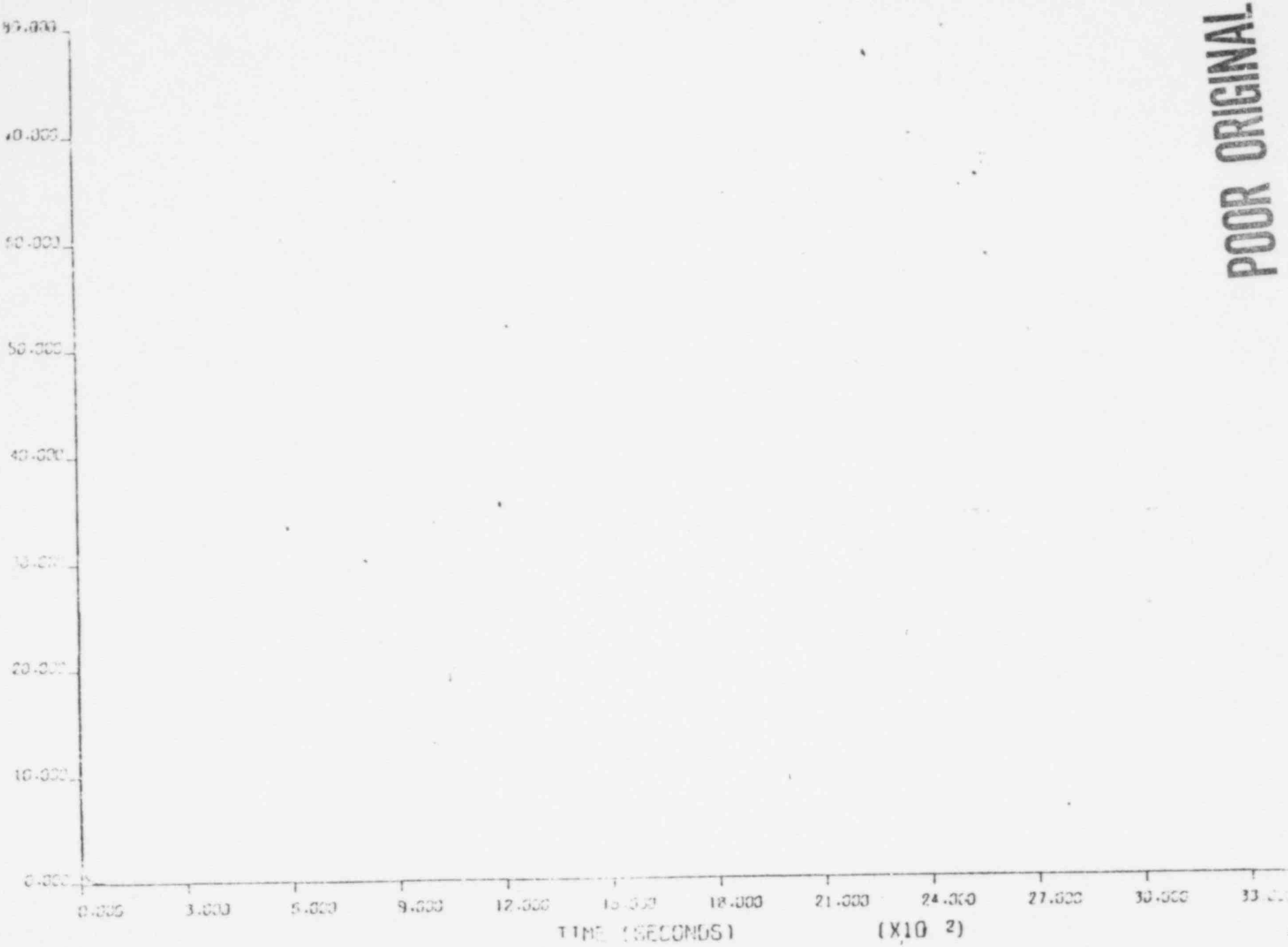

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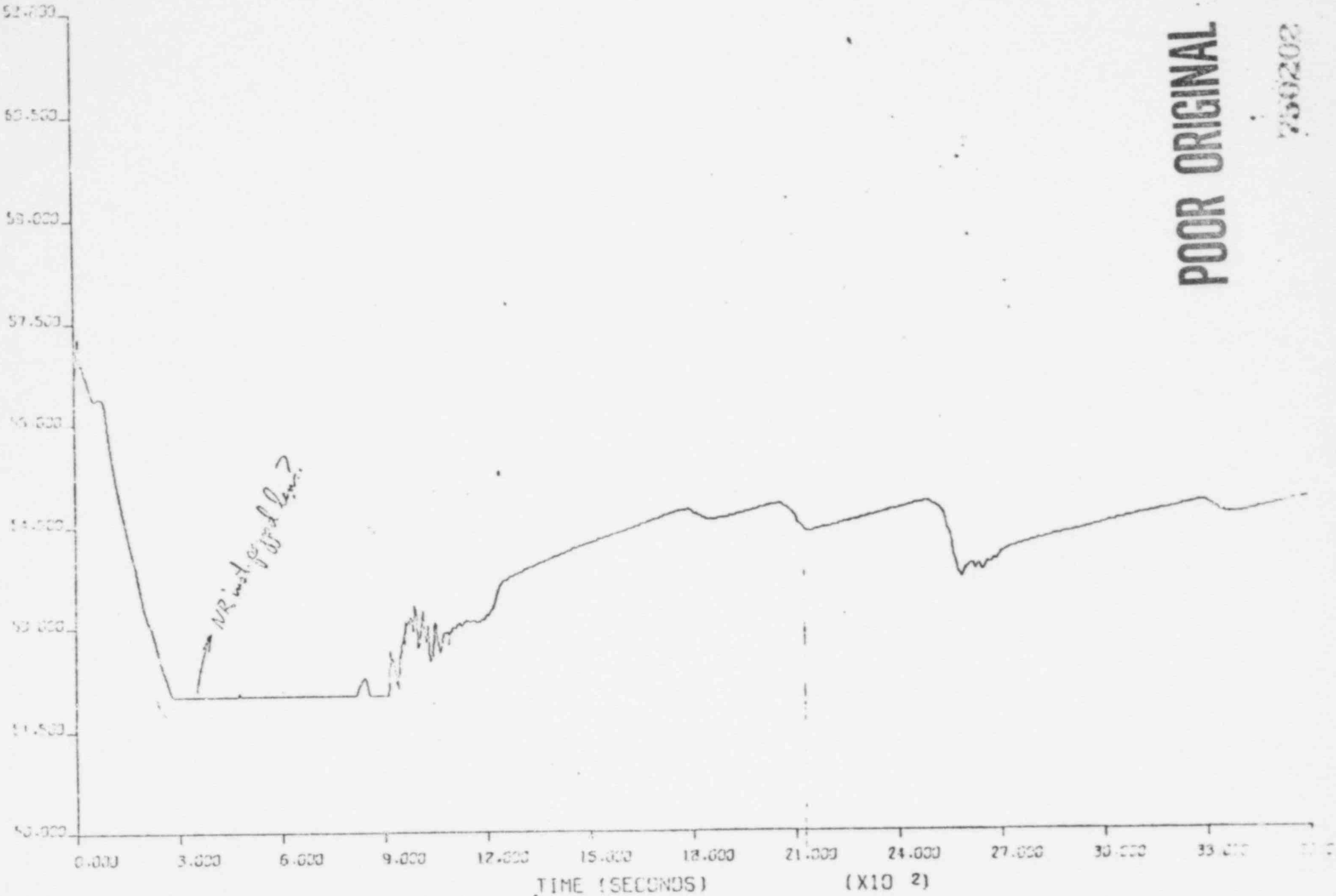

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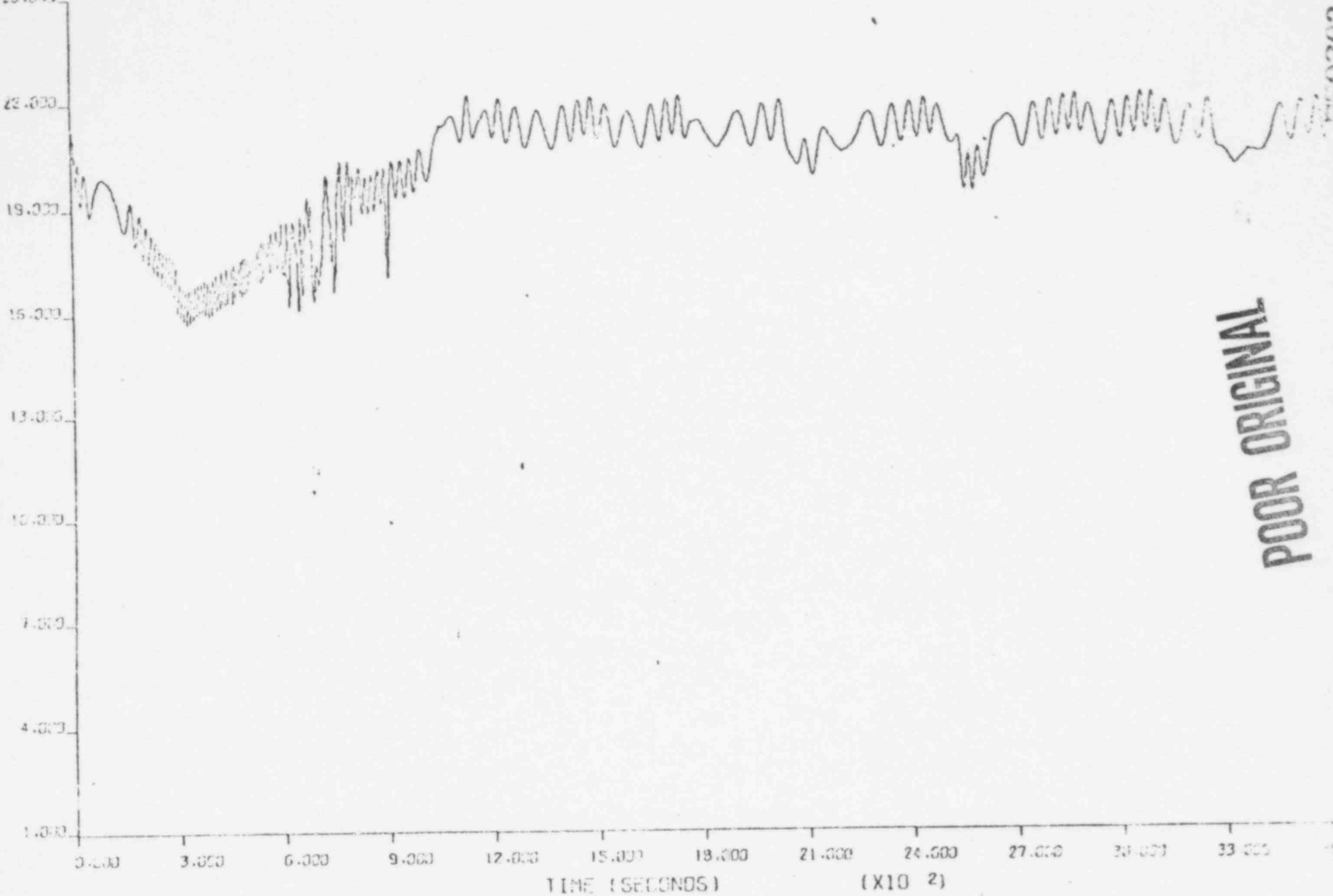

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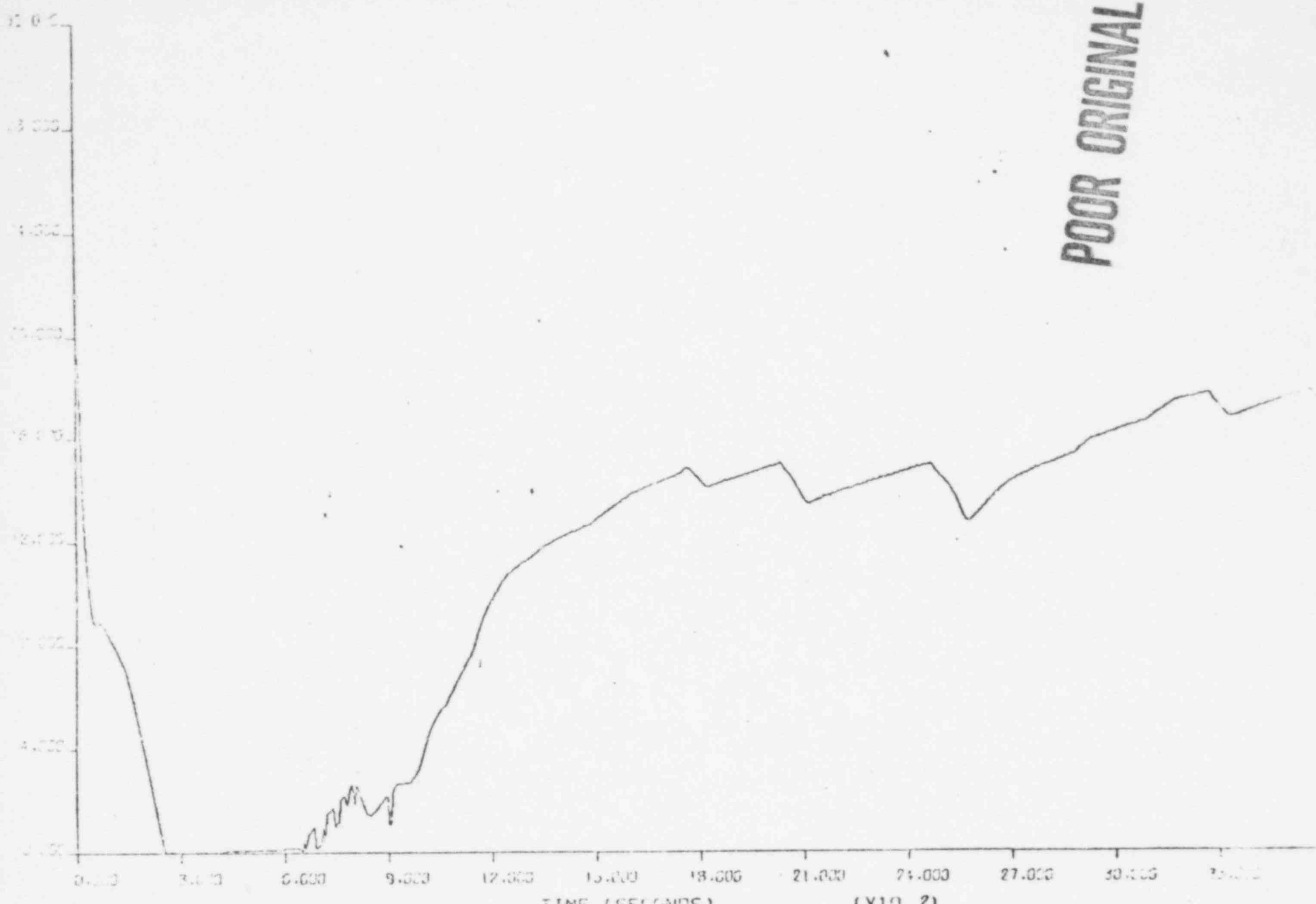
POOR ORIGINAL

7502O3



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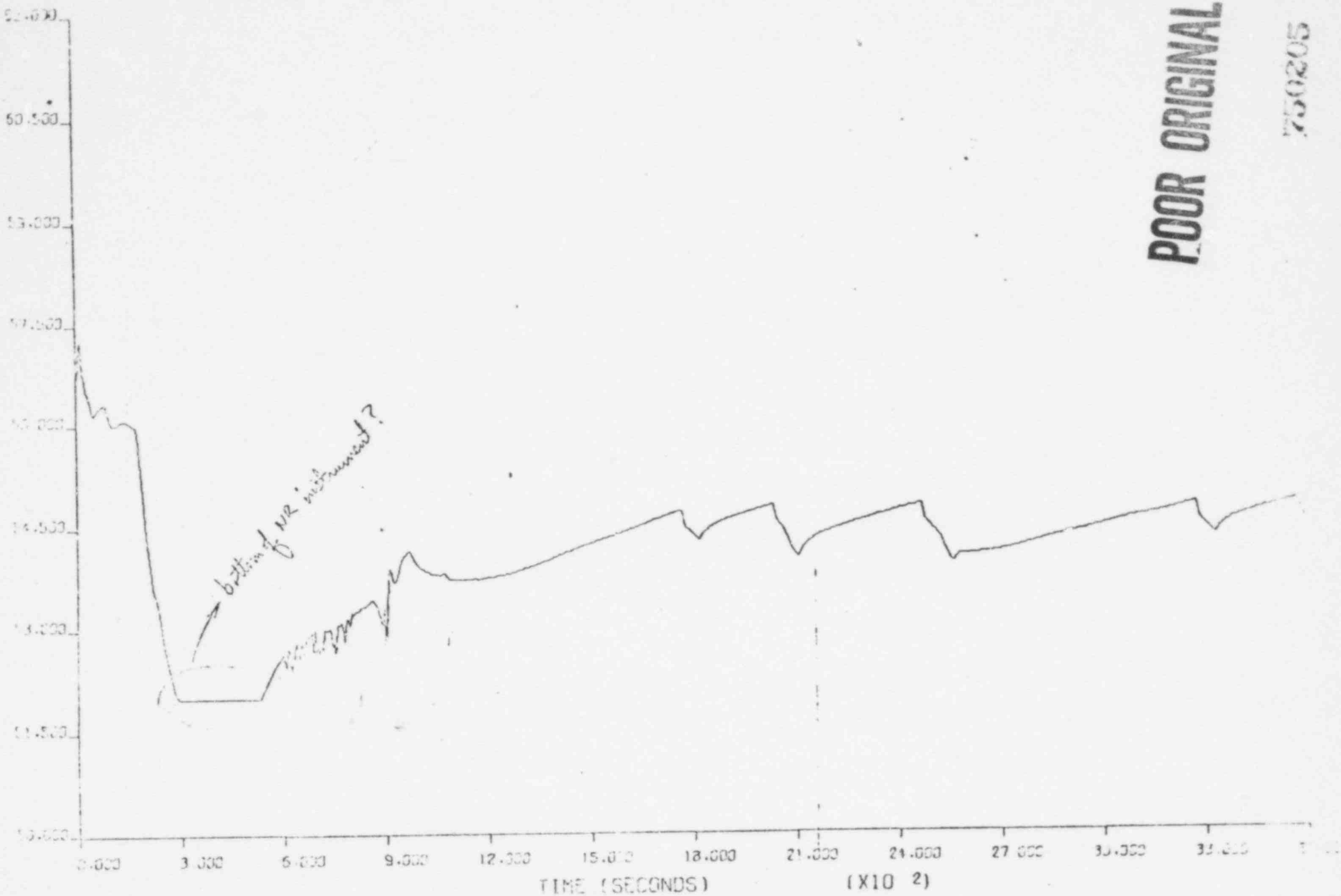
POOR ORIGINAL

7502O4



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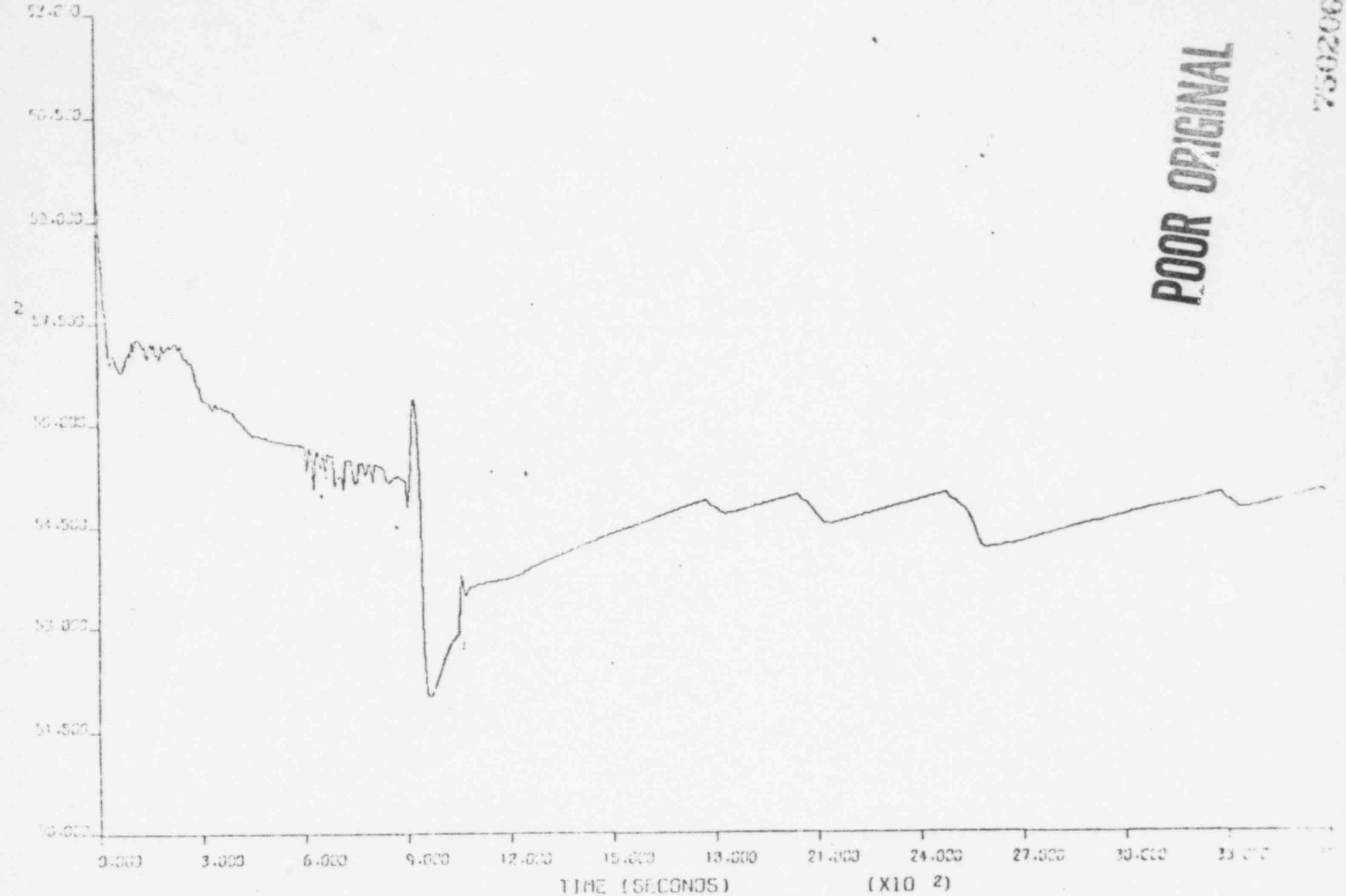

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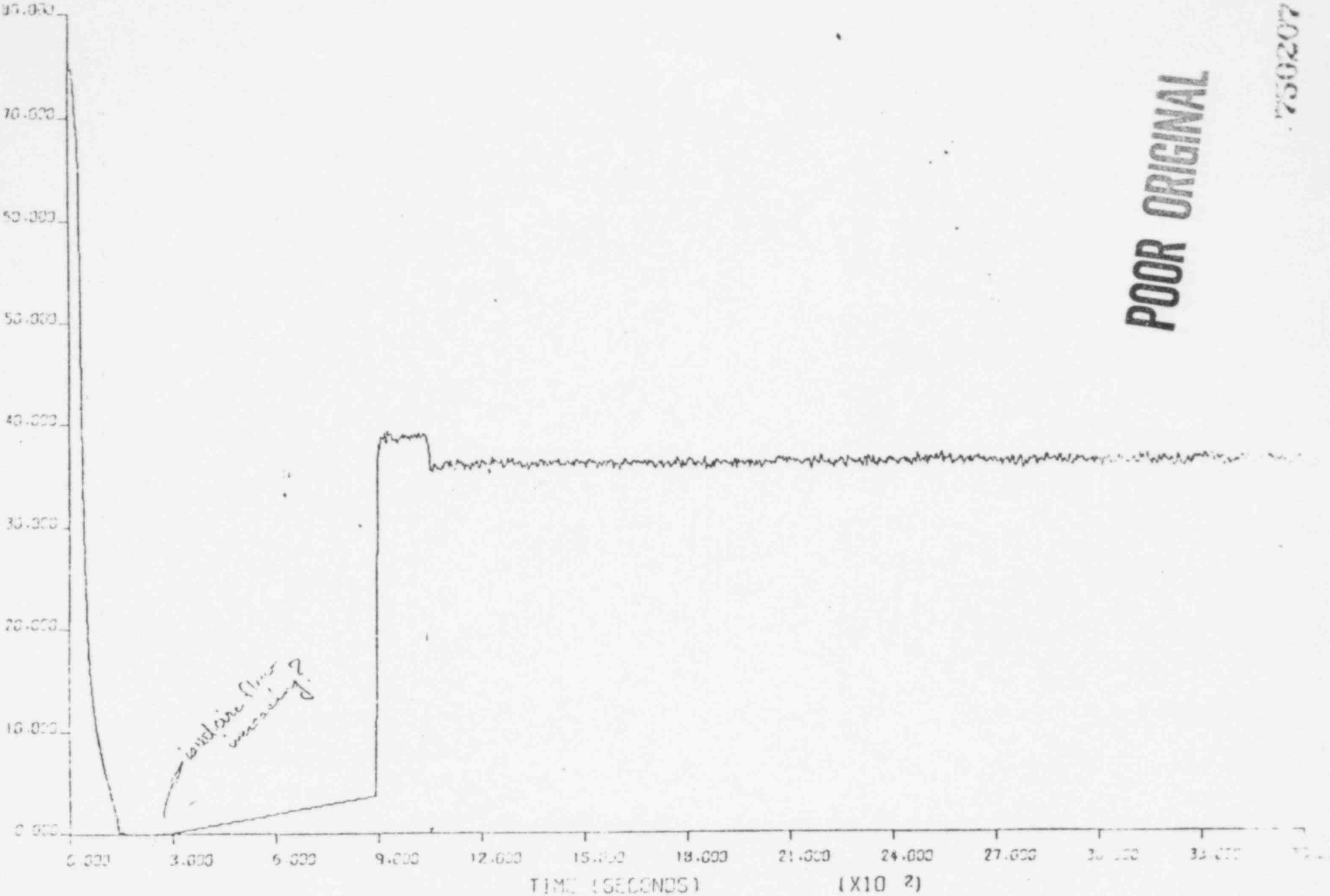
POOR ORIGINAL

7502060

POOR ORIGINAL

7502070



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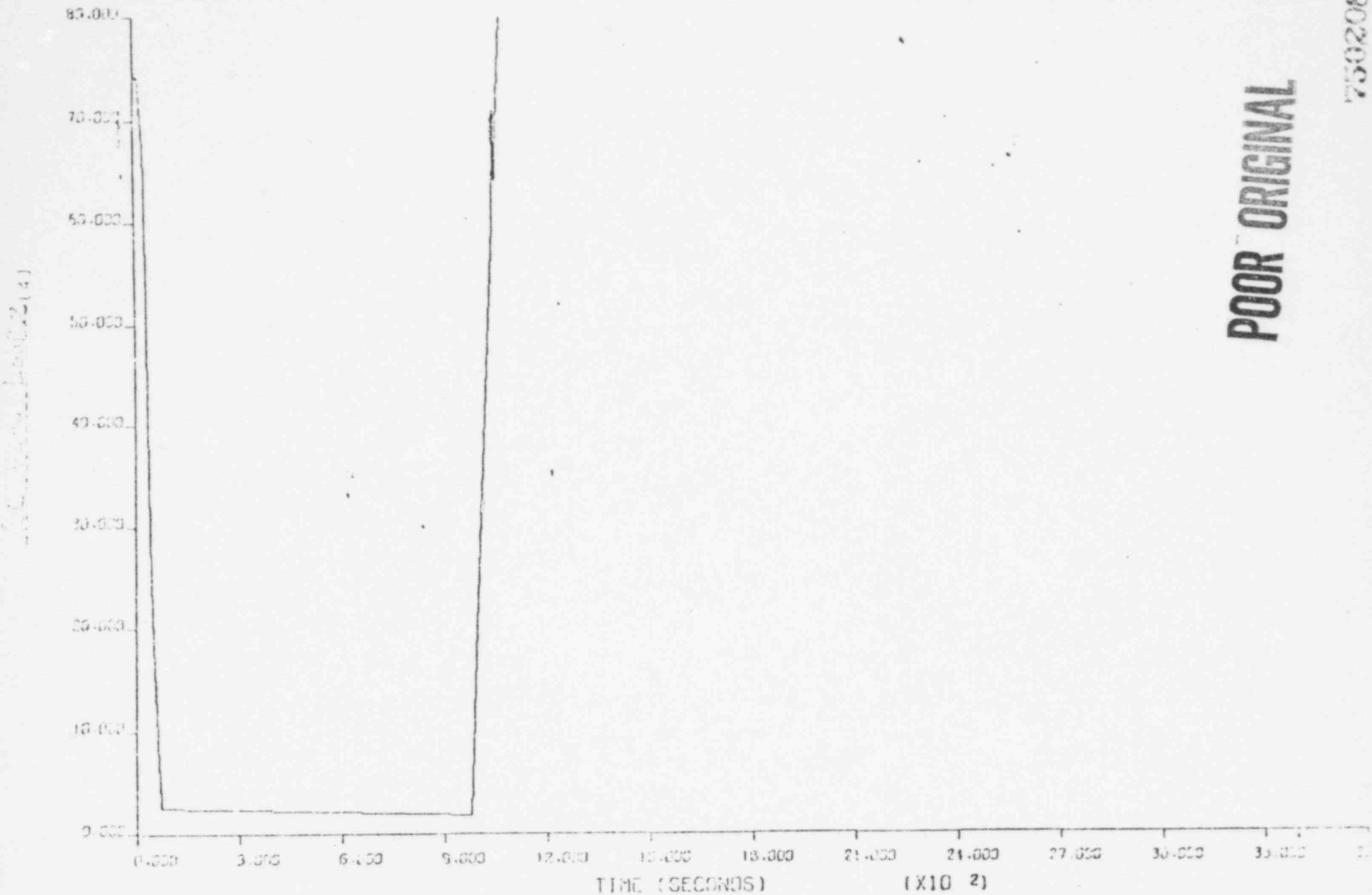

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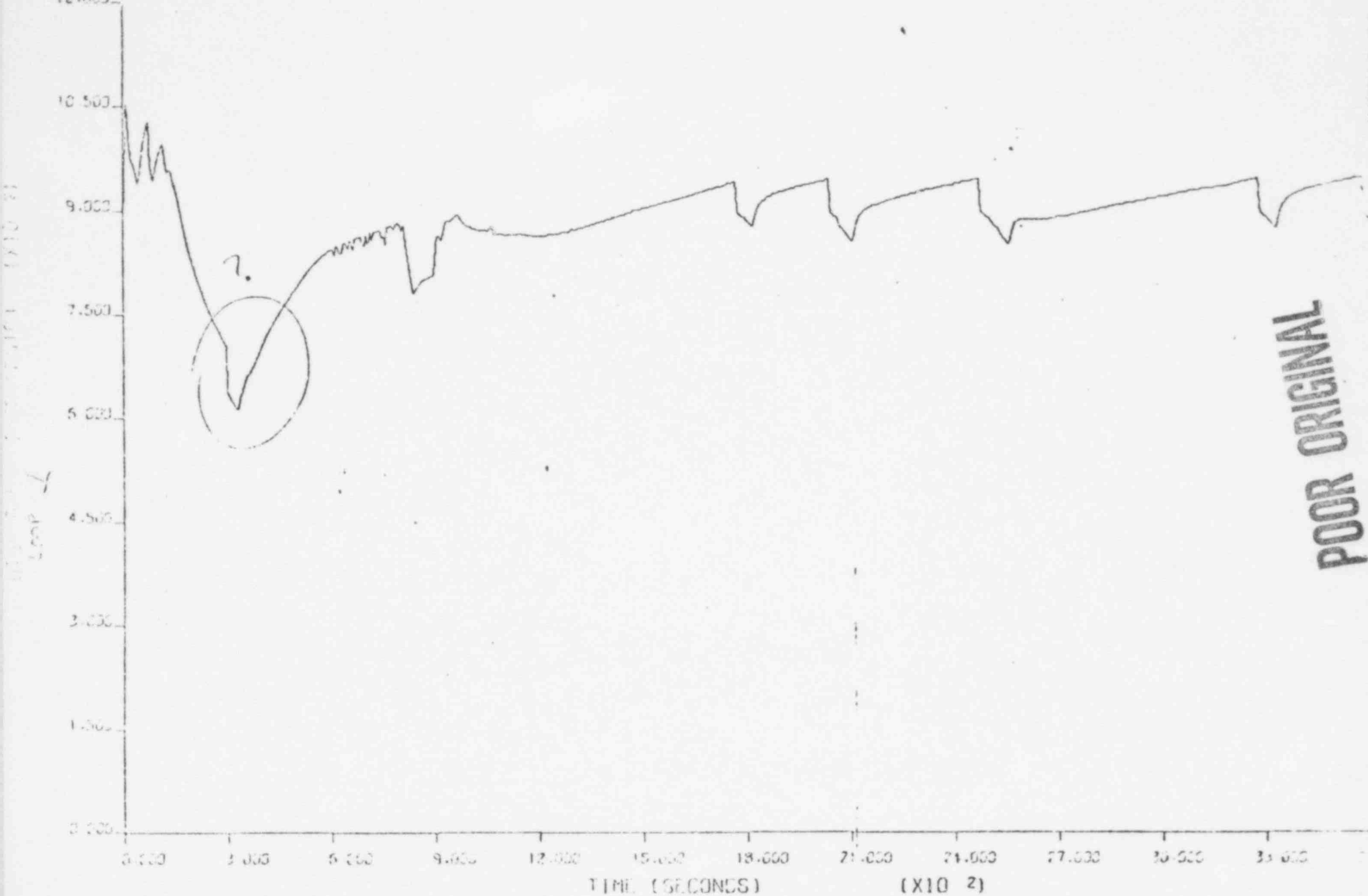

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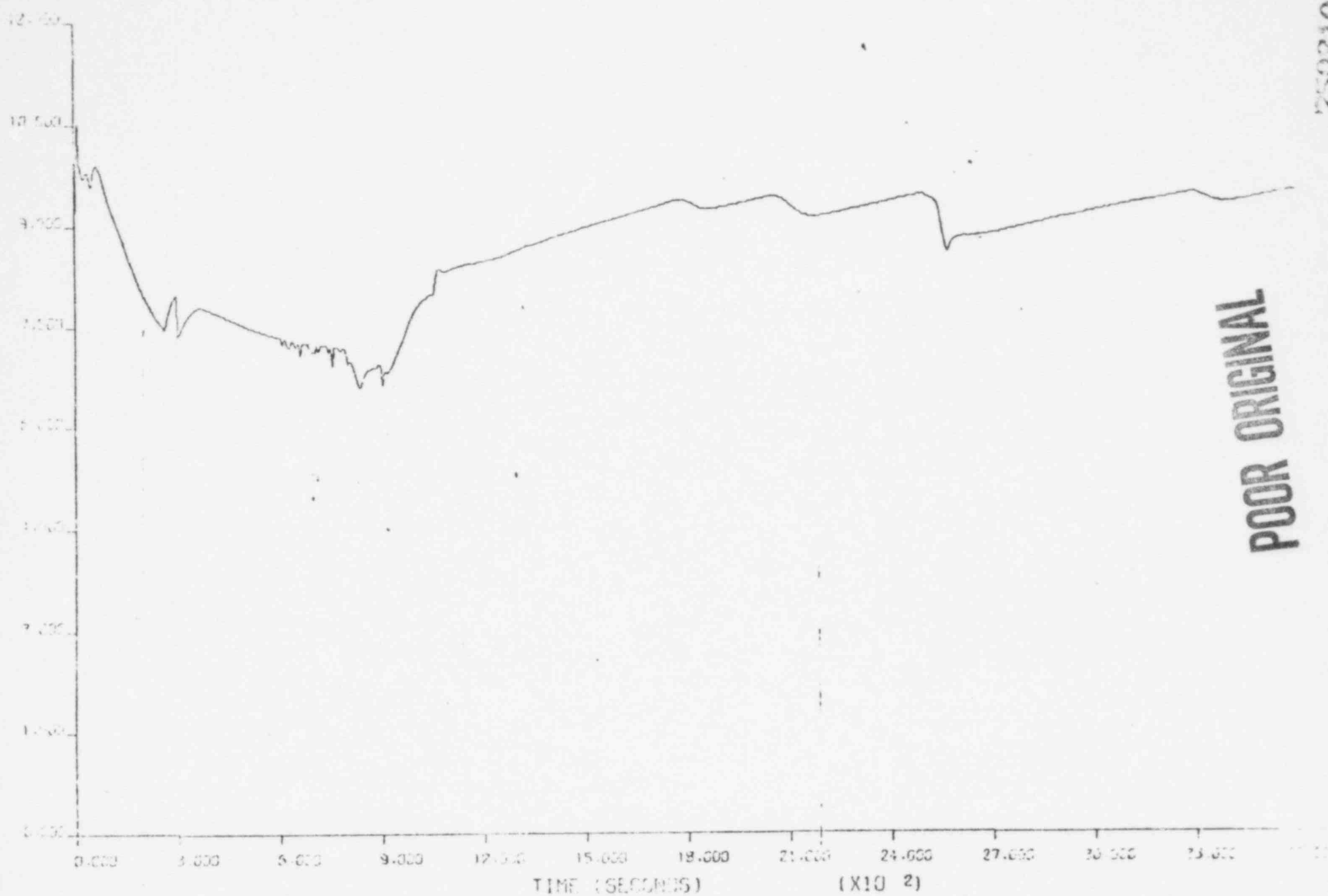
POOR ORIGINAL

7950209



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POOR ORIGINAL

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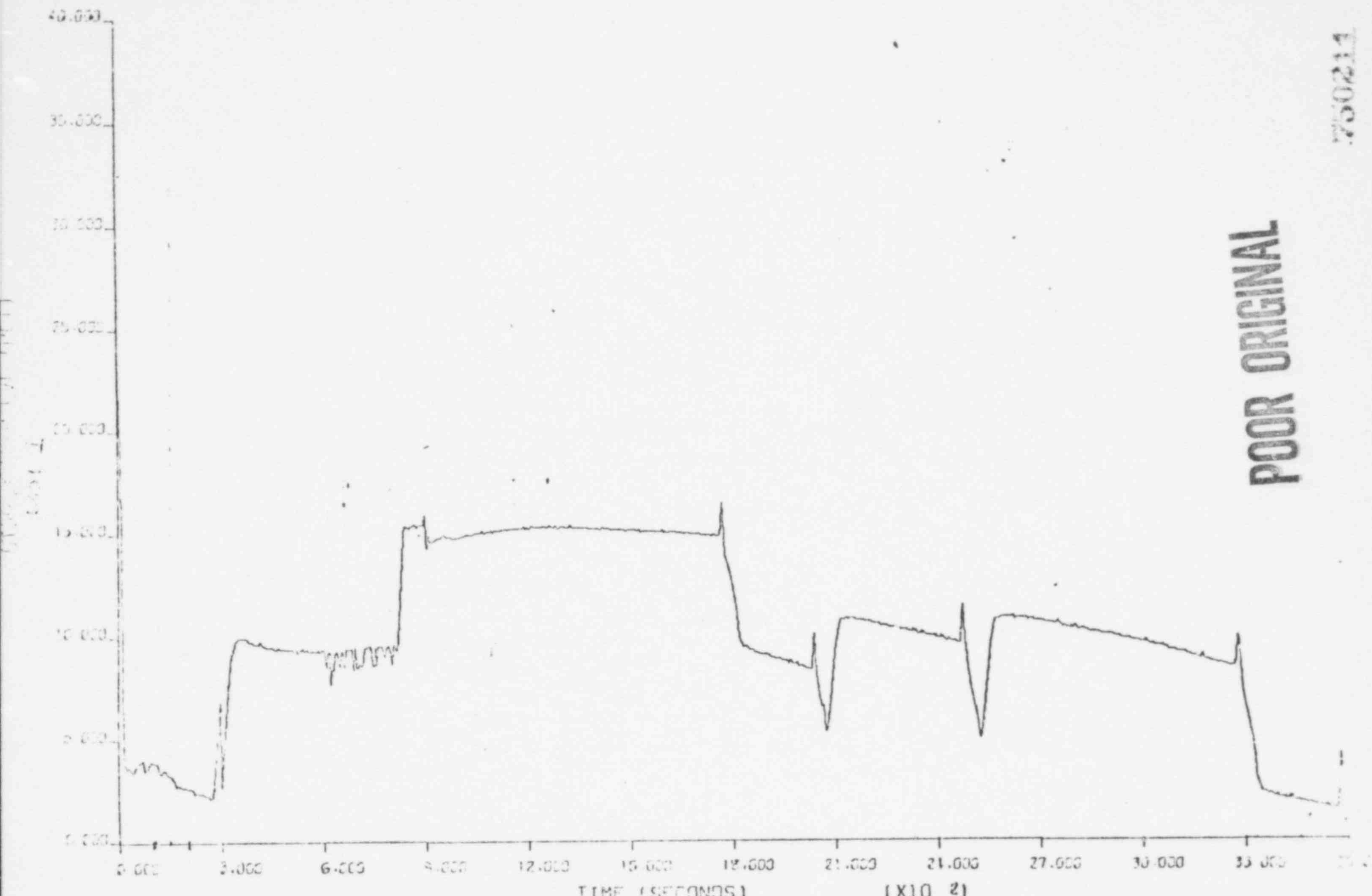

REACTIMETER PLOT TSN C7

750212

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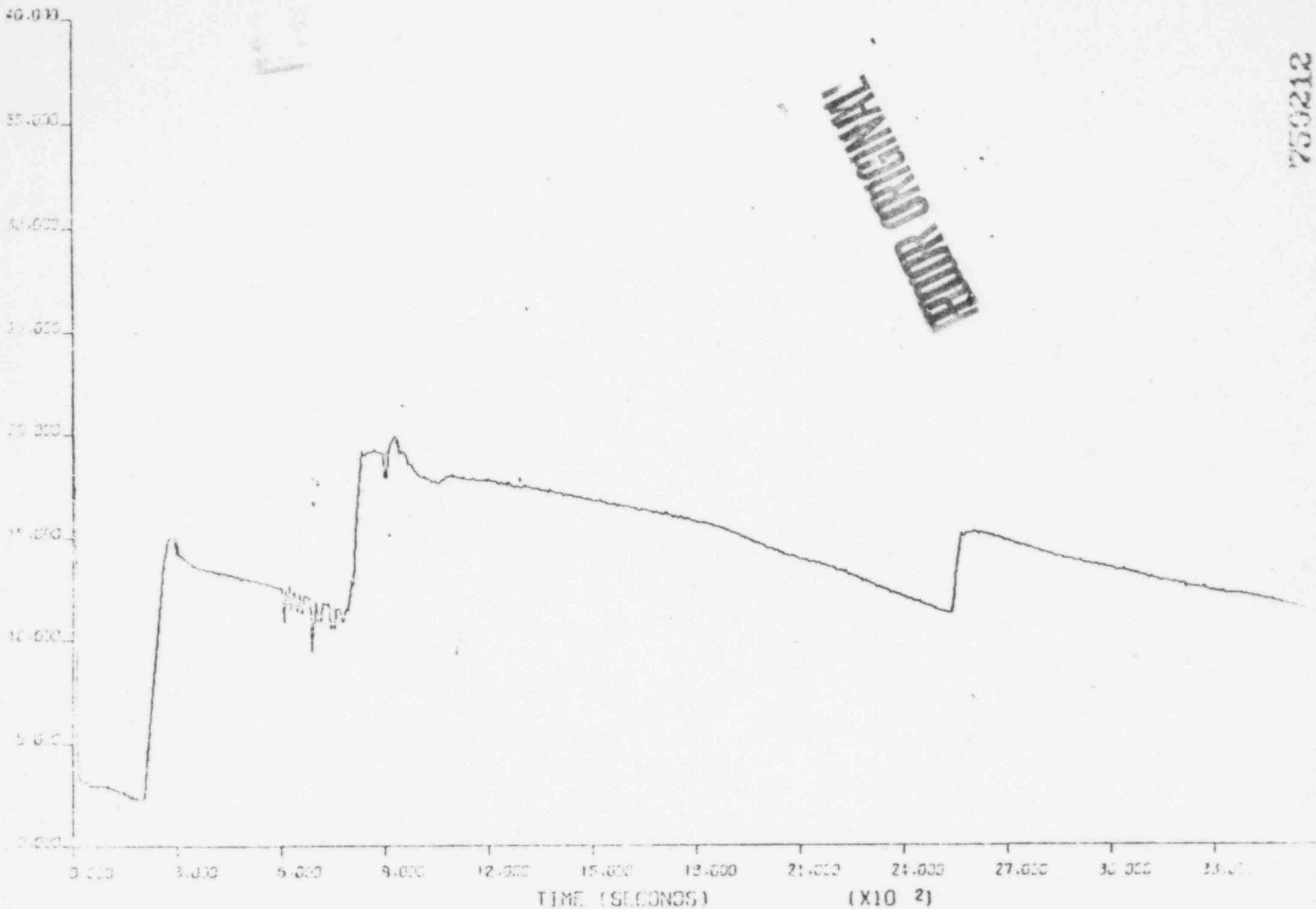

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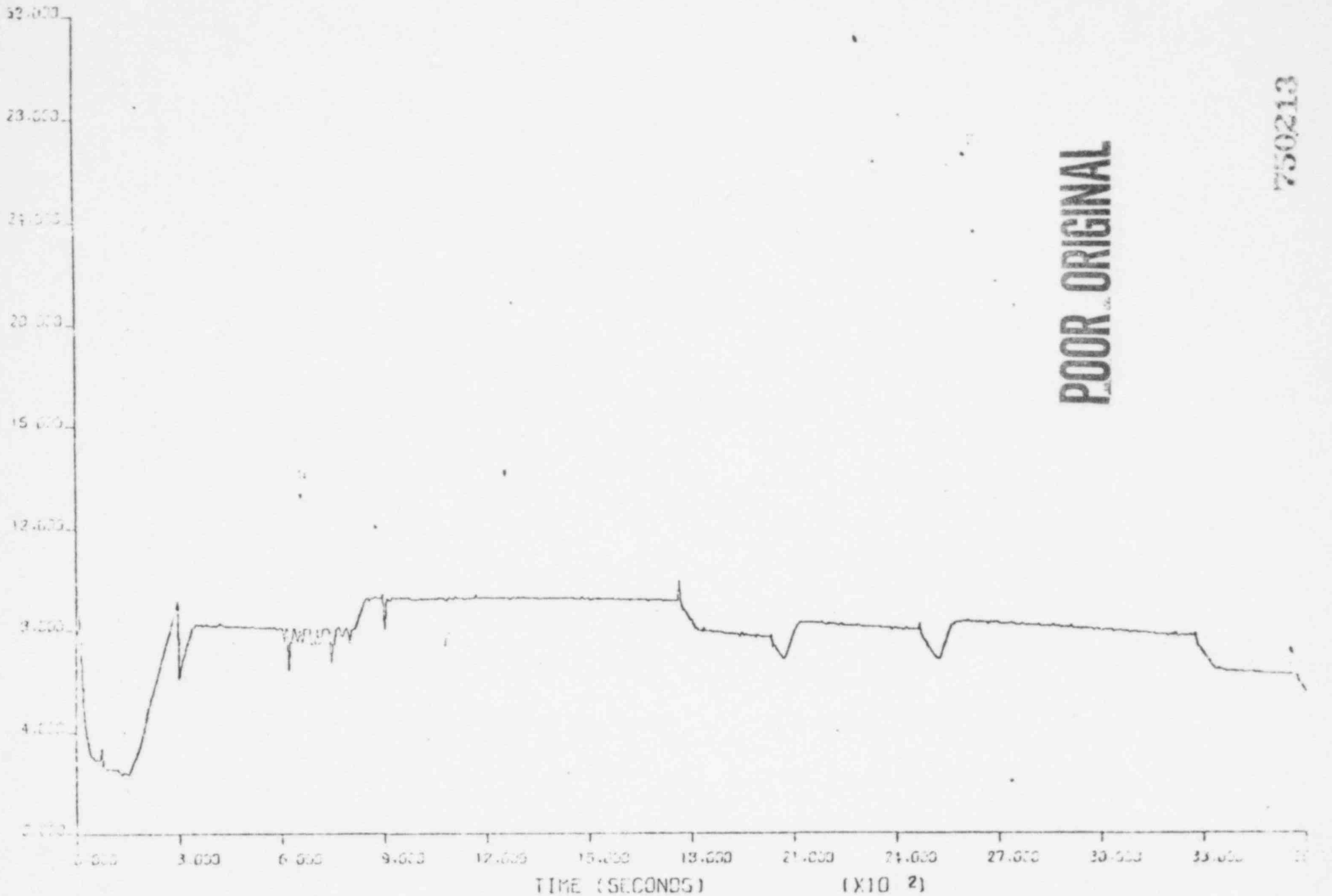

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7502l4

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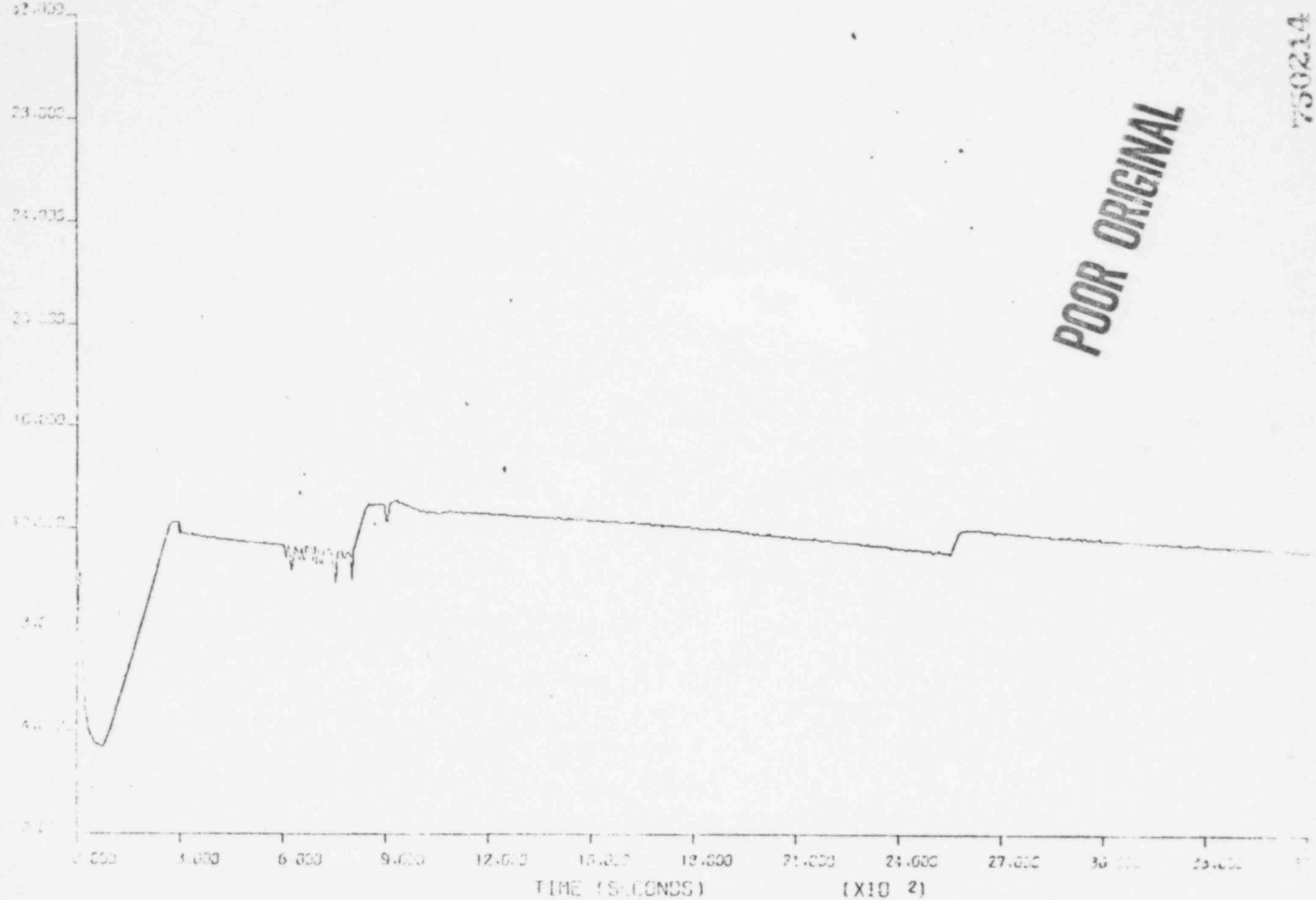

REACTIMETER PLOT TSN=67

Babcock & Wilcox

Power Generation Group

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October 10, 1978

BWT-1707
File: T1.2/12B

bcc: (with attachment)
Ivan Green
WH Spangler
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AH Lazar
FR Faist
RC Luken
Records Center
RED/FRF

Mr. C. R. Domeck
Nuclear Project Engineer
Toledo Edison Company
300 Madison Avenue
Toledo, OH 43652

Subject: Toledo Edison Company
Davis-Besse Unit 1
NSS-14
PRESSURIZER PERFORMANCE DURING REACTOR TRIPS

Reference: C. R. Domeck letter to A. H. Lazar, dated September 18, 1978, TBW-495

Dear Mr. Domeck:

As requested in the reference letter, B&W has calculated the effect of net makeup flow after reactor trip on pressurizer level at Davis-Besse 1. The attached report by R. W. Winks dated October 6, 1978 is forwarded for your use.

Very truly yours,

R C Luken

R. C. Luken
Project Manager

For A. H. Lazar
Senior Project Manager

RCL/hj

Attachment

cc: J. D. Lenardson w/a
J. C. Lewis
D. J. DeLaCroix
M. Malcom/4 w/a
E. C. Novak/1 w/a

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THE EFFECT OF NET MAKEUP FLOW AFTER REACTOR TRIP ON PRESSURIZER LEVEL AT DAVIS-BESSE 1

BY:

Robert W. Winks
Babcock & Wilcox
Lynchburg, Va.

October 6, 1978

Introduction

A study of the change in pressurizer level following a trip of the reactor was performed recently for Toledo Edison Company specifically for the Davis-Besse 1 plant. The mathematical technique assumed that the contraction of the fluid in the reactor coolant system would occur with no net gain or loss in mass during the nominal sixty second interval until a minimum pressurizer level was achieved. The purpose of this study is to determine the net addition of coolant to the RC system within this nominal sixty second period and to calculate the effect it has on the change in pressurizer level described in the previous report.

Summary

Analysis of recorded data on seal injection, makeup and letdown flowrates during four specific reactor trip transients indicates that approximately 325 gallons of cold leg temperature fluid was added to the RC system to try to maintain RC pressure and pressurizer level in the interval of time between reactor trip and minimum pressurizer level. This is equivalent to 14 inches of pressurizer level even though it represents only a 0.4% addition to the total volume of the RC system (~84,000 gallons).

The source of data for seal injection, makeup and letdown flowrates during the reactor trip transients was the Post Trip Review log. Since it records actual values of the monitored parameters once every thirty seconds, the number of data points for a nominal sixty second period between reactor trip and minimum pressurizer level is very limited. Hence, accurate knowledge of these in flow and out flow values for the RC system is very approximate.

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In most cases, the volume of fluid added to the RC system is most strongly influenced by the makeup flowrate when two makeup pumps are operating. Since the maximum indication of makeup flowrate is 160 gpm and is approximately one half the expected or calculated flowrate, no verification of the makeup flowrate when two pumps are running is available.

The contraction of the reactor coolant due to the temperature change in a nominal sixty second interval of time is corrected by 0.4% using a calculated net addition of 325 gallons to the total volume of the system. It is reasonable to assume that six temperature measurements, each having a time constant of approximately four seconds, could lead to an uncertainty in the calculated contraction nearly equal to 0.4%.

Since the addition of net makeup flow into the RC system is only known approximately and reduces the total change in pressurizer level due to the temperature contraction of the system, it will be more conservative to continue to use the assumption of constant RC system mass in calculating minimum pressurizer level for reactor trip transients.

Discussion of Analysis

With the assistance of Messrs. Sushil Jain and Fred Miller of the Toledo Edison Company, a complete set of Post Trip Review data logs for the following reactor trip transients at Davis-Besse 1 was made available:

Reactor Trip Date	Reactor Trip Time	SPR No.
2/24/78	05:51:06	431
4/2/78	08:30:12	435
8/2/78	09:50:44	476
11/29/77	22:43:24	396

The plant parameters required for this study were the following:

RC Pumps Seal Injection Flowrate	F-782
RC System Letdown Flowrate	F-717
RC System Makeup Flowrate	F-740
RC System Pressure	Reactimeter
Loop 1 or 2 Cold Leg Temperature	Reactimeter

Seal Injection and letdown flowrates appeared to remain on-scale or decreased to 0 gpm during the reactor trip transients; however, makeup flowrate was frequently greater than 160 gpm which is the full scale indication. A separate but related effort was performed for determining the maximum flowrate of makeup into the RC system at various pressures for either one or two makeup pumps operating.

In the following figures, the net additional volume to the RC system is the integral of the net makeup flowrate from reactor trip time to the time that minimum pressurizer level occurs. The net makeup flowrate is defined as:

$$\hat{W}_{net} = \dot{W}_{seal\ injection} + \dot{W}_{makeup} - \dot{W}_{letdown}$$

All of these flowrates are measured at approximately 100F and represent the net volume addition to the RC system at 100F prior to being heated to the cold leg temperature of approximately 550F. The ratio of volume for the mass of coolant being added to the RC system is approximately 1.3 and varies for each specific reactor trip transient due to slightly different cold leg temperatures at time of minimum pressurizer level.

Figure 1 shows the profiles of seal injection makeup and letdown flowrates following the trip of the reactor on February 24, 1978. The lower portion of the figure displays the net makeup flowrate into the RCS based on these flowrate profiles. The total volume of fluid added to the RC system and corrected to 550F is 199 gallons which is equivalent to 8.3 inches of pressurizer level.

Figure 2 exhibits the seal injection, makeup, and letdown flowrate profiles after the reactor trip on April 2, 1978. Also shown is the net makeup flowrate profile determined from the individual flowrate profiles. Adjusting to a final temperature of 550F, the calculated final volume added to the RC system was 197 gallons. This volume is equivalent to 8.2 inches of pressurizer level.

Figure 3 also shows the seal injection, makeup, and letdown flowrate profiles as derived from the Post Trip Review log from the reactor trip transient of August 2, 1978. The lower portion of Figure 3 displays the net makeup flowrate profile in the time interval until minimum pressurizer level was reached. The total volume of fluid added to the RC system at 555F was 548 gallons and is considerably larger than the other calculated volumes for two reasons:

(1) The operator turned on the second makeup pump about 15 seconds earlier than in previous reactor trip transients.

(2) The time to reach minimum pressurizer level was at least thirty seconds longer than for other reactor trip transients.

The volume added to the RC system is equivalent to 22.9 inches of pressurizer level.

Figure 4 presents the flowrate profiles of seal injection makeup and letdown that occurred on the unusual reactor trip and station blackout transient of November 29, 1977. With loss of power, no seal injection flowrate and very little makeup flowrate existed until it was possible to re-start a makeup pump.

Shortly after four minutes beyond the time the reactor was tripped, pressurizer level dropped below a zero indication, therefore, the net makeup flowrate profile was integrated from 0 to 4 minutes rather than to the time estimated for minimum pressurizer level. In this way, measured and calculated changes in pressurizer level could be compared and the correction due to the added volume could be applied to the calculated change in pressurizer level.

The volume of fluid added to the RC system at a temperature of 529F was 352 gallons which is equivalent to 14.7 inches of pressurizer level.

Conclusion

Though the Post Trip Review log was available for each of the four reactor trips, the infrequent update time of every 30 seconds leads to a fairly inaccurate determination of flowrate profiles for seal injection, makeup and letdown.

An effort to define the net makeup flowrate profile was accomplished for the four reactor trips and the total volume of heated fluid added to the RC system was calculated. Since the primary source of fluid added to the system is that due to the makeup pumps, it was necessary to calculate (and verify with other previous calculations) the maximum makeup flowrate with valve wide open whenever one or two makeup pumps were operating. Figure 6 is included

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to show the sensitivity of makeup system flowrate with RC system pressure and the valve wide open condition is represented by the lines labeled K = 0.0050. Since all these makeup system flowrates exceed the maximum indication of the makeup flowrate indicator, there is no verification of the actual system flowrate at Davis-Besse 1.

For these two reasons, B&W recommends that this method of correcting calculated pressurizer level change following a reactor trip not be treated as an accurate or reliable technique for determining true minimum pressurizer level during any future reactor trip transients.

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R.C. Syste.. Flowrates After Re..ctor Trip On Feb 24, 1978 At Davis-Besse 1

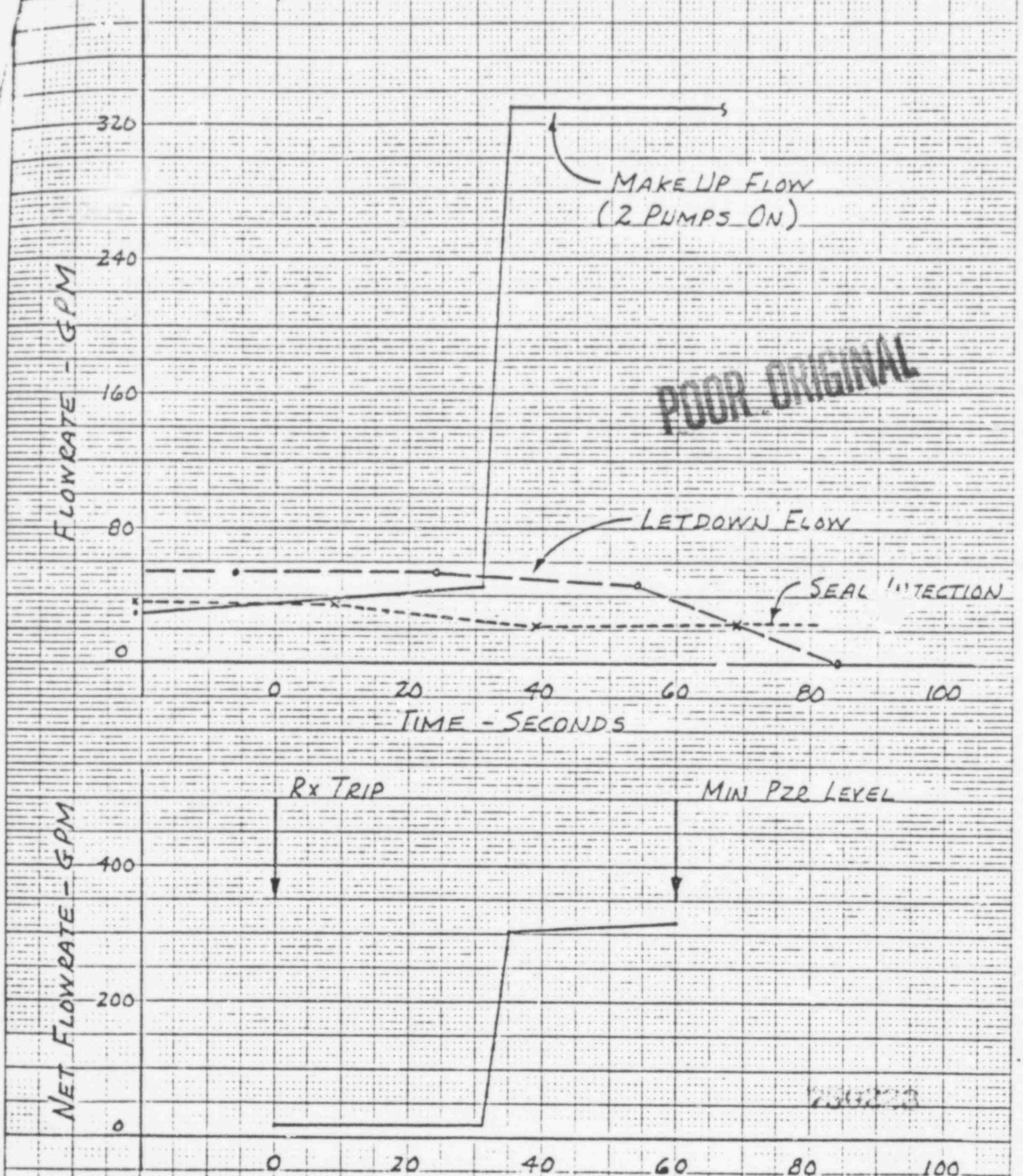

FIG 1

NET RC S..TEM FLOW AFTER REAC.OR TRIP ON
APRIL 2, 1978 AT DAVIS-BESSE 1

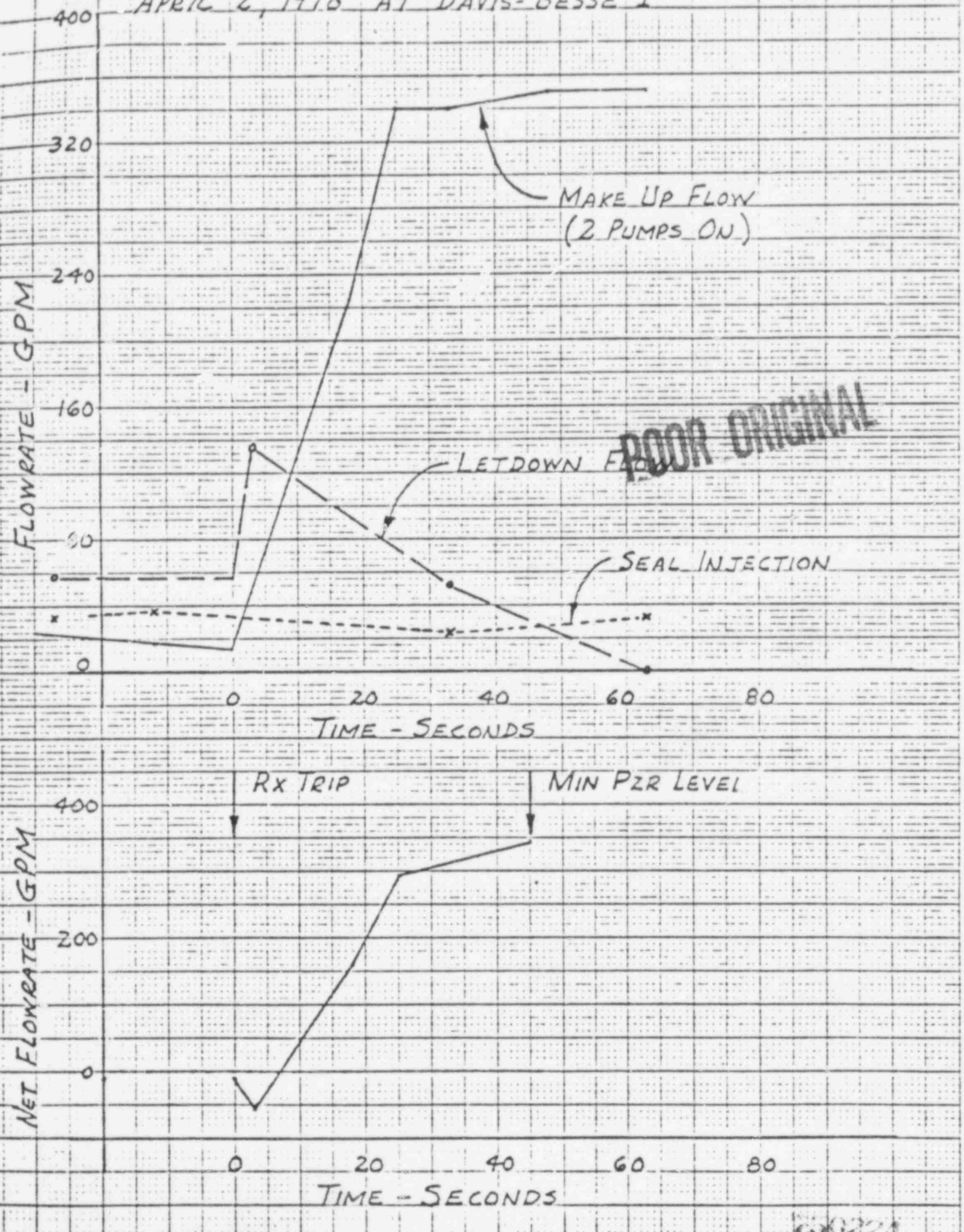

FIG 2

RC SYSTEM FLOWRATES AFTER REACTOR TRIP ON AUG 2, 1978 AT DAVIS-BESSE 1

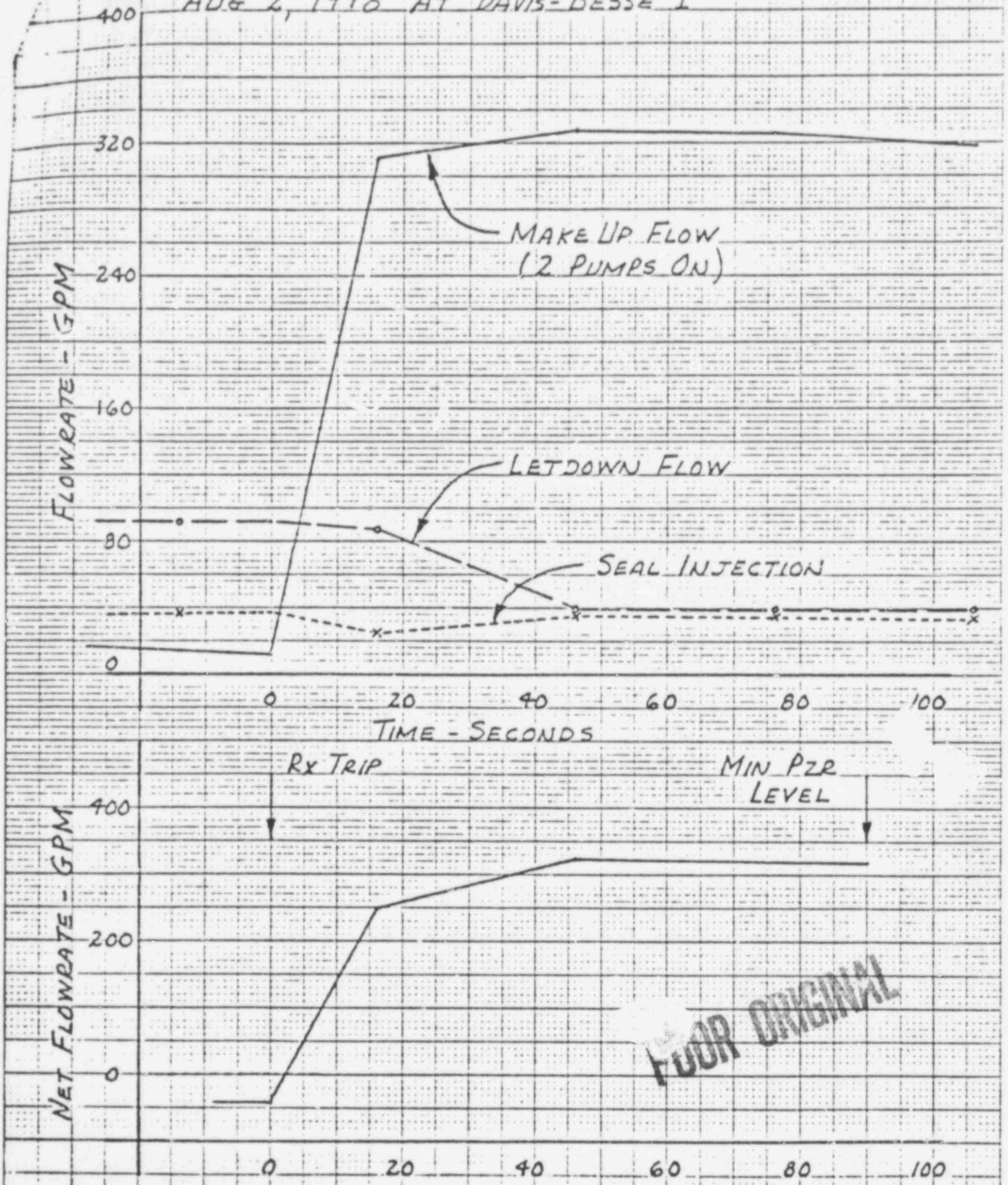

FIG 3

R.C. SYSTEM FLOWRATES AFTER REACTOR TRIP AND STATION BLACKOUT ON NOV 29, 1977

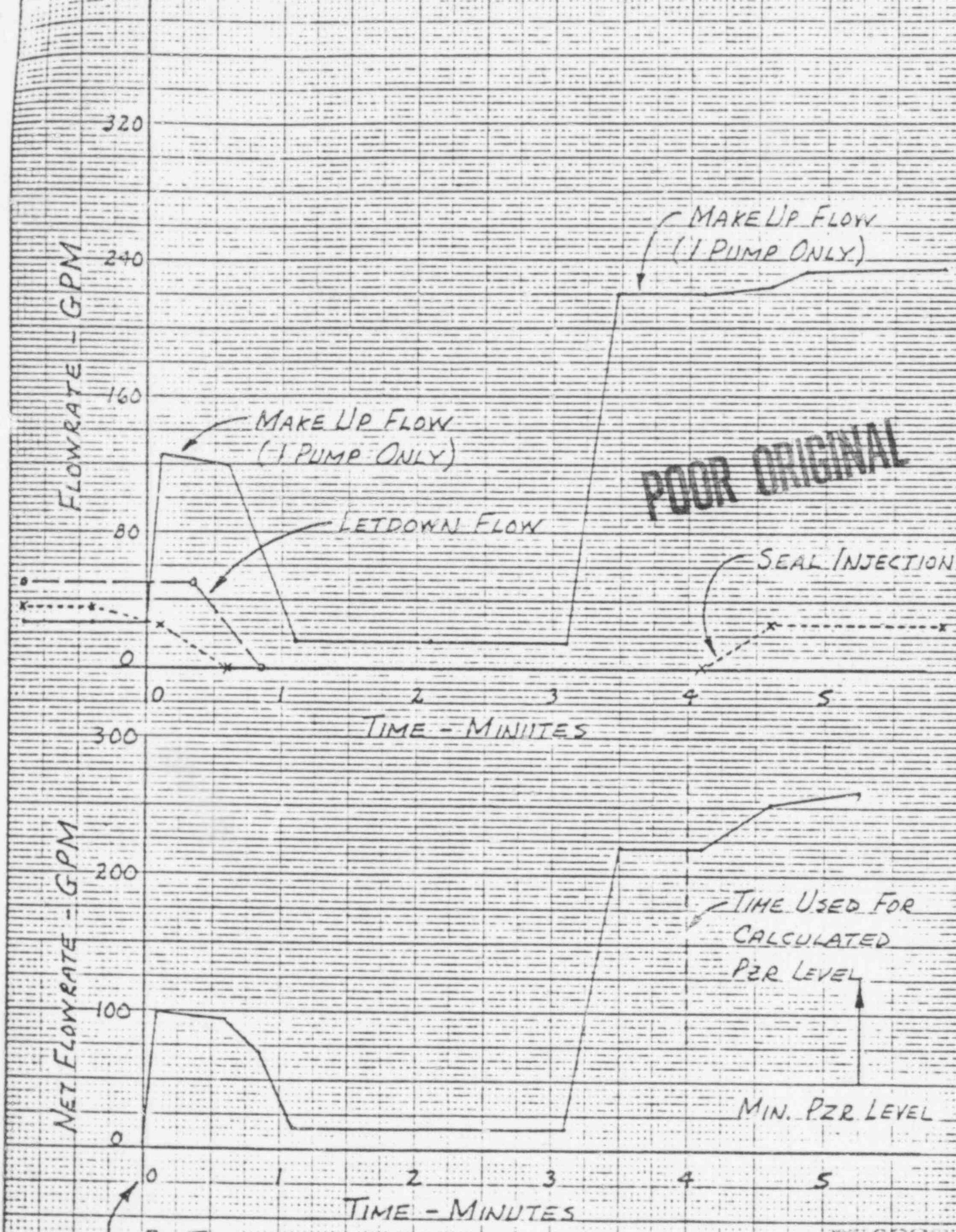

FIG 4

CALCULATED MAKEUP FLOWRATES FOR EITHER 1 OR 2 MAKE UP PUMPS VERSUS RC PRESSURE AT DAVIS-BESSE 1

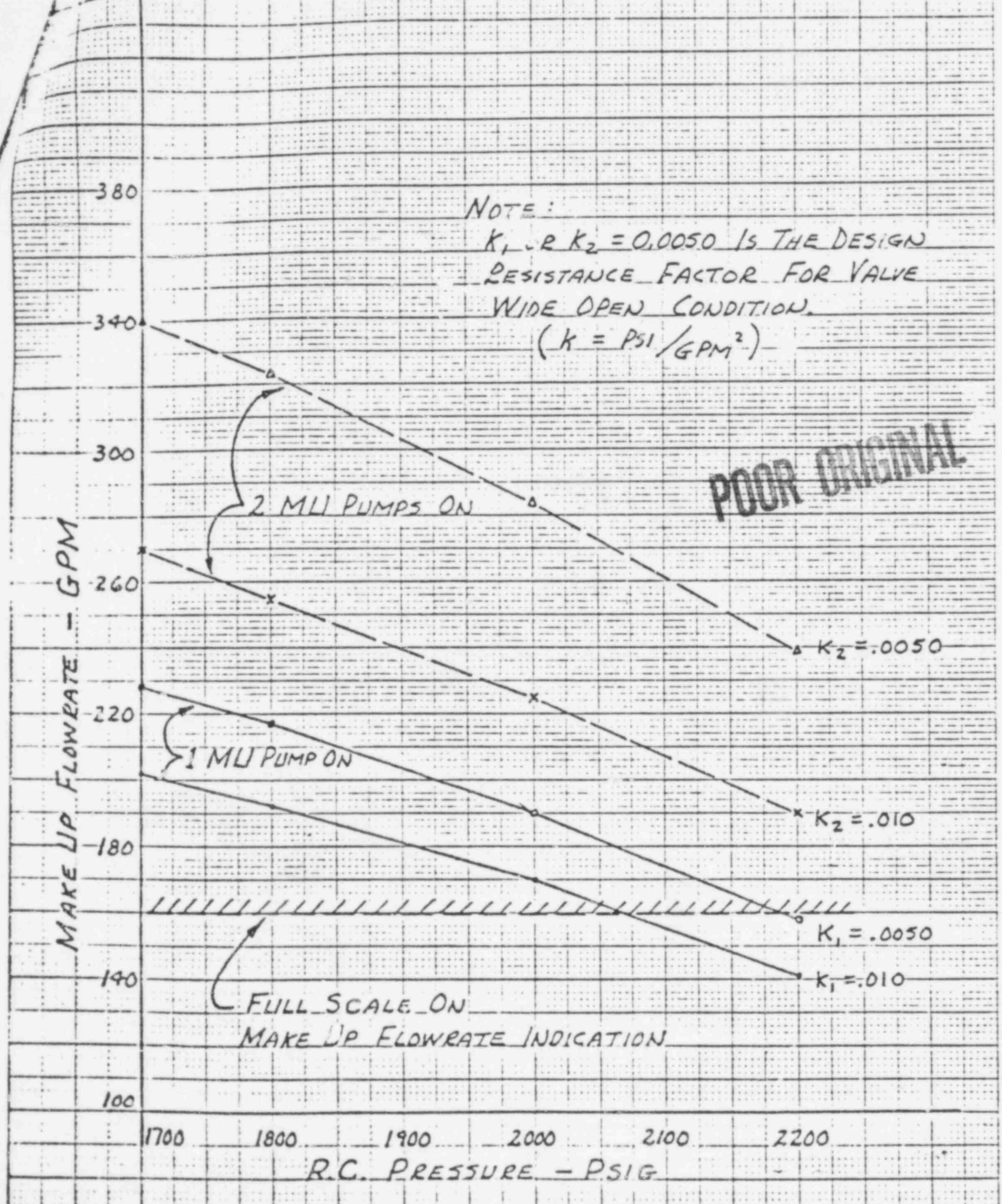

FIG 6

Babcock & Wilcox TELECOPY

Power Generation Group
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September 8, 1978

BWT-1698
File: T1.2/12B

Mr. C. R. Domeck
Nuclear ProjectEngineer
Toledo Edison Company
300 Madison Avenue
Toledo, OH 43652

Subject: Toledo Edison Company
PRESSURIZER PERFORMANCE DURING REACTOR TRIPS
Davis-Besse Unit 1
B&W, REFERENCE NSS-14

Dear Mr. Domeck:

Attached per your request is a report describing the dynamic performance of the pressurizer during reactor trips at Davis-Besse Unit 1.

Very truly yours,

R. C. Luken

R. C. Luken
Project Manager

For A. H. Lazar
Senior Project Manager

RCL/hj
Attachment

cc: J. D. Lenardson w/a
J. C. Lewis
D. J. DeLaCroix
M. Malcom/4 w/a
E. C. Novak/1 w/a

bcc: (with attachment)
Ivan Green
W. H. Spangler
R. W. Winks
A. H. Lazar
Records Center
F. R. Faist
R. C. Luken

750228

Babcock&Wilcox ATTACHMENT TO BWT-1698

DYNAMIC PERFORMANCE OF THE PRESSURIZER DURING REACTOR TRIPS AT DAVIS-BESSE 1

I. INTRODUCTION

During the reactor trip transient at Davis-Besse 1 on November 29, 1977, the pressurizer level indicator went off scale. This incident and subsequent reactor trip transients have raised a concern that the pressurizer will empty completely during a reactor trip from full power with simultaneous loss of station power. The reactor trip transients to date have occurred at partial power levels with either all RC pumps running or all four RC Pumps tripped.

The purpose of this report is to present the results of calculations indicating the minimum pressurizer level reached during the November 29, 1977 transient. Additionally, this report will present a calculational technique for predicting minimum pressurizer levels following a reactor trip transient and account for either tripped or running RC pumps. Actual reactor trip transient test data from Davis-Besse 1 has been used to support the calculational technique.

II. SUMMARY

The minimum pressurizer level that occurred on the November 29, 1977 reactor trip transient with loss of all four RC pumps is calculated to have been 32 inches below the low level tap. A fluid reserve equivalent to 43 inches of level existed in the pressurizer before makeup flow increased the volume of reactor coolant. Minimum main steam pressures were 610 and 730 psig for the two steam generators.

A calculational technique has been developed for predicting changes in pressurizer level during reactor trips which agrees very well with observed reactor trip transients at Davis-Besse 1.

The method has been used to predict the final minimum pressurizer level for two possible transients (both from 100% power): a reactor trip with simultaneous trip of all RC pumps, and a reactor trip with all RC pumps operating.

For the first transient above, the pressurizer level will decrease only 100 inches, provided that main steam pressure will not decrease below 950 psig. If main steam pressure decreases to 700 psig the pressurizer would become empty.

For the reactor trip transient with all RC pumps running, the pressurizer level will decrease below the lower level tap if the main steam pressure drops to 950 psig. Since a minimum main steam pressure of 980 psig is anticipated on future reactor trip transients, the predicted minimum pressurizer level will be a few inches above the zero indication and nearly 80 inches above the bottom of the pressurizer. If steam pressure decreases to 840 psig on this transient, the pressurizer would become empty.

Two graphs have been developed (Figures 2 and 3) which relate minimum T_{ave} to minimum pressurizer level for the two different reactor trip transients. These graphs can be used to predict pressurizer performance during any large transients at Davis-Besse 1.

III. ANALYSIS OF NOVEMBER 29, 1977 TRANSIENTS

The following reactor trip transients have been analyzed to determine a realistic primary system cooldown profile for analyzing and predicting pressurizer performance:

TABLE 1

Date	Initial Power Level	RC Pumps Running	Comments
2/24/78	74	yes	Trip initiated by the failure of a flowmeter ΔP transmitter.
4/2/78	75	yes	Turbine trip test with unsuccessful runback of reactor power.
8/2/78	40	yes	Reactor trip due to divergent oscillations while in tracking mode.
11/29/77	40	no	Reactor trip and station blackout causing loss of RC pumps.

The response of the ICS and plant was adequately similar for these four transients to be able to characterize the relationship between T_{ave} and RC pressure following the trip of the reactor. Figure 1 displays this relationship. This curve was utilized in predicting minimum conditions in the reactor coolant system for calculating minimum values of level in the pressurizer.

The objective of our analysis was to compare the predicted change in pressurizer level with measured changes in level and verify that the mathematical model was sufficiently accurate to predict pressurizer level changes that dropped below the lower level tap.

The mathematical model used to represent the contraction of the RC system during these transients utilizes the following equation:

Total mass of fluid in the RC system = M_o =

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$$\frac{\text{Equivalent Volume of Hot Fluid}}{\text{Specific Volume of Hot Fluid}} + \frac{\text{Equivalent Volume of Cold Fluid}}{\text{Specific Volume of Cold Fluid}}$$

Cont'd

$$+ \quad \frac{\text{Liquid Volume of the Pressurizer}}{\text{Specific Volume of Pressurizer Fluid}}$$

The equivalent volume of hot fluid consists of upper half of each steam generator, one half of the reactor vessel and all the hot leg piping.

Similarly the equivalent volume of cold fluids consists of the other half of both steam generators, the lower half of the reactor vessel, and all the cold leg piping. the sum of the hot and cold fluid volumes is equivalent to the total reactor coolant system volume excluding the pressurizer.

The calculational technique requires the determination of the initial and final pressures and temperatures of the reactor coolant system, an evaluation of the specific volumes for those conditions plus saturated conditions within the pressurizer, and the difference in pressurizer volume due to the calculated contraction of the constant mass in the RC system.

Table 2 below, presents a comparison of calculated pressurizer level changes with measured level changes at selected time intervals in the four reactor trip transients.

TABLE 2

Comparison of Measured and Calculated Changes in Pressurizer Levels During Reactor Trip Transients at Davis-Besse 1

Date of Rx Trip	Measured Δ Level - inches	Calculated Δ Level - inches	Time Elapsed - seconds
2/24/78	191	184	60
4/2/48	162	167	45
8/2/78	196	206	90
11/29/77	139	132	170
11/29/77	184	181	240

The test data from the November 29, 1977 reactor trip was examined to find the minimum RC pressure and temperatures that probably occurred while the pressurizer level was off scale and the values were determined to be the following:

At clock time 22:48:50, minimum RC pressure was 1625 psig ($\pm$50 psig due to oscillations). The corresponding value of hot leg temperature was 562.5F whereas the cold leg temperature was off-scale (below 520F) and was calculated to be 508.5F. T_{ave} for Loop 2 was determined to be 535.5F and the Loop 1 and 2 steam pressures indicated 610 and 760 psig respectively.

These values were used to specify the final specific volumes required in the equation and revealed that the change in pressurizer level was 224 inches. Since the initial pressurizer level at instant of reactor trip was 192 inches, then the final pressurizer level was 32 inches below the lower level tap. There was another 43 inches of water remaining in the pressurizer at this time.

IV. PREDICTED PRESSURIZER PERFORMANCE AT 100% FULL POWER

The extent of reactor coolant volume contraction following a reactor trip is primarily governed by the wetted surface area of the tube bundle and by the steam pressure maintained within both Once Through Steam Generators. It is also affected by the flowrate of reactor coolant through both steam generators, that is, all pumps running versus all pumps tripped.

Figure 2 was developed for the situation of a reactor trip from full power plus loss of all RC pumps. The minimum T_{ave} will be controlled by the steam pressure in each steam generator. By selecting decreasing values of T_{ave} and corresponding values of steam pressure, minimum pressurizer levels were predicted.

The intent is to be able to predict the total change in pressurizer level that will occur as T_{ave} changes from a normal 582F to a known or anticipated minimum temperature.

Figure 2 shows that T_{ave} has to decrease to 534F to empty the pressurizer for this reactor trip transient (no RC pumps running) and that this require a minimum steam pressure in each steam generator to be equal to 665 psig.

By controlling steam pressure above 800 psig during this transient, the pressurizer level can remain above the lower level tap. The blowdown on all the main steam safety relief valves has been adjusted by Toledo Edison Company at the Davis-Besse 1 plant early in 1978. The values of minimum steam pressure after a recent reactor trip transient indicate that the performance of the steam pressure relief system is greatly improved over that observed during earlier reactor trip transients.

If the initial power level had been 100% on the November 29, 1977 transient then the calculated minimum pressurizer level would have been 58 inches below the lower level tap. Since the initial power level was only 40%, the amount of contraction in the RC system was only -32 inches. Both of these calculated values are less than predicted (by application of Figure 2), and demonstrate the conservatism of the method. The dependence of the contraction of reactor coolant on initial power level is exhibited in Table 3 below:

Table 3 750232

RC Contractions for Reactor Trips
(With Station Blackout) From 40% and 100% Power Levels

Power Level: - %	40	100
Initial RC Pressure - psia	2138	2138
Initial Thot - F	592	605.5

Initial Level - Inches	192	192
Initial RC Volume - Ft^3	11,264	11,264
Initial RC Mass - Lbs.	496,969	493,437
Final RC Pressure - psia	1640	1640
Final T_{hot} - F	562.5	562.5
Final T_{cold} - F	508.5	508.5
Final RC Mass - Lbs	496,969	493,437
Final Pzr. Volume - Ft^3	122	37
Final Pzr. Level - Inches	-32	-58

Figure 3 was similarly developed for a regular reactor trip from full power (all pumps running). This transient is more severe than the previous situation in that the forced convection of reactor coolant quickly removes all stored heat in the primary system. Below a T_{ave} value of 550F, T_{ave}, cold leg temperature, and saturation temperature in the steam generators are almost all equal. Thus, much greater care must be exercised in maintaining steam pressure to avoid emptying the pressurizer. An expected main steam pressure of 980 psig should occur, as has been demonstrated on the August 2, 1978 reactor trip, and the pressurizer level will remain above the lower level tap.

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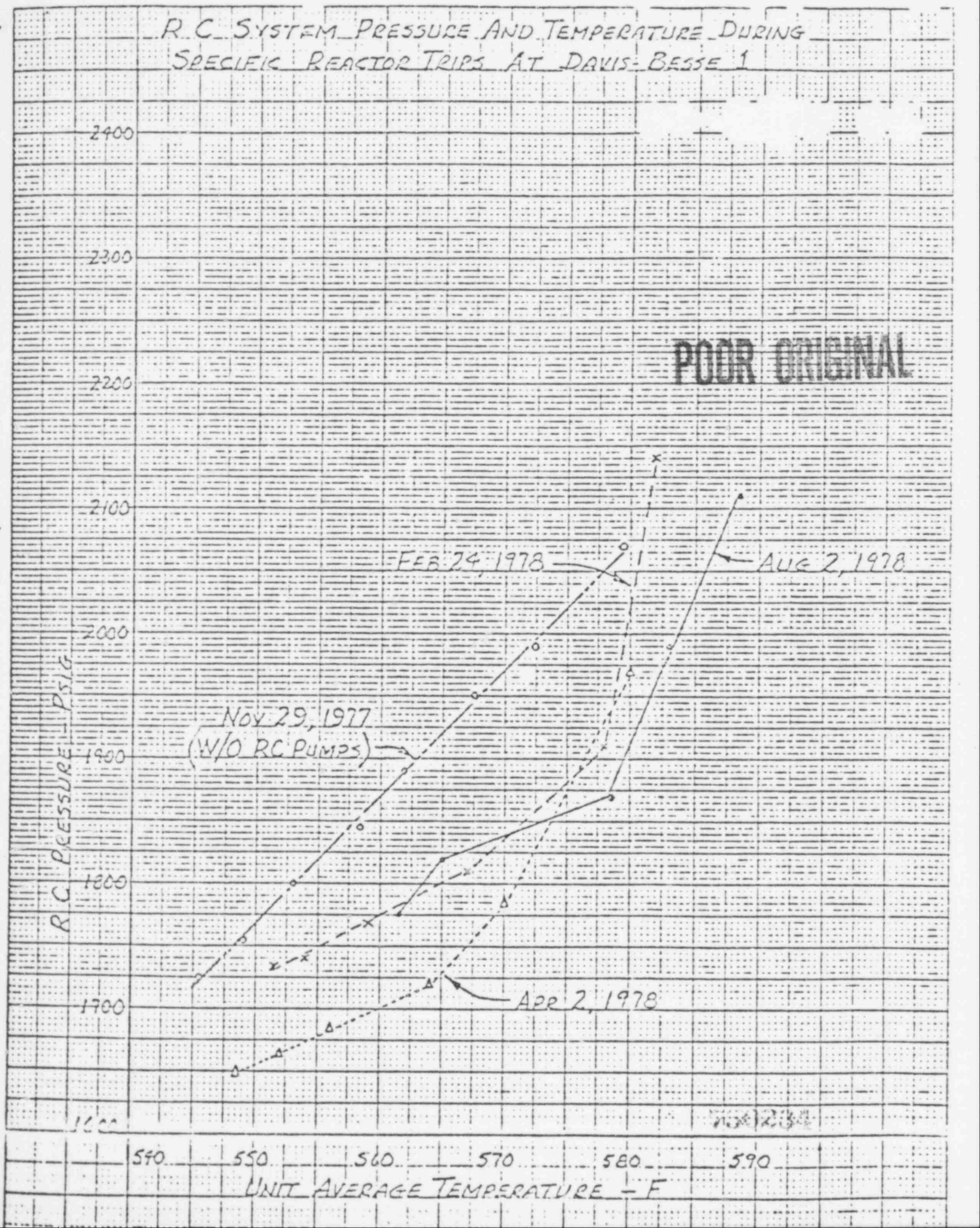
R C System Pressure and Temperature During
Specific Reactor Trips at Davis-Besse 1
2400
2300
2200
2100
2000
1900
1800
1700
1600
R C Pressure – PSIG
Feb 24, 1978
Aug 2, 1978
Nov 29, 1977
(W/O RC Pumps)
Apr 2, 1978
540
550
560
570
580
590
Unit Average Temperature – F

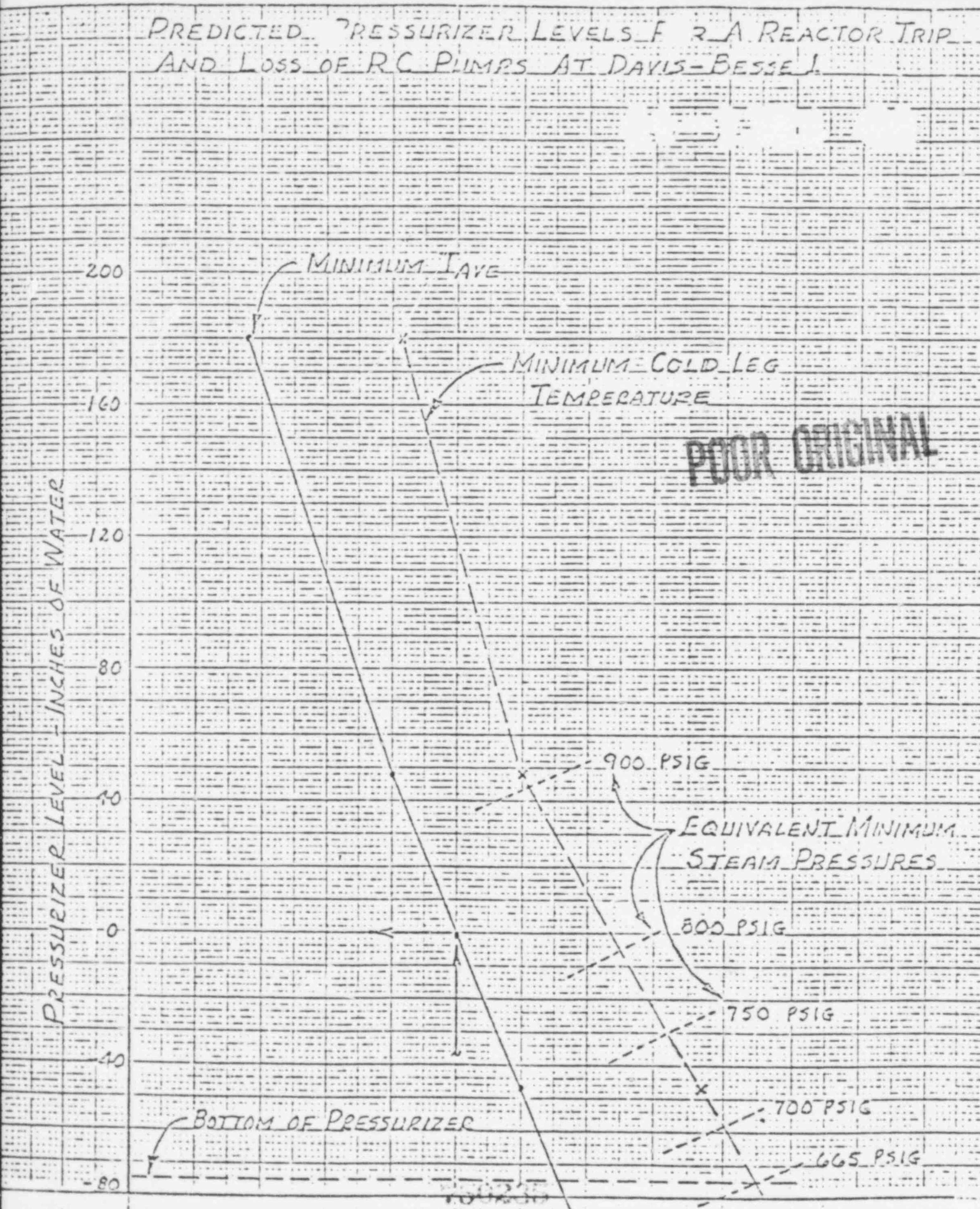
PREDICTED PRESSURIZER LEVELS F R A REACTOR TRIP AND LOSS OF RC PUMPS AT DAVIS-BESSE 1
MINIMUM TAVE
MINIMUM COLD LEG TEMPERATURE
POOR ORIGINAL
900 PSIG
EQUIVALENT MINIMUM STEAM PRESSURES
800 PSIG
750 PSIG
700 PSIG
665 PSIG
BOTTOM OF PRESSURIZER
PRESSURIZER LEVEL - INCHES OF WATER
200
160
120
80
40
0
-40
-80
600
580
560
540
520
500
RC TEMPERATURE - F

FIG 2

PREDICTED PRESSURIZER LEVELS FOR REACTOR TRIP FROM FULL POWER AT DAVIS-BESSE 1

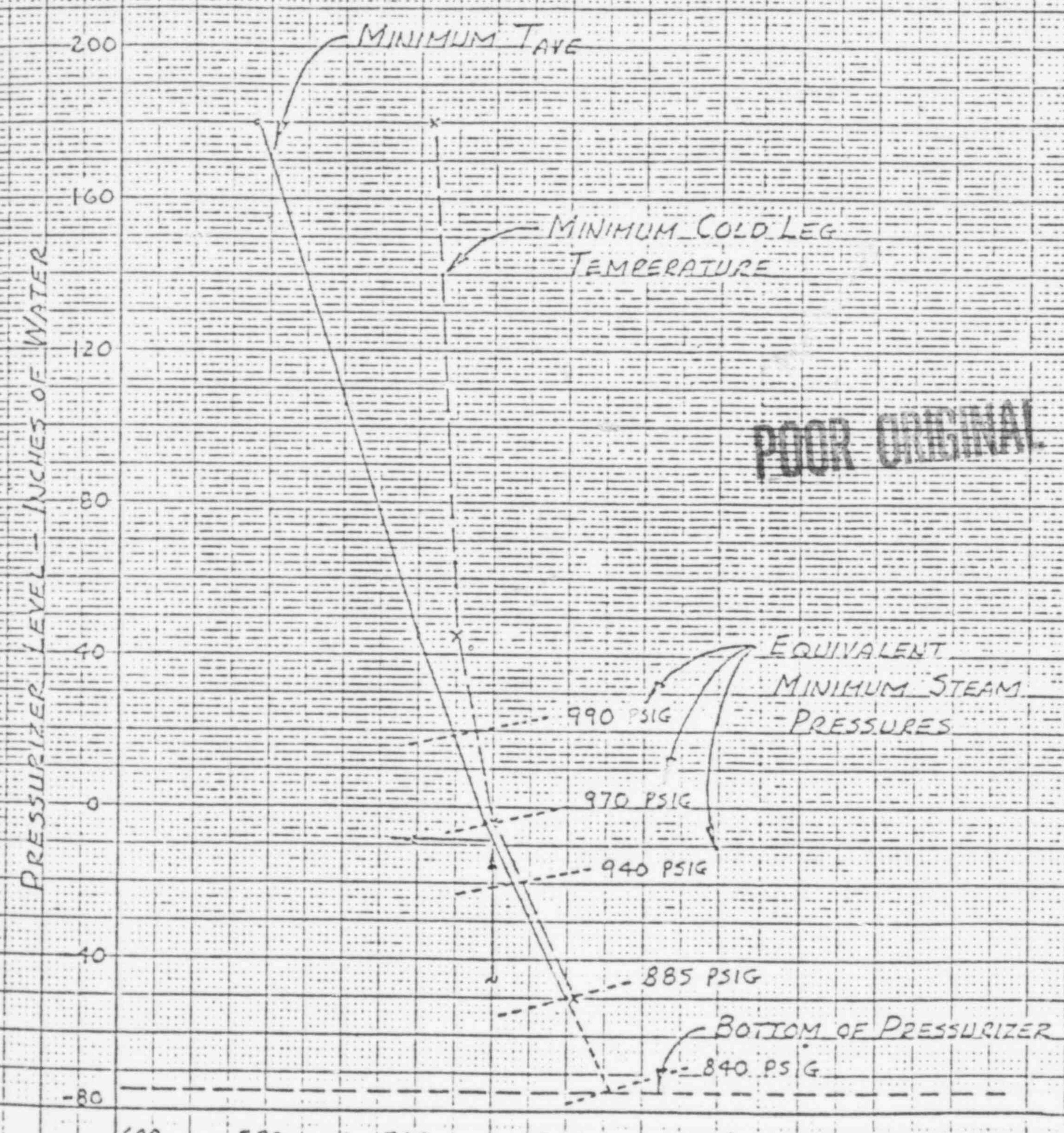

FIG 3