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August 31, 1984
5211-84-2221

Office of Nuclear Reactor Regulation
Attn: John F. Stolz, Chief
Operating Reactors Branch #4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Sir:

Three Mile Island Nuclear Station, Unit 1 (TMI-1)
Operating License No. DPR-50
Docket No. 50-289
Subcooling Margin Monitor (SMM)

During recent discussions with Mr. J. Van Vliet (NRC) on July 11, 1984, GPUN became aware of some apparent inconsistencies identified concerning the 25° F subcooling margin monitor and its associated error. The purpose of this letter is to clarify our position and to describe recent analyses that we have done to verify the validity of the 25°F SMM action point.

By letter dated March 31, 1983, GPUN notified the NRC of the intent to revise the reactor coolant pump trip criterion during a small break LOCA from 1600 psig (ESAS setpoint) to 25° F subcooling margin (reduced from 50° F). In May 1983 the TMI-1 Restart Atomic Safety and Licensing Appeal Board required NRC staff to verify SMM instrument error to be less than 20° F (plus a 5°F system configuration error). On September 7, 1983 GPUN submitted a detailed calculation indicating a subcooling margin instrument error of ± 22.1° F and a system configuration error of ± 1.3° F which in total is less than 25° F. Then on June 25, 1984 GPUN provided to the ASLB on Steam Generator repair a report entitled "TMI-1 GORB Subcommittee on Steam Generator Repair Report to the TMI-1 GORB" dated June 13, 1984 for their information. This report contained a recommendation that:

(1) An independent verification should be made of the error analysis which supports selecting the subcooled margin limit applicable to reactor coolant pump trip following a steam generator tube break. The verification should be equivalent to that required by ANSI Standards for design verification. The analysis and the verification should be subject to an interdisciplinary technical review by senior engineers who understand error analysis and primary system response to tube breaks and other loss of coolant accidents.

A001
1/1

Additionally, this GORB subcommittee report contains several apparent inconsistencies with our earlier submittal. In particular pages 9 and 10 item 2 states:

(2) For tube rupture transients, the Subcommittee concurs with the desirability of reducing indicated subcooling to 25°F (provided this value is verified as noted above) or to emergency RCP NPSH limits (whichever is more limiting). However, the possibility exists that an instrument string which measures subcooling margin could read erroneously high by more than 25°F. If that were to happen, it is important that the operator recognize that the instrument is in error, since once actual saturation has been reached the instrument reading will "hang up" at the value of error (higher than 25°F in this postulated case) while the operator continues to reduce pressure. The instrument will not indicate lower saturation margin until superheating from uncovered fuel commences. Since there are several independent instrument strings which can be used to measure subcooling, the Subcommittee does not consider it credible - that they would all read erroneously high by more than 25°F at the same time, provided calibration procedures and equipment preclude a common error in all the instrument strings. Therefore, the operator should be able to avoid reaching saturation conditions without knowing it. However, it is important that all operators understand the symptom (described above) which would be observed in this case and that they understand which other plant symptoms would indicate saturation had occurred (i.e., changes in pressurizer level, pump current, etc.). The Subcommittee recommends these matters be addressed in the training discussed in Section II (2).

This concern on operability, namely instrument failure, is independent of the error analysis. GPUN had previously recognized the need for training in this area and this training has been accomplished. Failures in one of the instruments can be checked against the other redundant instrument and through the plant computer.

As a result of the GORB-recommended independent verification, several factors have been identified which affect the calculation provided earlier to you and to the GORB.

1) The propagation of the pressure transmitter string error through the function generator was not adequately modeled.

2) The pressure transmitter manufacturer's equation for error due to high ambient temperature over predicts the error when the measured pressure is less than the upper limit of the calibrated span.

3) The manufacturer's published values for accuracy include linearity, hysteresis, dead band and repeatability.

4) The difference in ranges among the instruments in the string were not accounted for in some instances.

5) The effect of RB pressure was not considered.

6) Recent changes (improvements in the instrument string) had not been included.

GPU's assessment of the effects of these items on the earlier conclusion is summarized in Enclosure 1. The complete recalculation is provided in Enclosure 2. The re-evaluation includes consideration of abnormal transients for which the instrument is used, including steam generator tube rupture, main steam line break, and small break LOCA under worst-case containment conditions. Results available to date support the following conclusions:

1) The instrument is acceptable for tube rupture and any other event which does not result in degraded containment conditions.

2) The instrument is acceptable for main steam line break and any other overcooling event above 200 psig actual RCS pressure under worst case containment conditions. Even worst case steam line rupture accidents remain above an actual RCS pressure of 400 psig (450 psig indicated with a 50 psi error) since core flood tanks hold up RCS pressure. The plant will be stabilized above this pressure for some time, and the cooldown below 400 psig actual pressure will continue under more favorable containment conditions.

3) The instrument is acceptable above 200 psig actual pressure (250 psig indicated with 50 psi error) for small break LOCA. Below this pressure the RC pumps are tripped and the SMM is not used.

Based on the above, the SMM is acceptable for all conditions for which it is used. The means to determine subcooling margin for SB LOCA below 250 psig indicated pressure with the RC pumps off is being evaluated to determine if changes are needed.

Sincerely,

H. D. Hukill
Director, TMI-1

HDH:LWH:dls:0079A

cc: R. Conte
J. Van Vliet

Instrumentation Error Basis Change

The function generator converts the pressure signal to a saturation temperature signal. It is essentially an 8-stage amplifier where each stage covers a segment of the total pressure range. A particular stage has a gain which approximates the slope of the Saturation Temperature/Pressure curve for its segment of the pressure range. Therefore, for a given pressure, the pressure errors are amplified by a factor equal to the dT/dP of the applicable pressure range. The values of dT/dP vary from 0.064 in the 1900-2500 psig range to 0.496 in the 100-200 psig range, and 1.264 in the 0-100 psig range. The omission of this factor was equivalent to using dT/dP=1 throughout the 0-2500 psig range. This resulted in calculated error values which were non-conservative by a factor of 1.264 in the 0-100 psig range. However, the values in the 100-2500 psig range were conservative by a factor ranging from 2 to 15.6.

The pressure transmitter manufacturer's published equations for error due to high ambient temperature are of the form:

Error = $\pm$ (a x URL + b x Span)

Where:

a and b are constants

URL = Upper Range Limit

The highest value that the transmitter can be adjusted to measure.

Span = The algebraic difference between the highest and lowest values that the transmitter is calibrated to measure.

The manufacturer confirmed the following:

1) The equation is for the error when actual pressure is at the upper limit of the calibrated span. It overpredicts the error at lower measured pressures.

2) To calculate the error at measured pressures below the upper limit of the calibrated span, span is defined as follows:

   Span = The algebraic difference between the measured pressure and the lowest value that the transmitter is calibrated to measure.

In the case where the lower limit is 0 psig,

Span = Measured Pressure

In some instances, error values for linearity, repeatability, and dead band were included in the original calculation in addition to values for accuracy. Since the manufacturer's published accuracy value already includes these errors, they were accounted for twice.

The range of the final modules of the instrument string is -100F to 400F Subcooling. The calculated loop error is expressed in percent of this range. However, there are modules in the string with different ranges. Therefore, the percent error for these modules must be multiplied by the ratio of the module range to the final module range. This error was non-conservative by a factor of 5 for the pressure transmitter and the I/E converter.

The calculation has been revised to account for these factors.

Enclosure 2

T M I - 1

S A T U R A T I O N   M A R G I N

M O N I T O R

L O O P   E R R O R   A N A L S I S

SUBJECT TMI - SATURATION MARGIN MONITOR

LOOP ERROR ANALYSIS

OBJECTIVE

Determine the expected errors for the alarm, indicator, and calibration instrument loops during normal operations and also for small break LOCA, and steam line break conditions. This calculation is based on the instrument loop defined by the Reference 1 modification and includes the verification comments (Reference 2) to the original issue.

REFERENCES

1. GPUN B/A 123072 - Modification of TSAT to replace non-1E temperature inputs with 1E temp. inputs.
2. GPUN verification of Calculation C-1101-665-5350-005 by J. P. Moore dated 7/10/84.
3. USNRC Memo - Peter S. Kapotow 8/23/82 page A6 NUREG-0737 analytical solutions to two problems pertinent to Items II.F.1.4, 5, 6, a statistical treatment of deadband and hysteresis errors.
4. Control valve handbook, Fisher Controls, Properties of Saturated Steam.
5. GPUN memo EP&I/84/1525-047M, Rosemount 1153 accuracy.
6. GPUN Calculation C-1101-665-5300-006, "TMI-1 Saturation Margin Monitor Error Analysis - Rosemount Pressure Transmitter".

ASSUMPTIONS

1. Unless otherwise stated, Vendor published accuracy data includes the combined effects of linearity, hysteresis, deadband and repeatability as stated in Standard ISA-S51.1, 1959.
2. Unless otherwise stated Vendor published accuracy data represents 3 Sigma (3σ) values, and can be converted to 2σ values by multiplying by 2/3 as stated in Reference 3.
3. Accident conditions are:

   SBLOCA 30 PSIG (no RB spray), 100% RH, 5×10^7R, 245°F.
   Steam line break 38 psig, 390°F. (245°F at pressure transmitter.) | 3

4. Signal conditioning electronics and display devices are located within controlled environments within the control building.

DISCUSSION

The saturation margin monitor measures RC temperature and pressure. The pressure signal is used to electronically compute the fluid saturation temperature. This computed saturation temperature is compared to the actual measured temperature and a margin to saturation is determined and displayed. An alarm is provided. There are two channels. The RTD's and RC pressure transmitters are inside containment and exposed to the SBLOCA/SLB environment. The system is used under normal, SBLOCA/SLB, and OTSG tube rupture conditions only.

Error calculations are organized in four parts. |3

a) Part 1 derives the random error for non-accident and SBLOCA/SBL conditions in the alarm instrument loop. |3

The Rosemount RC pressure transmitter latest test results (1153 series B/D) is based on LOCA conditions with a maximum temperature of 420° and radiation exposure of 5×10^7 RAD. This is too conservative compared with SBLOCA conditions of 245°F and 5×10^7 R. Therefore, original test data was reviewed to calculate the standard deviation of temperature effect error data. It was determined that a conservative estimate of the SBLOCA/SLB 2σ temperature error could be obtained by dividing the LOCA temperature error equation provided by Rosemount by three (Ref. 6). Analysis of the SBLOCA indicates that elevated LOCA temperature and radiation will not occur concurrently. Therefore, the worst of these two error values (temperature) was used alone in the "Accident" error calculations. |3

b) Part 2 derives the random error for non-accident and SBLOCA/SBL conditions, in the Indicator instrument loop. The same pressure transmitter temperature error values described in paragraph a) above are used. |3

c) Part 3 derives the random error for calibration of the alarm instrument loop.

d) Part 4 derives the systematic worst case errors due to the characterizer RC pressure to saturation temperature conversion error and containment pressure errors during SBLOCA and SLB conditions. |3

In addition to the loop uncertainty errors that are random in nature, there exists systematic errors that are fixed quantities under certain conditions.

The systematic errors consist of:

a) Characterizer Curve Error.
b) Containment Pressure Error

Characterizer curve error is a function of reactor coolant pressure conversion to saturation temperature. For each of eight segments of RC pressure, the error varies from slightly positive at the segment end values to negative errors in between. For this application, this would be the maximum negative error (conversion to a saturation temperature value that is lower than the actual saturation value). Therefore, the maximum negative error for each RC pressure segment is presented as a systematic error and the random error should be added to it where applicable.

Containment pressure error is a function of ambient pressure in the containment building where the low side of the RC pressure transmitter vents. During SBLOCA and steam line break accident conditions when the containment pressure is elevated the RC pressure transmitter will provide a pressure signal that will be decreased by an amount equal to the increase of containment pressure over atmospheric. The increase in containment pressure during SBLOCA is 30 psig, and for steam line break is a maximum of 38 psig approximately 80 seconds after the break. The RC pressure is converted to its equivalent saturation temperature and the erroneous decreased pressure transmitter signal would result in a lower value of saturation temperature than actually exists for the true RC pressure. For this application, this would be the maximum negative error value (°F) for each of the eight segments. 2

Therefore, the containment pressure error is presented as a systematic error during accident conditions and the random error should be added to it.

CONCLUSIONS

The calculated errors are the difference between the indicated margin value and the true margin value. A negative error is conservative and denotes that the indicated value is less than the true value. When the error is algebraically subtracted from the indicated value it gives the true value. For example, if the indicated margin and error is 50°F (-10+15°F), the true margin is between 60°F and 35°F.

The worst case loop systematic error for eight segments of RC pressure is presented in Table 1 below.

a) For non-accident conditions, systematic error equals characterizer curve error.

b) For SBLOCA, systematic error equals characterizer curve error plus containment pressure error at 30 psig.

c) For steam line break, systematic error equals characterizer curve error plus containment pressure error at 38 psig.

RC Pressure (PSIG)	SYSTEMATIC ERROR (°F)		
	NON-ACCIDENT	ACCIDENT	
	CHAR. CURVE ERROR	SBLOC	SLB
0-100	-24.4	-62.3	-72.4
100-200	-2.7	-17.6	-21.5
200-400	-3.8	-12.8	-15.2
400-600	-1.6	- 7.7	- 9.4
600-900	-1.5	- 6.1	- 7.3
900-1300	-1.1	- 4.5	- 5.4
1300-1900	-1.3	- 3.9	- 4.5
1900-2500	-0.8	- 2.7	- 3.2

TABLE 1
SYSTEMATIC ERROR

Table 2 contains the random loop error uncertainty at a 2σ level for eight segments of RC pressure from 0-2500 psig for both non-accident and worst case temperature and pressure SBLOCA/SLB conditions.

RC PRESSURE (PSIG)	LOOP UNCERTAINTY - RANDOM					
	NON ACCIDENT			ACCIDENT		
				SBLOCA/SLB		3
	ALARM (°F)	INDICATOR (°F)	CALIBRATION (°F)	ALARM (°F)	INDICATOR (°F)	
0-100	±23.0	±22.7	±15.6	±60.3	±60.2	
100-200	±11.5	±11.0	± 9.4	±25.4	±25.2	
200-400	± 9.0	± 8.4	± 8.1	±17.0	±16.6	3
400-600	± 8.0	± 7.2	± 7.6	±12.8	±12.4	
600-900	± 7.6	± 6.7	± 7.3	±11.1	±10.5	
900-1300	± 7.2	± 6.4	± 7.1	± 9.7	± 9.1	
1300-1900	± 7.1	± 6.1	± 7.0	± 8.8	± 8.1	
1900-2500	± 6.9	± 6.0	± 6.9	± 8.7	± 8.0	

TABLE 2
RANDOM LOOP ERROR

Table 3 presents the total alarm loop error for eight ranges of RC pressure. During normal operating conditions, the negative error is the sum of the negative random error and ther worst negative characterizer curve error, and the total positive error is the sum of the positive random error and the best (zero) characterizer curve error. For the accident conditions, the total negative error is the sum of the negative random error and the applicable accident systematic error, and the total positive error is the positive random error alone

RC PRESSURE (psig)	TOTAL ALARM LOOP UNCERTAINTY		
	Normal (°F)	SBLOCA (°F)	SLB (°F)
0-100	-47.4 +23.0	-122.6 +60.3	-189.7 +60.3
100-200	-14.2 +11.5	-43.0 + 25.4	-69.8 + 25.4
200-400	-12.8 + 9.0	-29.8 + 17.0	-46.1 + 17.0
400-600	- 9.6 + 8.0	-20.5 + 12.8	-31.5 + 12.8
600-900	- 9.1 + 7.6	-17.2 + 11.1	-25.5 + 11.1
900-1300	- 8.3 + 7.2	-14.2 + 9.7	-20.4 + 9.7
1300-1900	- 8.2 + 7.1	-12.7 + 8.8	-17.3 + 8.8
1900-2500	- 7.7 + 6.9	-11.4 + 8.7	-15.7 + 8.7

3

TABLE 3
TOTAL ALARM LOOP ERROR

(8)

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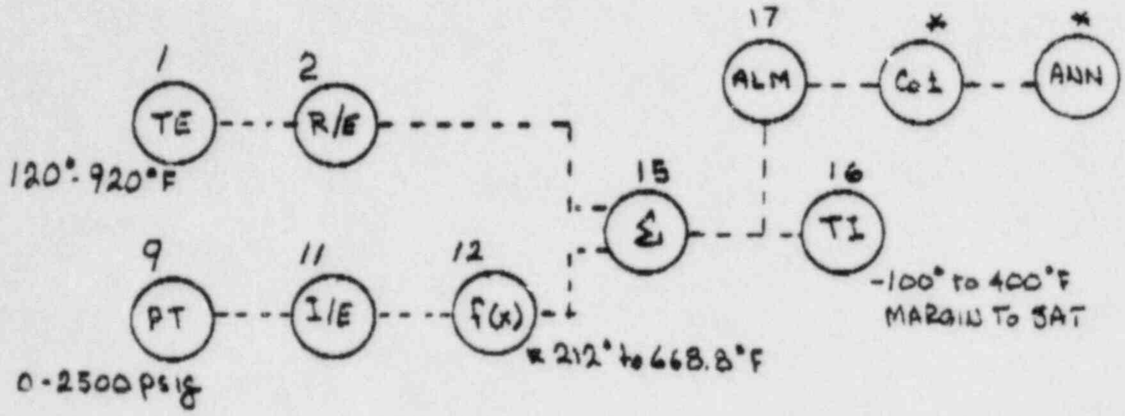
CALC. NO. C-1101-665-5350-005 Rev 1
SHEET NO. 6 OF 28
SUBJECT ...
DATE ...
COMP. BY/DATE ...
CHK'D. BY/DATE ...

INSTRUMENT LOOP DIAGRAM
(ONE OF TWO LOOPS)



* DIGITAL - NO ERROR CONTRIBUTION

MODULES 1 & 2

1. WEED 100Ω RTD #1030/612D-1B-6-C-20-0-0 | 2

2. FOXBORO R/E CONVERTER N-2AI-P2V

RTD error is negligible alone and temp. input accuracy is a function of module 2

	PROD SPEC EP20R (3σ)	APPLICATION ERROR	
A_2 ACCURACY	± 0.5%	± 0.333% · 2σ	
T_2 AMBIENT TEMP EFFECT OF SPAN FOR ΔT = 45°F	< 0.5%	± 0.166%	NOTE 1
V_2 SUPPLY Veffect FOR 5% VARIATION	< 0.25%	± 0.083%	NOTE 2

NOTE 2: POWER SUPPLY/VITAL BUS REGULATION VERY MUCH BETTER THAN 5% ∴ A VALUE EQUIV. to 1σ IS CONSIDERED CONSERVATIVE.

NOTE 1: EQUIPMENT LOCATED IN TEMP. CONTROLLED ENVIRONMENT A VALUE EQUIV. to 1σ IS CONSIDERED CONSERVATIVE.

MODULE 9 ROSEMOUNT PT 1153GD9 (TAG NOS PT949, PT963)

NON ACCIDENT CONDITIONS

	% (3σ)	APPLICATION	
A9 ACCURACY	± 0.25% SPAN	± 0.167% = 2σ	NOTE 5
S9 STABILITY	± 0.25% URL	± 0.2 % 2σ	NOTES 3 & 5
T9 TEMP EFFECT per 50°F	± (0.75% URL + 0.5% span) / 2	± 0.467 ≈ 2σ	NOTES 3, 5 & 6

ACCIDENT CONDITIONS

TE9 ENVIRO ACCUR.	±4.5% URL + 3.5% SPAN	(SEE APPENDIX)	NOTES 4 & 6
R9 RADIATION	± 5%	N/A	NOTE 4

NOTE 3
URL IS UPPER RANGE LIMIT DEFINED AS MAX RANGE OF D/P CELL CAPSULE.

NOTE 4
THESE VALUES ARE BASED ON LOCA CONDITION TEST DATA. FOR SBLOCA CONDITIONS ELEVATED TEMPERATURE AND RADIATION EFFECTS (R9) ARE NOT BOTH APPLICABLE CONCURRENTLY DURING REACTOR OPERATION. THEREFORE ONLY THE WORST OF THE TWO VALUES (TE9) WILL BE USED IN THE ACCIDENT CONDITIONS CALCULATION.

NOTE 5 MODULE 9 PRESSURE TRANSMITTER ERROR VALUES ARE NOT APPLICABLE FOR 'CALIBRATION ERROR CALCULATIONS' OF THE INSTRUMENT LOOP SINCE A TEST SIGNAL IS USED INPLACE OF THE TRANSMITTER OUTPUT DURING MONTHLY CALIBRATION TESTS. THE TRANSMITTER IS CALIBRATED SEPARATELY DURING REFUELING AND THE ERROR VALUES ARE APPLICABLE TO TRANSMITTER CALIBRATION AND FOR THE NON ACCIDENT LOOP ERROR ANALYSIS.

NOTE 6 TEMP. EFFECT ERROR CALCULATION IS FUNCTION OF APPLIED PRESSURE. SEE REFERENCE 5 AND APPENDIX.

MODULE 11 FOXBORO I/E 2AI-I2V (TAG Nos PY963A, PY949)

	3σ	APPLICATION	
A_{11} Accuracy	± 0.5 %	± 0.333 2σ	
V_{11} (5% VARIATION)	± 0.25%	± 0.083	NOTE 2
T_{11} (PER 50°F)	± 0.50%	± 0.167	NOTE 1

MODULE 12 FOXBORO SIGNAL CHARACTERIZER 2AP-SGC (TAG Nos TY963B, TY949B)

	3σ	APPLICATION	
A_{12} Accuracy	± 0.5 %	± 0.333% 2σ	
T_{12} (PER 50°F)	± 0.5%	± 0.167%	NOTE 1
V_{12} (5% VARIATION)	± 0.5%	± 0.167%	NOTE 2

MODULE 15 FOXBORO SUMMER 2AP+SUM (TAG Nos. TY977D, TY978D)

	3σ	APPLICATION	
A_{15} ACCURACY	± 0.5%	± 0.333 2σ	
T_{15} (per 50°F)	± 0.5%	± 0.167%	NOTE 1
V_{15} (5% VARIATION)	± 0.5%	± 0.167%	NOTE 2

MODULE 16 WESTON DIGITAL INDICATOR

	3σ	APPLICATION
A_{16} Accuracy	± .05	± .03 2σ

MODULE 17 FOXBORO ALARM 2AP+ALM-AR (TAG. Nos. TI977, TI978)

	3σ	APPLICATION	
A_{17} ACCURACY	± 1.0 %	± 0.667 % (2σ)	NOTE 7
V_{17} (5% VARIATION)	± 0.25%	± 0.083% (1σ)	NOTE 2
T_{17} (per 50°F)	± 0.5%	± 0.167 (1σ)	NOTE 1

NOTE 7 CALIBRATION ACCURACY WHEN TEST JACKS ARE USED PER FOXBORO MI-2AP-102 page 4.

CALCULATIONS

MODULE 12 IS A CHARACTERIZER THAT CONSISTS OF EIGHT STRAIGHT LINE SEGMENTS THAT DESCRIBE THE SATURATION TEMPERATURE OVER A PRESSURE RANGE OF 0-2500 PSI. THEREFORE ERRORS FOR MODULES 9 & 11 MUST BE MULTIPLIED BY dT/dP, WHICH IS THE SLOPE OF THE CURVE FOR SATURATION TEMP. TO PRESSURE RANGE WITHIN WHICH THE MEASURED PRESSURE FALLS.

PRESSURE RANGE	dT/dP (°F/PSI)
0-100 PSIG	1.26
100-200	0.50
200-400	0.30
400-600	0.20
600-900	0.15
900-1300	0.11
1300-1900	0.08
1900-2500	0.07

THE RANGE OF THE FINAL ELEMENTS OF THE LOOP IS -100°F TO 400°F SUBCOOLING. THE CALCULATED LOOP ERROR IS EXPRESSED IN PERCENT OF THIS RANGE. HOWEVER THERE ARE SEGMENTS OF THE LOOP WITH DIFFERENT RANGES. THEREFORE THE % ERROR FOR THE MODULES IN THESE SEGMENTS MUST BE MULTIPLIED BY THE RATIO OF THE SEGMENT TO FINAL RANGES.

MODULE #	RANGE	RANGE RATIO
2	800 F	800/500
9	2500 PSI	(2500×dT/dP)/500
11	2500 PSI	2500×dT/dP)/500
12	457 °F	457/500
15	500 F	1.0
16	500 F	1.0
17	500 F	1.0

PRESSURE-SAT. TEMP RELATIONSHIP - SLOPE
per Reference 4.

0-100 psig $\frac{\Delta T}{\Delta P} = \frac{338.07 - 212}{100 - 0} = 1.26$

100-200 psig $\frac{\Delta T}{\Delta P} = \frac{387.89 - 338.07}{200 - 100} = 0.50$

200-405 psig $\frac{\Delta T}{\Delta P} = \frac{449.39 - 387.89}{405 - 200} = 0.30$

405-605 psig $\frac{\Delta T}{\Delta P} = \frac{489.75 - 449.39}{605 - 405} = 0.20$

605-905 psig $\Delta T/\Delta P = \frac{534.59 - 489.75}{905 - 605} = 0.15$

905-1335 psig $\frac{\Delta t}{\Delta P} = \frac{582.35 - 534.59}{1335 - 905} = 0.11$

1335-1885 psig $\frac{\Delta t}{\Delta P} = \frac{628.58 - 582.35}{1885 - 1335} = 0.08$

1885-2485 psig $\frac{\Delta t}{\Delta P} = \frac{668.13 - 628.58}{2485 - 1885} = 0.07$

PART-1

NON-ACCIDENT ALARM LOOP ERROR

$$\text{Loop ERROR} = \Big[\left(\tfrac{2500}{500}\left(\tfrac{dt}{dp}\right)\cdot S_9\right)^2 + \left(\tfrac{2500}{500}\tfrac{dt}{dp}\cdot A_9\right)^2 + \left(\tfrac{2500}{500}\tfrac{dt}{dp}A_{11}\right)^2 + \left(\tfrac{2500}{500}\tfrac{dT}{dp}T_9\right)^2$$

$$+\left(\tfrac{2500}{500}\cdot\tfrac{dt}{dp}\cdot V_{11} + \tfrac{457}{500}V_{12} + V_{15} + V_{17} + \tfrac{800}{500}\cdot V_2\right)^2$$

$$+\left(\tfrac{2500}{500}\cdot\tfrac{dt}{dp}\cdot T_{11} + \tfrac{457}{500}T_{12} + T_{15} + T_{17} + \tfrac{800}{500}T_2\right)^2$$

$$+\left(\tfrac{457}{500}\cdot A_{12}\right)^2 + (A_{15})^2 + (A_{17})^2 + \left(\tfrac{800}{500}\cdot A_2\right)^2\Big]^{1/2}$$

$$\text{Loop ERROR} = \Big[\left(5\tfrac{dt}{dp}\times 0.2\right)^2 + \left(5\tfrac{dt}{dp}\times 0.167\right)^2 + \left(5\tfrac{dt}{dp}\times 0.333\right)^2 + \left(5\tfrac{dt}{dp}\times .467\right)^2$$ 3

$$+\left(\left(5\tfrac{dt}{dp}\times 0.083\right) + (0.91\times 0.167) + (0.167) + (0.083) + (1.6\times 0.083)\right)^2$$

$$+\left(\left(5\tfrac{dt}{dp}\times 0.167\right) + (0.91\times 0.167) + (0.167) + (0.167) + (1.6\times 0.167)\right)^2$$

$$+ (0.91\times 0.333)^2 + (0.333)^2 + (0.667)^2 + (1.6\times 0.333)^2\Big]^{1/2}$$

$$\text{Loop ERROR} = \Big[1.0\left(\tfrac{dt}{dp}\right)^2 + 0.697\left(\tfrac{dt}{dp}\right)^2 + 2.772\left(\tfrac{dt}{dp}\right)^2 + 5.45\left(\tfrac{dt}{dp}\right)^2$$ 3

$$+\left(0.415\tfrac{dt}{dp} + 0.152 + 0.167 + 0.083 + 0.133\right)^2$$

$$+\left(0.835\tfrac{dt}{dp} + 0.152 + 0.167 + 0.167 + 0.267\right)^2$$

$$+ 0.092 + 0.111 + 0.445 + 0.284\Big]^{1/2}$$

$$\text{Loop ERROR} = \left[9.93\left(\tfrac{dt}{dp}\right)^2 + \left(0.415\tfrac{dt}{dp} + 0.535\right)^2 + \left(0.835\tfrac{dt}{dp} + 0.753\right)^2 + 0.93\right]^{1/2}$$ 3

USING $\frac{dt}{dp}$ values from proceeding page

NON ACCIDENT ALARM LOOP ERROR - CONTINUED

0-100 PSIG (dt/dp = 1.26)

LOOP ERROR = $[15.76 + 1.12 + 3.29 + 0.93]^{1/2} = \sqrt{21.07}$ | 3

= 4.59 % ±23.0 °F

100-200 PSIG (dt/dp = 0.5)

LOOP ERROR = $[2.48 + .513 + 1.370 + .93]^{1/2} = \sqrt{5.29}$ | 3

= ±2.3 % = ±11.5 °F

200-400 PSIG (dt/dp = 0.3)

LOOP ERROR = $[.893 + .435 + 1.007 + .93]^{1/2} = \sqrt{3.26}$ | 3

= ±1.81 % = ±9.03 °F

400-600 PSIG (dt/dp = 0.20)

LOOP ERROR = $[.397 + .382 + .846 + 0.93]^{1/2} = \sqrt{2.56}$ | 3

= ±1.6 % = ± 8.0 °F

600-900 PSIG (dt/dp = 0.15)

LOOP ERROR = $[.223 + .357 + .771 + 0.93]^{1/2} = \sqrt{2.28}$ | 3

= ± 1.51 % = ±7.6 °F

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CALC. NO. C-1101-665-5350-005 Rev 3
SHEET NO. 14 OF 28
SUBJECT
DATE 8-29-84
COMP. BY/DATE Kg
CHK'D. BY/DATE LLT.D

NON ACCIDENT ALARM LOOP ERROR - CONTINUED

900-1300 PSIG $(dt/dp = 0.11)$

$$\text{LOOP ERROR} = [.120 + .337 + .714 + 0.93]^{1/2} = \sqrt{2.1}$$

$$= \boxed{\pm 1.45\% = \pm 7.2^\circ F}$$

3

1300-1900 PSIG $(dt/dp = 0.08)$

$$\text{Loop Error} = [.063 + .323 + .672 + 0.93]^{1/2} = \sqrt{2.0}$$

$$= \boxed{\pm 1.41\% = \pm 7.1^\circ F}$$

3

1900-2500 PSIG $(dt/dp = 0.07)$

$$\text{Loop Error} = [.049 + .318 + .658 + 0.93]^{1/2} = \sqrt{1.9}$$

$$= \boxed{\pm 1.39\% = \pm 6.9^\circ F}$$

PART 1

ACCIDENT (SBLOCA/SLB) ALARM LOOP ERROR

THE LOOP ERROR EQUATIONS FOR ACCIDENT AND NON ACCIDENT CONDITIONS ARE THE SAME EXCEPT FOR THE INDIVIDUAL MODULE 9 (PRESSURE TRANSMITTER) ERROR VALUES. THEREFORE THE TERMS CONTAINING Sq, Aq & Tq WILL BE SUBTRACTED FROM THE PREVIOUS NON ACCIDENT RESULTS, AND A NEW TERM $\left(\frac{2500}{500}(dt/dp)\,TEq\right)$ WILL BE ADDED.

ALARM LOOP ERROR (ACCIDENT) = LEA

$$LEA = \left[\text{Loop Error}^2 - \left(\frac{2500}{500}\frac{dt}{dp}\cdot Sq\right)^2 - \left(\frac{2500}{500}\frac{dt}{dp}Aq\right)^2 - \left(\frac{2500}{500}\frac{dt}{dp}Tq\right)^2 + \left(\frac{2500}{500}\frac{dt}{dp}TE\right)^2\right]^{1/2}$$

$$= \left[\text{Loop Error}^2 - \left(5\frac{dt}{dp}\times 0.167\right)^2 - \left(5\frac{dt}{dp}\times 0.2\right)^2 - \left(5\frac{dt}{dp}\times .467\right)^2 + \left(5\frac{dt}{dp}\times TEq\right)^2\right]^{1/2}$$

$$= \left[(\text{Loop Error})^2 - .697\left(\frac{dt}{dp}\right)^2 - (1)\left(\frac{dt}{dp}\right)^2 - 5.452\left(\frac{dt}{dp}\right)^2 + \left(5\times\frac{dt}{dp}\times TEq\right)^2\right]^{1/2}$$

$$= \left[(\text{Loop Error})^2 - 7.15\left(\frac{dt}{dp}\right)^2 + \left(5\times\frac{dt}{dp}\times TEq\right)^2\right]^{1/2}$$

ACCIDENT ALARM LOOP ERROR - CONTINUED

0-100 PSIG (LE = ± 4.59%, dt/dp = 1.26, TEq = 1.85%) 3

$$LE_A = \pm\left[(4.59)^2 - 7.15\,(1.26)^2 + (5\times1.26\times1.85)^2\right]^{1/2} = \sqrt{145.52}$$

$$= \boxed{\pm 12.06\% = \pm 60.3°F}$$

100-200 PSIG (LE = ± 2.3%, dt/dp = 0.5, TEq = 1.89%) 3

$$LE_A = \pm\left[(2.3)^2 - 7.15\,(.5)^2 + (5\times0.5\times1.89)^2\right]^{1/2} = \sqrt{25.82}$$

$$= \boxed{\pm 5.08\% = \pm 25.4°F}$$

200-400 PSIG (LE = 1.81 %, dt/dp = 0.3, TEq = 1.99%) 3

$$LE_A = \pm\left[(1.81)^2 - 7.15\,(.3)^2 + (5\times.3\times1.99)^2\right]^{1/2} = \sqrt{11.55}$$

$$= \boxed{\pm 3.40\% = \pm 17.0°F}$$

400-600 PSIG (LE = 1.6 %, dt/dp = 0.2, TEq = 2.08%) 3

$$LE_A = \pm\left[(1.6)^2 - 7.15\,(.2)^2 + (5\times.2\times2.08)^2\right]^{1/2} = \sqrt{6.59}$$

$$= \boxed{\pm 2.57\% = \pm 12.8°F}$$

600-900 PSIG (LE = 1.51%, dt/dp = 0.15, TEq = 2.22%) 3

$$LE_A = \pm\left[(1.51)^2 - 7.15\,(.15)^2 + (5\times0.15\times2.22)^2\right]^{1/2} = \sqrt{4.90}$$

$$= \boxed{\pm 2.21\% = \pm 11.1°F}$$

ACCIDENT ALARM LOOP ERROR - CONTINUED

900-1300 PSIG (LE = 1.45%, dt/dp = 0.11, TEq = 2.41%)

$$LE_A = \pm\left[(1.45)^2 - 7.15\ (0.11)^2 + (5 \times 0.11 \times 2.41)^2\right]^{1/2} = \sqrt{3.78}$$

$$= \boxed{\pm 1.94\% = \pm 9.7^\circ F}$$

1300-1900 PSIG (LE = 1.41%, dt/dp = 0.08, TEq = 2.69%)

$$LE_A = \pm\left[(1.41)^2 - 7.15\ (0.08)^2 + (5 \times 0.08 \times 2.69)^2\right]^{1/2} = \sqrt{3.10}$$

$$= \boxed{\pm 1.76\% = \pm 8.8^\circ F}$$

1900-2500 PSIG (LE = 1.39%, dt/dp = 0.07, TEq = 2.97%)

$$LE_A = \pm\left[(1.39)^2 - 7.15\ (0.07)^2 + (5 \times 0.07 \times 2.97)^2\right]^{1/2} = \sqrt{3.01}$$

$$= \boxed{\pm 1.74\% = \pm 8.7^\circ F}$$

PART 2

TSAT INDICATOR LOOP ERROR

THE LOOP ERROR EQUATIONS FOR THE ALARM LOOP AND THE INDICATOR LOOP ARE THE SAME EXCEPT TERMS FOR MODULE 17 (FOXBORO ALARM) ERROR ARE SUBTRACTED AND MODULE 16 (WESTON DIGITAL PANEL METER) ERROR VALUES ARE ADDED. THIS IS APPLICABLE FOR BOTH ACCIDENT AND NON ACCIDENT CONDITIONS.

INDICATOR LOOP ERROR NON ACCIDENT = ILE

$$ILE = \left[(\text{ALARM LOOP ERROR})^2 - (V_{17})^2 - (T_{17})^2 - (A_{17})^2 + (A_{16})^2\right]^{1/2}$$

$$= \left[(LE)^2 - (.083)^2 - (.167)^2 - (.667)^2 + (.03)^2\right]^{1/2}$$

$$= \left[(LE)^2 - (.479)\right]^{1/2}$$

INDICATOR LOOP ERROR SBLOCA ACCIDENT = ILE_A

$$ILE_A = \left[(LEA)^2 - .479\right]^{1/2}$$

NOTE THE TERMS $(V_{17})^2$ & $(T_{17})^2$ ARE NOT MATHEMATICALLY EXACT BECAUSE THEY WERE SUMMED WITH OTHER TERMS BEFORE SQUARING. HOWEVER THIS WILL ALWAYS YIELD A GREATER CALCULATED ERROR THAN IF HANDLED MORE PRECISELY.

PART 2 - INDICATOR LOOP ERROR - CONTINUED

0-100 PSIG (LE = ± 4.59 %, LEA = ± 12.06%) | 3

$$ILE = [(4.59)^2 - .479]^{1/2} = \sqrt{20.6} = \boxed{\pm 4.54\% = \pm 22.7°F}$$

$$ILEA = [(12.06)^2 - .479]^{1/2} = \sqrt{144.96} = \boxed{\pm 12.04\% = \pm 60.2°F}$$

100-200 PSIG (LE = ± 2.3 %, LEA = ± 5.08%) | 3

$$ILE = [(2.3)^2 - .479]^{1/2} = \sqrt{4.81} = \boxed{\pm 2.19\% = \pm 11.0°F}$$

$$ILE_A = [(5.08)^2 - .479]^{1/2} = \sqrt{25.33} = \boxed{\pm 5.03\% \pm 25.2°F}$$

200-400 PSIG (LE = 1.81 %, LE A = ± 3.40%) | 3

$$ILE = [(1.81)^2 - .479]^{1/2} = \sqrt{2.8} = \boxed{\pm 1.67\% = \pm 8.4°F}$$

$$ILE_A = [(3.40)^2 - .479]^{1/2} = \sqrt{11.08} = \boxed{\pm 3.33\% = \pm 16.6°F}$$

400-600 PSIG (LE = ± 1.6 %, LEA = ± 2.57%) | 3

$$ILE = [(1.6)^2 - .479]^{1/2} = \sqrt{2.08} = \boxed{\pm 1.44\% = \pm 7.2°F}$$

$$ILE_A = [(2.57)^2 - .479]^{1/2} = \sqrt{6.13} = \boxed{\pm 2.48\% = \pm 12.4°F}$$

(22)

PART 2. INDICATOR LOOP ERROR - CONTINUED

600-900 PSIG (LE = ±1.51%, LEA = ±2.21%)

$$ILE = [(1.51)^2 - .479]^{1/2} = \sqrt{1.80} = \boxed{\pm 1.34\% = \pm 6.7°F}$$

$$ILEA = [(2.21)^2 - .479]^{1/2} = \sqrt{4.41} = \boxed{\pm 2.10\% = \pm 10.5°F}$$

900-1300 PSIG (LE = ±1.45%, LEA = ±1.94%)

$$ILE = [(1.45)^2 - .479]^{1/2} = \sqrt{1.62} = \boxed{\pm 1.27\% = \pm 6.4°F}$$

$$ILEA = [(1.94)^2 - .479]^{1/2} = \sqrt{3.28} = \boxed{\pm 1.81\% = \pm 9.1°F}$$

1300-1900 PSIG (LE = ±1.41%, LEA = ±1.76%)

$$ILE = [(1.41)^2 - .479]^{1/2} = \sqrt{1.51} = \boxed{\pm 1.23\% = \pm 6.1°F}$$

$$ILEA = [(1.76)^2 - .479]^{1/2} = \sqrt{2.62} = \boxed{\pm 1.62\% = \pm 8.1°F}$$

1900-2500 PSIG (LE = ±1.39%, LEA = ±1.74%)

$$ILE = [(1.39)^2 - .479]^{1/2} = \sqrt{1.45} = \boxed{\pm 1.21\% = \pm 6.0°F}$$

$$ILE_A = [(1.74)^2 - .479]^{1/2} = \sqrt{2.55} = \boxed{\pm 1.60\% = \pm 8.0°F}$$

PART 3 - TSAT CALIBRATION LOOP ERROR

THE INSTRUMENT LOOP IS CALIBRATED IN TWO PARTS

1) THE PRESSURE TRANSMITTER (MODULE 9)

LOCATED IN THE REACTOR BUILDING IS CALIBRATED AT REFUELING INTERVALS;

2) THE REMAINDER OF THE INSTRUMENT LOOP, LOCATED IN A CONTROLLED ENVIROMENT HAS A MONTHLY CALIBRATION TEST, BY INSERTING PRECISION CURRENT INPUT IN PLACE OF THE P TRANSMITTER AND RESISTANCE IN PLACE OF THE RTD INPUT.

THEREFORE, THE ALLOWABLE ERROR FOR CALIBRATION OF THE INSTRUMENT LOOP CAN BE DETERMINED BY TAKING THE LOOP ERROR FOR THE NON ACCIDENT CONDITION (LE) AND SUBTRACTING THE CONTRIBUTION OF MODULE 9 (MODULE 1 (RTD) WAS CONSIDERED NEGLIGABLE IN THE LOOP ERROR EQUATION).

CALIBRATION INSTRUMENT LOOP ERROR = CLE

$$CLE = \left[(\text{LOOP ERROR})^2 - (1)\left(\frac{dt}{dp}\right)^2 - .697\left(\frac{dt}{dp}\right)^2 - 5.45\left(\frac{dt}{dp}\right)^2 \right]^{1/2}$$

$$= \left[(LE)^2 - 7.15 \left(\frac{dt}{dp}\right)^2 \right]^{1/2}$$

3

PART 3 CALIBRATION LOOP ERROR - CONTINUED

SUGGESTED SURVEILLANCE REQUIREMENT

0-100 PSIG (LE = ±4.59%, dt/dp = 1.26)

$$CLE = \left[(4.59)^2 - 7.1\ (dt/dp)^2\right]^{1/2} = \sqrt{9.79}$$

= ±3.13 % = ±15.6 °F | 3 | ± 2.5%

100-200 PSIG (LE = ±2.3 %, dt/dp = 0.5)

$$CLE = \left[(2.3)^2 - 7.1\ (dt/dp)^2\right]^{1/2} = \sqrt{3.5}$$

= ±1.87% = ±9.4°F | 3 | ± 1.4%

200-400 PSIG (LE = ±1.81 %, dt/dp = 0.3)

$$CLE = \left[(1.81)^2 - 7.1\ (dt/dp)^2\right]^{1/2} = \sqrt{2.64}$$

= ±1.62% = 8.1 °F | 3 | ± 1.2%

400-600 PSIG (LE = ±1.6 %, dt/dp = 0.2)

$$CLE = \left[(1.6)^2 - 7.1\ (dt/dp)^2\right]^{1/2} = \sqrt{2.27}$$

= ±1.51% = ±7.6°F | 3 | ± 1.1%

600-900 PSIG (LE = ±1.51 %, dt/dp = 0.15)

$$CLE = \left[(1.51)^2 - 7.1\ (dt/dp)^2\right]^{1/2} = \sqrt{2.13}$$

= ±1.46% = ±7.3°F | 3 | ± 1.1%

(25)

PART 3 CALIBRATION LOOP ERROR

SUGGESTED SURVEILLANCE REQUIREMENT

900 - 1300 PSIG (LE = ±1.45 %, dt/dp = 0.11) | 3

$$CLE = \left[(1.45)^2 - 7.1 \left(dt/dp\right)^2\right]^{1/2} = \sqrt{2.03}$$

= **±1.42% = ±7.1°F**

±1.1%

1300 - 1900 PSIG (LE = ±1.41 %, dt/dp = 0.08) | 3

$$CLE = \left[(1.41)^2 - 7.1 \left(dt/dp\right)^2\right]^{1/2} = \sqrt{1.95}$$

= **±1.40% = ±7.0°F**

±1.1%

1900 - 2500 PSIG (LE = ±1.39 %, dt/dp = 0.07) | 3

$$CLE = \left[(1.39)^2 - 7.1 \left(dt/dp\right)^2\right]^{1/2} = \sqrt{1.90}$$

= **±1.38% = ±6.9°F**

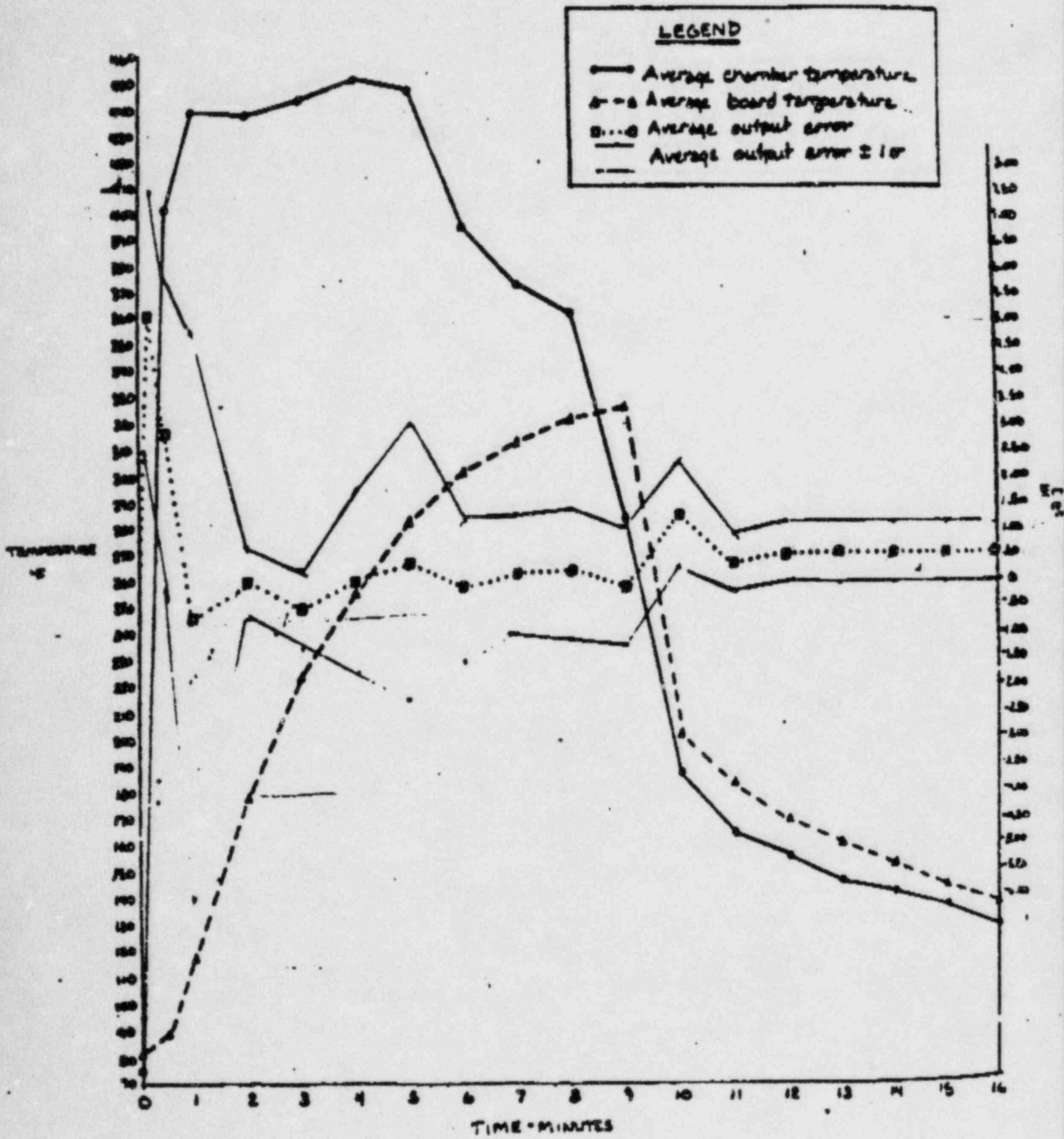
±1.1%

CONTENTS OF THIS PAGE DELETED IN REV. 3.

THIS PAGE HAD SLB ALARM LOOP ERROR BASED UPON A PRESSURE TRANSMITTER TEMPERATURE OF 300°F DURING SLB. ANALYSIS OF SLB CONDITIONS SHOWS THAT WITHIN THE FIRST 100 SECONDS CONTAINMENT VAPOR TEMPERATURE PEAKS AT 380°F AT 80 SECONDS AND RETURNS TO APPROX. 240°F. A REVIEW OF THE ROSEMOUNT 1153 TEST DATA (PROVIDED AS GRAPH 1, NEXT PAGE) SHOWS THAT WHEN SUBJECTED TO 440°F TEMPERATURE FOR TWO MINUTES THE TRANSMITTER BOARD TEMPERATURE RISES TO 180°F.

FOR CONSERVATISM THE TEMPERATURE ERROR FOR SLB WAS SET EQUAL TO THAT USED FOR SBLOCA (245°F), THEREFORE THE RANDOM ERROR WILL EQUAL THAT CALCULATED FOR SBLOCA ACCIDENT CONDITIONS (SEE PART 1)

"ROSEMOUNT 1153 SERIES D"



GRAPH 1

PART 4 SYSTEMATIC LOOP ERRORS | 3

CHARACTERIZER CURVE ERROR (CCE)

THE SIGNAL CHARACTERIZER (MODULE 12) UTILIZES EIGHT LINEAR LINE SEGMENTS TO APPROXIMATE THE SATURATION CURVE. WITHIN EACH LINE SEGMENT THE APPROXIMATED SATURATION TEMPERATURE VARIES FROM THE STEAM TABLE VALUE. THIS VARIATION IS ALLWAYS IN THE NEGATIVE DIRECTION EXCEPT FOR RC PRESSURE VALUES WHERE THE LINE SEGMENT ENDS INTERSECT THE CURVE. THEREFORE THE DERIVED SATURATION TEMP. IS LESS THAN THE ACTUAL SATURATION TEMPERATURE, AND THE MARGIN TO SATURATION WILL BE MORE THAN INDICATED BY THE INSTRUMENT LOOP BY AN AMOUNT EQUAL TO THE DIFFERENCE. FOR CONSERVATISM THE MAXIMUM NEGATIVE ERROR FOR EACH RC PRESSURE RANGE IS INCLUDED AS A SYSTEMATIC ERROR. | 3

CCE = STEAM TABLE VALUE - SIGNAL CHARACTEIZER VALUE

0-100 psig:	CCE = 280.63 - 256.84 337.88 - 338.4	= =	−24.4 °F @ 55 psig + 0.5 °F @ 100 psig
100-200 psig:	CCE = 363.40 - 360.72 387.79 - 388.	=	− 2.7 °F @ 145 psig + 0.2 °F @ 200 psig
200-400 psig	CCE = 418.77 - 415 448.14 - 448	= =	−3.8 °F @ 293 psig + 0.1 °F @ 400 psig
400-600 psig	CCE = 468.37 - 466.76 488.81 - 488.8	= =	− 1.6 °F @ 492 psig + 0 °F @ 600 psig
600-900 psig	CCE = 511.55 - 510.05 533.87 - 534.4	= =	−1.5 °F @ 740 psig +0.5 °F @ 900 psig
900-1300 psig	CCE = 557.92 - 556.8 578.88 - 579.2	=	−1.1 °F @ 1100 psig +0.3 °F @ 1300 psig
1300-1900 psig	CCE = 603.86 - 602.26 629.65 - 630.46	=	−1.3 °F @ 1570 psig +0.8 °F @ 1900 psig
1900-2500 psig	CCE = 654.28 - 653.44 668.97 - 668.8	=	−0.8 °F @ 2260 psig + 0.2 °F @ 2500 psig

PART 5 CONTINUED

CONTAINMENT PRESSURE ERROR

THE RC PRESSURE TRANSMITTER IS LOCATED WITHIN CONTAINMENT AND MEASURES IN PSIG. THUS IF THE CONTAINMENT IS OVER ATMOS. PRESSURE THE RC PRESSURE SIGNAL WILL BE DECREASED BY AN AMOUNT EQUAL TO CONTAINMENT PRESSURE. THIS REDUCES THE INDICATED SUBCOOLING MARGIN. THIS ERROR (CPE) IS SYSTEMATIC AND WORST CASE IS:

ΔP SBLOC = 30 PSIG *

ΔP SLB = 38 PSIG *

(ΔP NON ACCIDENT = -1 to +2 PSIG) **

CPE = (ΔP) (dt/dp)

RC PRES RANGE	dt/dp	CPE (LOCA)	CPE (SLB)
0-100 PSIG	1.264	-37.9 °F	-48.0 °F
100-200	0.496	-14.9 °F	-18.8 °F
200-400	0.30	-9.0 °F	-11.4 °F
400-600	0.204	-6.1 °F	-7.8 °F
600-900	0.152	-4.6 °F	-5.8 °F
900-1300	0.112	-3.4 °F	-4.3 °F
1300-1900	0.085	-2.6 °F	-3.2 °F
1900-2500	0.064	-1.9 °F	-2.4 °F

* THIS IS A SHORT TERM TRANSIENT WITHIN THE FIRST 120 SECONDS AFTER THE ACCIDENT, AND IS INCLUDED IN THE CALCULATIONS AS THE WORST CASE CONDITION.

** RESULTANT ERROR FOR NEGATIVE PRESSURE IS INSIGNIFICANT AND IS NOT INCLUDED IN CALCULATION.

COMP. BY/DATE [illegible] 7-31-84
CHK'D. BY/DATE [illegible] 7-31-84

APPENDIX

MODULE 9

(30)

ACCIDENT TEMPERATURE EFFECT (TEq) CALCULATION
(PER REFERENCE 3)

$$TEq = \pm(4.5\%\ URL + 3.5\%\ SP) \text{ FOR LOCA}$$

WHERE $SP = \frac{\text{APPLIED PRES}}{\text{TRANS. SPAN}} = \frac{\text{APPLIED P}}{2500 \text{ PSIG}}$

URL = 3000 PSIG

TO BRING ENTIRE EQ ERROR IN TERMS OF SPAN:

$$TEq = \pm\left(4.5\% \frac{3000}{2500} + \frac{\text{APPLIED P}}{2500}(3.5\%)\right) = \pm\left(5.4\% + \frac{\text{APPLIED P}}{2500}(3.5\%)\right)$$

APPLIED P	TEq (LOCA)	TEq*
100 PSIG	5.54%	1.85%
200	5.68%	1.89%
400	5.96%	1.98%
600	6.24%	2.08%
900	6.66%	2.22%
1300	7.22%	2.41%
1900	8.06%	2.69%
2500	8.90%	2.97%

R3

* CONSERVATIVE APPROXIMATION OF 2σ VALUE FOR SBLOCA CONDITIONS