GPU Nuclear

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November 30, 1984
5211-84-2291

Office of Nuclear Reactor Regulation
Attn: J. F. Stolz, Chief
Operating Reactors Branch No. 4
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Stolz:

Three Mile Island Nuclear Station Unit 1 (TMI-1)
Operating License No. DPR-50
Docket No. 50-289
Error Analysis - Subcooling Margin Indication

This is in response to your request for additional information dated September 28, regarding the Saturation Margin Monitor Loop Error Analysis for TMI-1 as modified and clarified as a result of our meeting of October 30, 1984.

Enclosed as Attachment 1 is our "Summary Description of Tsat Margin Monitoring and Alarm Capability" which was requested by Dr. P. Kadambi of your staff in a telephone conversation on November 2, 1984.

Attachment 2 provides GPUN's response to (7) of the (11) questions. Our response to questions 2, 5, 7, and 11 will be provided by December 14, 1984 along with a set of the revised instrument loop diagrams as discussed with Dr. Kadambi.

Sincerely,

H. D. Hukill
Director, TMI-1

HDH/SK/MRK/kds
Attachments

cc: R. Conte
J. Van Vliet
Dr. P. Kadambi

A001
1/1

Summary Description of Tsat Margin Monitoring and Alarm Capability

The temperature saturation (Tsat) margin monitoring system is a redundant system consisting of an A and a B loop. Each loop provides a continuous control room display of the margin between the actual reactor coolant system temperature and the saturation temperature based upon the existing pressure of the reactor coolant system. Tsat provides alarm annunciation in the control room when either loop indicates insufficient margin. Detailed discussion of the Tsat margin monitoring system is provided in the following paragraphs.

In each of the redundant loops, reactor coolant temperature and pressure inputs are brought into signal conditioning cabinets. Signal conditioning circuits convert the RC pressure to a signal that is proportional to the saturation temperature for that pressure. The signal is compared with a signal proportional to the actual RC temperature, and the difference represents the temperature margin to saturation. Tsat margin monitor information is displayed on digital indicators on the control room back panel. The indicators display Tsat margin in degrees fahrenheit for RC Loop "A" and Loop "B". The Tsat margin monitor also provides an isolated output to the plant computer and an isolated, low Tsat margin to the annunciation system for control room alarm annunciation, should Tsat margin be less than set point. The outputs to the plant computer provide trending and status monitoring information.

The individual components that comprise the Tsat system, with the exception of the digital indicators, are IE qualified (Digital indicators will be qualified by January 1985). The system consists of the following components:

a) RTD's (TE 958, TE 960), Weed Instrument Co. Model 1D3D/611D

b) Pressure Transmitters (PT 963, PT 949), Rosemount Model 1153D

c) Signal Conditioning Modules, Foxboro Model Spec. 200.

d) Digital Indicators (TI-977, TI-978), Weston Model 2470.

All Tsat equipment in the A loop is powered from the A1 signal conditioning cabinet (Red), and the B loop from the B1 signal conditioning cabinet (Green).

Pressure transmitter PT 963 and temperature sensor TE 958 are located in the hot leg associated with OTSG A. Pressure transmitter PT 949 and temperature sensor TE 960 are located in the hot leg associated with OTSG B. The pressure input range is 0 to 2500 psig. The digital display meter will indicate -100° to +400°F Tsat margin. During normal operation of the plant, the set point for alarm for each loop shall be whenever the Tsat margin is less than 25°F or at the value determined by plant operating procedures and technical specification. Signal conditioning circuits for the Tsat A loop are located at elevation 338 ft. in the control tower, and for Tsat B loop at elevation 322 ft. The temperature inputs have a range of 120° to 920°F.

Tsat margin information is provided as an aid to the operator to promote safe operation and shutdown of the plant. The Tsat margin monitor performs no initiation or actuation of safety devices. The plant procedures stress that other plant parameters such as RC pressure and temperature should not be ignored, and constant surveillance of these other variables is a requirement. The margin to saturation computed by the Saturation Margin Monitoring System can be verified by manual calculations using alternate instrument readouts.

GPUN RESPONSE TO NRC QUESTIONS ON TMI-1 SATURATION MARGIN MONITOR LOOP ERROR ANALYSIS

Question 1

Sheet 2 of the loop error analysis discusses the error allowance for the steam line break and small break LOCA conditions. For the purpose of determining the error allowance, the manufacturer's test results for more severe accident conditions were divided by a factor of three. It is the staff's concern that this may be nonconservative. Manufacturer's tests are typically one time tests that yield a single curve or data point. In lieu of requiring that several tests be performed with a statistical evaluation of the results, the staff has accepted a single curve or data point provided there is conservatism in the temperature and radiation levels. Accordingly, we request that additional information be provided to support this method of estimating the environmental error allowance.

Response

Based on LOCA/HELB tests, the manufacturer specified the 3σ LOCA/HELB error as follows:

LOCA/HELB Error = $\pm$ (4.5% URL + 3.5 % span)

where 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. When determining error at measured pressures below the upper limit of the calibrated span, span is defined as the algebraic difference between the measured pressure and the lowest value that the transmitter is calibrated to measure.

To express the entire equation in terms of % span:

$$\text{LOCA/HELB Error} = \pm\left[(4.5\%)\left(\frac{\text{URL}}{\text{transmitter span}}\right) + 3.5\%\left(\frac{\text{applied pressure}}{\text{transmitter span}}\right)\right]$$

$$= \pm\left[(4.5\%)\left(\frac{3000}{2500}\right) + 3.5\%\left(\frac{\text{applied pressure}}{2500}\right)\right]$$

Since the LOCA/HELB conditions (420°F/85 psig) far exceed the SBLOCA conditions (245°F/30 psig), a conservative SBLOCA error can be estimated as follows:

SBLOCA 2σ error = 1/3 (LOCA/HELB 3σ error)
= $\pm$ (4.5/3 % URL + 3.5/3 % span)
= $\pm$ (1.5% URL + 1.17% span)

Subsequently, we evaluated the validity of the assumed SBLOCA equation by analyzing actual test data taken at 240°F and comparing it with the SBLOCA error equation.

The manufacturer's tests involved ramping the test chamber, containing five transmitters. Test data was provided for the following times and temperatures:

Time	Temperature
30 minutes	320°F
4 hours	240°F
24 hours	180°F

The test was conducted by running each transmitter, up to full scale, and back to 0, recording data at 0, 25, 50, 75 and 100 percent of scale. Since the 240°F condition is very close to the SBLOCA temperature of 245°F, it provides a basis for evaluating the validity of the SBLOCA error assumed in the loop error analysis.

The test data for the five transmitters has been plotted on Figure 1 (vertical lines at 0, 25, 50, 75 and 100 percent of span). The line of regression was then determined by the method of least squares.

$\text{Error})_{LSQ} = [(-0.2084\%\ \text{URL}) + (-0.0088\%\ \text{URL})(\%\ \text{span})]$

where $B\emptyset = -0.2084$ y-intercept
$B1 = -0.0088$ slope

$S\emptyset = 0.2685$ Standard deviation of $B\emptyset$
$S1 = 0.0044$ Standard deviation of $B1$

$$\%\ \text{span} = \frac{\text{Measured Pressure}}{\text{Calibrated Span}} \times 100$$

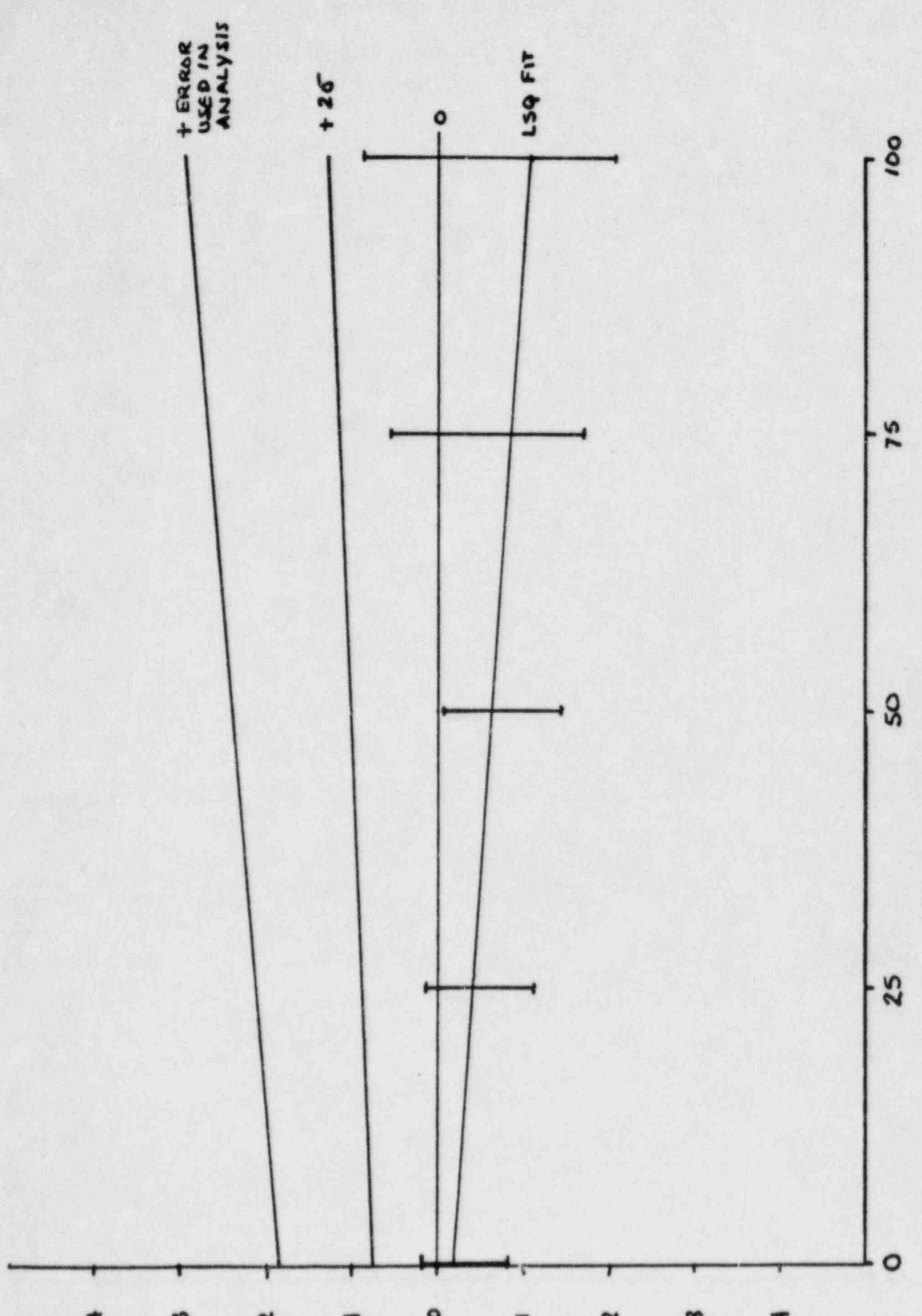
Since five transmitters were tested and this equation has two coefficients, the degrees of freedom are (5-2) = 3. At 95% confidence limits, the percentage point of a t-distribution with 3 degrees of freedom is 3.182. The 2σ values of $B\emptyset$ and $B1$ were calculated as follows:

$B\emptyset)_{2\sigma} = 3.182\ S\emptyset = \pm\ 0.8544\%\ \text{URL}$
$B1)_{2\sigma} = 3.182\ S1 = \pm\ 0.0140\%\ \text{URL}$

Therefore:

$$\text{Error})_{\pm 2\sigma} = [(-0.2084\%\ \text{URL} \pm 0.8544\%\ \text{URL}) + (-0.0088\%\ \text{URL} \pm 0.0140\%\ \text{URL})(\%\ \text{span})]$$

The error of interest is the $+2\sigma$, since it would indicate a higher subcooling margin than the actual margin. The $+2\sigma$ values have been plotted on Figure 1, demonstrating that the values used in the loop error analysis were indeed conservative.



+ ERROR USED IN ANALYSIS
+ 2σ
0
LSQ FIT
+4
+3
+2
+1
0
-1
-2
-3
-4
% ERROR
0
25
50
75
100
% SPAN

Figure 1

Question 3

Sheet 13 of the loop error analysis provides the calculations for alarm loop error under accident conditions. In considering the loop error associated with the harsh environment, the accuracy, stability, and temperature effect allowances were subtracted and a new term representing the error associated with the harsh environment's temperature was statistically added to the alarm loop error. It is the staff's concern that this may be a nonconservative method. Statistical methods of summing errors may not be appropriate when the errors are induced by harsh environmental conditions. These errors are not random in nature as, for example are stability errors. They represent a bias (systematic error) that should be treated algebraically in the error equations. Further, the errors induced by the harsh environment are typically considered in addition, to those random errors associated with accuracy, stability, temperature effects, and calibration. Accordingly, we request that you provide the basis for statistically summing the accident induced errors and subtracting the random errors.

Response

A review of the Rosemount LOCA/HELB qualification test data and the resulting harsh environment published error value confirm that the error is not systematic and varies in both the positive and negative directions, and should be treated statistically as random.

Rosemount has confirmed that under harsh environment accident conditions, the published data for harsh environment errors are intended to replace the normal environment errors. These values include the errors associated with accuracy and stability.

Attachments 1 and 2 are copies of GPUN/Rosemount correspondence confirming the application of harsh environmental error data.

Also, as discussed during our meeting of October 30, 1984, we would like to provide the following discussion of error classifications:

ERROR CLASSIFICATIONS

Error may be classified in the following ways:

a. Variability of an Individual Error
   1) Systematic
   2) Random
b. Relationship Between Random Errors
   1) Independent
   2) Nonindependent
c. Determination of Error Value
   1) Determinate
   2) Indeterminate

Systematic Error--With repeated measurements, the measured value is always in error by the same amount. Some causes of systematic error are:

a. Personal error which is consistently repeated.
b. Deviation of a process from the analytical model.

Random Error--With repeated measurements, the measured value is in error by varying amounts. Some causes of random error are:

a. Observer's estimation of the fraction of the smallest division of an instrument.
b. Fluctuating conditions such as temperature, pressure or supply voltage.
c. Small disturbances such as vibrations from nearby machinery.
d. Imprecise definition of exactly what is to be measured. For example, the measured diameter of an object can vary if taken at slightly different locations.

Independent Random Errors--For a given random error, there is a certain probability of occurrence associated with each value that it may assume. Two random errors are independent if fixing the value of one has no effect on the probability of occurrence of each value of the other. This means that for independent errors in measurements x and y, the probability that the error in x will have a value of dx while the error in y has a value of dy can be expressed as follows:

$$P\ (\Delta x = dx,\ \Delta y = dy) = P(\Delta x = dx)\ P(\Delta y = dy)$$

Nonindependent Random Errors--If fixing the value of one random error has an effect on the probability of occurrence of each value of the other, then the two errors are said to be nonindependent.

The degree of dependence of one random error upon the other is expressed in terms of the coefficient of correlation (ρ) which has limits of zero and one. A coefficient of one means that two random errors are perfectly correlated such that one error is single valued when the other is fixed. On the other hand, a coefficient of zero means that the two random errors are independent, since by definition there is no correlation between independent random errors. Values between zero and one mean that the nonindependent random errors are really composed of both independent and dependent elements which cannot be separated.

Combining Random Errors

Let: $V = V(x, y)$

Where:

V = quantity to be computed
x = measured quantity
y = measured quantity

The probable error in v is expressed as follows:

$$e_v = \sqrt{e_x^2 + e_y^2 + 2\rho_{xy}\, e_x\, e_y}$$

Where:

e_v = total probable random error in v
e_x = probable random error in v due to error in x
e_y = probable random error in v due to error in y
ρ_{xy} = coefficient of correlation

If the errors e_x and e_y are independent, then:

$$\rho_{xy} = 0$$

$$e_v = \sqrt{e_x^2 + e_y^2}$$

This reflects the fact that there is clearly a probability of compensation. When the error in x causes the computed value of V to be larger, the error in y may cause it to be smaller. Thus, on average, the total error in V will be algebraically less than the sum of the separate contributions of e_x and e_y.

If e_x and e_y are nonindependent and are perfectly correlated, then

$$\rho_{xy} = 1$$
$$e_v = \sqrt{e_x^2 + e_y^2 + 2e_x\, e_y}$$
$$e_v = e_x + e_y$$

This reflects the fact that there is no possibility of compensation for perfectly correlated errors.

If e_x and e_y are nonindependent but not perfectly correlated, then

$$0 < \rho_{xy} < 1$$

$$e_v = \sqrt{e_x^2 + e_y^2 + 2\rho_{xy}\, e_x\, e_y}$$

This reflects the fact that some compensation is possible when the two errors are not perfectly correlated. This compensation is due to the independent elements of the errors. In actual practice, it may be difficult to evaluate the coefficient of correlation for nonindependent errors. In this case, it is conservative to treat them as perfectly correlated with a coefficient of one.

Determination of Error Value

Errors which may be evaluated by some logical procedure, either theoretical or experimental, are called determinate, and the others are called indeterminate. Random errors are determinate, while systematic errors may be either determinate or indeterminate.

Determinate systematic errors can fall in two categories:

a. Those whose sign and magnitude at a particular time are known.
b. Those whose sign and magnitude at a particular time are unknown.

When the sign and magnitude of a systematic error are known, the systematic error is combined with the total probable random error by adding them algebraically. An example of this would be an instrument with a known calibration error.

In many cases, it is impossible to know the sign and magnitude of a systematic error. For example, it is impossible to predict the sign and magnitude of an instrument calibration when one is evaluating potential errors in an instrument at some future time. The error may be of either sign and the magnitude may be anywhere within the range permitted by the calibration procedure. In these cases, what would be a systematic error at a particular point in time becomes a random error when evaluated prior to calibration. This is due to the fact that the error from this source is evaluated on the basis of the probability of inducing a given systematic calibration error at the time the instrument is calibrated. Thus, it is a random error and is treated as such when combined with other errors. Furthermore, it is usually independent of other errors.

Reference: Beers, Yardley, Introduction to the Theory of Error, Addison Wesley, 2nd Eddition, 1962

Nuclear

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TELEX 136-482
Writer's Direct Dial Number:

October 31, 1984
EP&I/84/1861-0632M

ROSEMOUNT INC.
12001 W. 78 Street
Eden Prairie, Minn. 55344

Attn: Mr. Grieg Romanchuk

Dear Mr. Romanchuk:

It is our understanding, from previous conversations with your office, that the proper application of the 'error' values published for the Rosemount Pressure Transmitter Model 1153GD9 is as follows:

a) Under normal operating conditions, use the applicable data published under 'Performance Specifications - Zero Based Ranges, Reference Conditions'.

b) Under Harsh Environment Accident Conditions, use the applicable data published under 'Nuclear Specifications', and that these values include the errors associated Accuracy and Stability.

Grieg, we would appreciate a written confirmation or comments, for our records, regarding the above.

Thank you.

Very truly yours,

Lester Goldstein

Lester Goldstein
Engineer - EP&I

cc:
Engineer - S. Kowkabany
Manager Instrumentation - G. J. Sadauskas
EDCC - B/A 123072

ROSEMOUNT INC.

12001 West 78th Street
Eden Prairie, Minnesota 55344 U.S.A.
Tel. (612) 941-5560
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November 6, 1984

Rosemount

GPU Nuclear Corporation
100 Interpace Parkway
Parsippany, NJ 07054-1149

Attention: Mr. Lester Goldstein
Engineer - EP & I
Subject: Your letter dated October 31, 1984
EP & I/84/1861-0632M

Dear Mr. Goldstein:

Rosemount has received and reviewed the subject letter and find the information contained therein to be correct.

Should you have any further questions, feel free to call me.

Very truly yours,

Gregory M. Romanchuk

Gregory M. Romanchuk
Marketing Engineer

/jka

DISTRIBUTION
[redacted]
G.J. SADAUSKAS
EDCC - B/A 123072
WRITERS FILE

Question 4

Table 3 on sheet 5 of the loop error analysis provides the total alarm loop uncertainty. The discussion preceeding Table 5 states that the total positive (nonconservative) error is the positive random error alone. We request that you provide the basis for neglecting the systematic error associated with the characterizer curve, and provide the equations for calculating the values shown on the Table.

Response

1. Figure 2 shows a representative characterizer curve.

The actual characterizer is designed with eight linear segments. These eight linear segments which approximate the temperature-pressure saturation curve were plotted on the concave side of the curve, and provide a saturation temperature lower than actual (conservative). As calculated, the line segments intersect adjacent line segments at or slightly above the curve. However, according to the manufacturer (Foxboro product specification TI 2AP-140) "the transition from segment to segment is a smooth curve which follows the characteristics of a diode junction."

The positive values shown on sheet 26 of the calculation were calculated to determine their magnitude if smoothing did not occur, and do not represent the actual output of the characterizer.

Positive values of systematic characterizer curve errors were not included in the calculation because:

a) They occur at only seven very narrow regions of pressure.
b) Their calculated positive values before smoothing are all less than 1°F, and this value is smoothed in the negative direction.

2. The following equations were used to calculate the values shown in Table 3:

Total Error (-) = Random (-) + Systematic (-)
Total Error (+) = Random (+) + Systematic (+)

For non-accident conditions, Random (+) and (-) errors are calculated on sheets 13 and 14 and tabulated in Table 2. Systematic (-) errors are calculated on sheet 26 and tabulated in Table 1. Systematic (+) error equals zero (see discussion in Paragraph 4-1 above).

For accident conditions, Random (+) and (-) errors are calculated on sheets 16 and 17, and tabulated in Table 2. Systematic (-) error is the sum of the negative characterizer curve error and containment pressure error as tabulated in Table 1. Systematic (+) error equals zero.

Representative Characterizer Curve

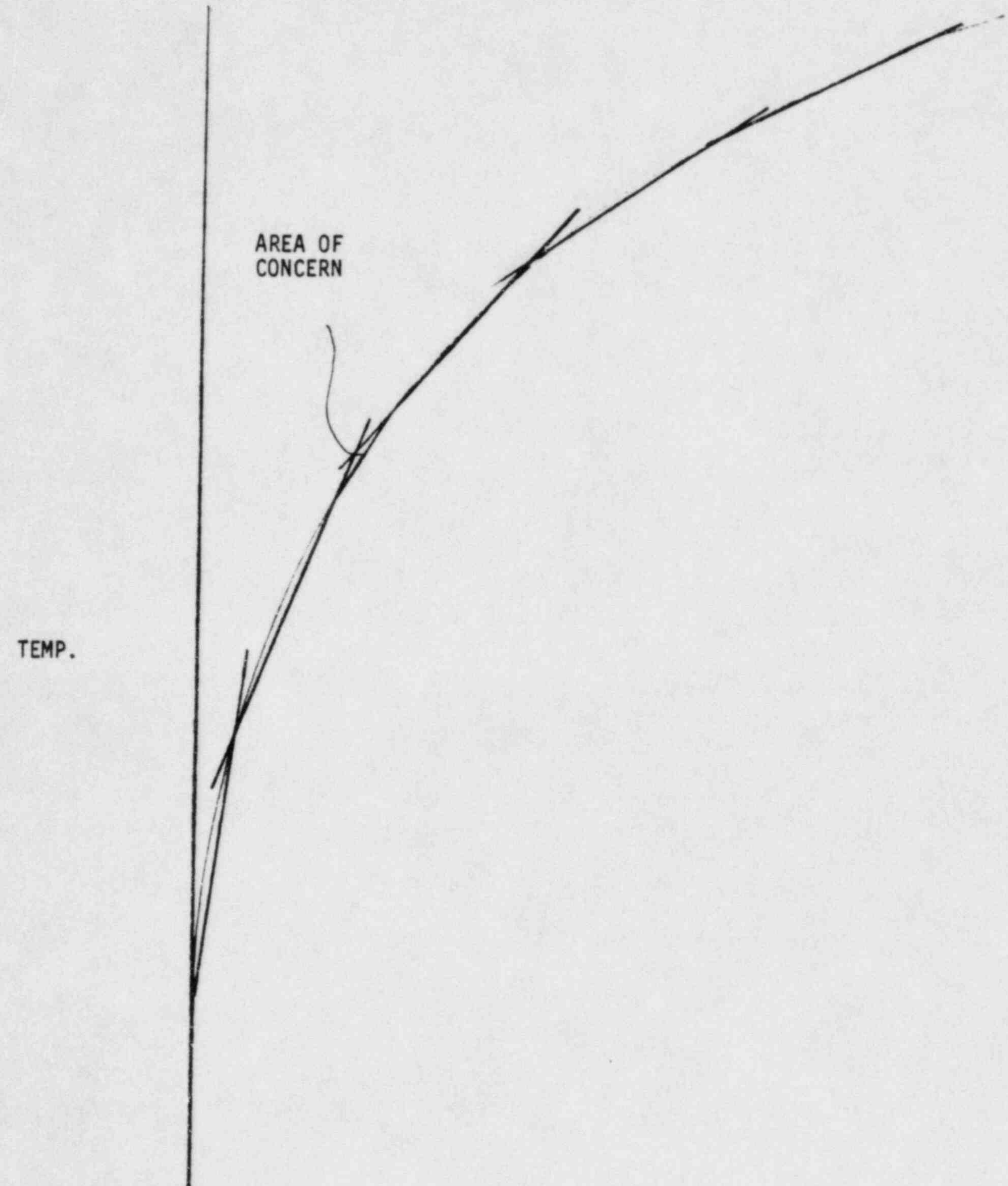


Figure 2

Question 6

Notes 1 and 2 on Sheet 6 of the loop error analysis provide qualitative basis for the use of statistically less conservative error allowances for temperature effects and power supply effects. We request that you provide test results or analyses to confirm the linear relationship between error and power supply/temperature variation.

Response

1. With regard to Note 1 on Sheet 6, the qualitative basis for derating the temperature effect error is that the equipment (Foxboro 200 modules) are located in the Control Building, which has redundant safety grade HVAC systems. A controlled environment of ± 5°F will always be available.

   Foxboro published error data is based on a 50°F heat rise of the modules. During the testing, temperature was changed in large increments (23°C, then smaller increments until limit was reached), and an error limit (less than ± .5%) was established that enveloped the worst case test data. The test data indicates that temperature effect error increases as temperature deviates further from the reference temperature of calibration to some function with a power greater than one. Thus a linear interpolation is conservative. (See Figure 3, below)

   The first step in establishing the temperature effect error used in the loop error analysis involved converting the manufacturer's 3σ error value for a 50°F temperature rise to a 2σ value by multiplying by 2/3 (See Sheet 2 of the loop error analysis).

   Assuming a linear relationship, one half of the 2σ error value for 50°F would be the 2σ error value for 25°F rise in temperature:

3σ Enveloping error limit	2σ (50°F rise)	2σ (25°F rise)
± 0.5%	± 0.333%	± 0.166%

   A temperature variation of ± 25°F is assumed in determining the temperature effect error.

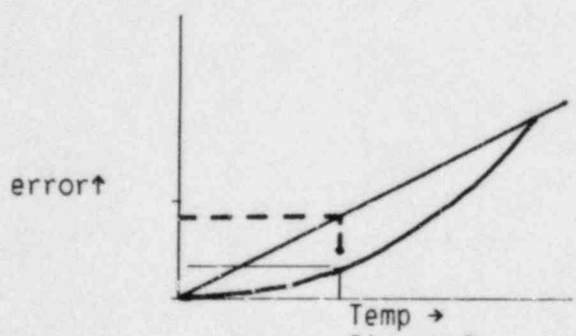


Figure 3

2. Note 2 on Sheet 6 specifies that power supply / vital bus regulation is very much better than 5%; therefore a value equivalent to 1σ is considered conservative.

The supply voltage error effect values provided by the manufacturer, Foxboro, are based on test data where the input voltage to the modules was changed in discrete increments of $\pm$ 5%. This data is provided primarily for users who use unregulated power supplies.

In the TMI-1 application modules are powered from Foxboro 2ARPS power supply, with output regulation of $\pm$ 0.2% for a -15 to 10 V change of input voltage. The input voltage is provided by a plant vital bus, which is also regulated to less than 0.2%.

The use in the calculation of a supply voltage error effect of 1σ, or 1/3 the 3σ value of a 5% variation for an application that is representing a 2σ value of a 0.2% variation is considered very conservative, as shown by the following:

	Module			
	2	11	12	15
Manufacturer's 3σ Supply Voltage Error for 5% Change in Voltage	$\pm$ 0.25%	$\pm$ 0.25%	$\pm$ 0.5%	$\pm$ 0.5%
2σ Supply Voltage Error = 2/3 (3σ error) for 5% Change in Voltage	$\pm$ 0.167%	$\pm$ 0.167%	$\pm$ 0.333%	$\pm$ 0.333%
2σ Supply Voltage Error for 0.2% Change in Voltage, using Linear Approximation = 0.2/5 (2σ supply voltage error for 5% change in voltage	$\pm$ 0.007%	$\pm$ 0.007%	$\pm$ 0.013%	$\pm$ 0.013%
1σ value (used in analysis)	$\pm$ 0.083%	$\pm$ 0.083%	$\pm$ 0.167%	$\pm$ 0.167%

N.B. Voltage variations are within the normal range for the instrument; they already are accounted for in normal accuracy factors. In any future revisions of this calculation, these error terms should be eliminated.

Question 8

Sheet 21 of the loop error analysis states that calibration error associated with the RTD was considered negligible and, therefore, excluded from consideration. We request that you provide the quantitative basis for excluding the calibration error associated with the RTD, the alarm module (setpoint), and the indicator.

Response

In the revised loop error analysis, the error associated with RTD (module 1) will be included. Results of the revised loop error analysis will be provided by December 14, 1984, as response to Question 5.

The alarm module was not excluded from the calculation. Values for the module (A_{17}, T_{17} and V_{17}) were included in the loop error calculation (sheet 12), and were not subtracted in the 'calbration' calculation (sheet 21).

The alarm loop and indicator loop error values were within 0.2% of each other over the entire range. The calibration calculation was for the alarm loop which has the greater error; it applies equally for the indicator loop.

Question 9

Sheet 10 of the loop error analysis states that the error for modules 9 and 10 must be multiplied by the slope of the saturation temperature/pressure curve (dT/dp). Over the pressure range of interest, the multiplication factor is less than one, reducing the error associated with modules 9 and 10 by a factor of 14 at the upper range. As discussed in Enclosure 1 to the letter dated August 31, 1984, from H. D. Hukill (GPU) to J. F. Stolz (NRC), this multiplication factor is necessary to correct for the amplifier gain in the function generator. From a review of the information provided, it is not clear why the uncorrected value for modules 9 and 10 are nonconservative and how you determined that dT/dp was the appropriate correction factor. Accordingly, we request that you provide additional information to suppprt the use of the dT/dp correction factor in computing error.

Response

The problem at hand is to express an individual component error, given as a percent of a 2500 psi span, as a percent of a 500°F span (the final elements of the loop), in order that it may be added as part of the overall loop error.

As shown in Figure 4, the following steps are followed:

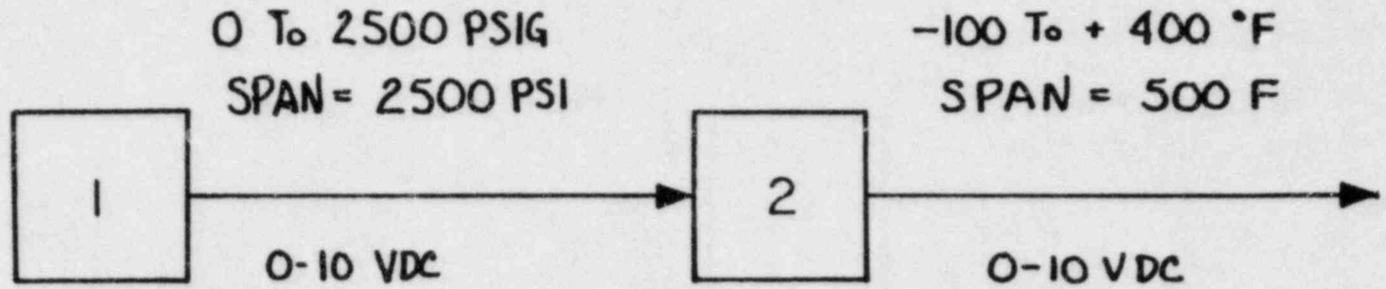
1. Convert the individual component error value (a percent of the 2500 psi span) to an absolute value in terms of psi, by multiplying by (2500 psi/100% span 1).

2. Convert the error (psi) to an error (°F) by multiplying by dT/dp (°F/psi).

3. Convert the error value in °F to a percent of span for the final components by dividing by (the span in °F/100 % span 2), or (500°F/100% span 2).

In addition, the manufacturer, Foxboro, has provided a technique called normalized equations which has been used to verify the above relationships.

The omission of dT/dp was equivalent to the assumption of dT/dp = 1. As discussed in Enclosure 1 to the August 31, 1984 letter and as shown on page 11 of the loop error analysis, the use of dT/dp = 1 resulted in calculated error values which were nonconservative by a factor of 1.264 in the 0-100 psig range, and overly conservative in the ranges above 100 psig.



Step 1 $$e_1 = e_1(\%\,\text{SPAN1}) \times \frac{2500}{100}\,\frac{(\text{PSI})}{(\%\,\text{SPAN1})} = \frac{2500}{100}\,e_1\,(\text{PSI})$$

Step 2 $$e_1 = \frac{2500}{100}\,e_1\,(\text{PSI}) \times \frac{dT}{dP}\,\frac{(^\circ\text{F})}{(\text{PSI})} = \frac{2500}{100}\,\frac{dT}{dP}\,e_1\,(\text{F})$$

Step 3 $$e_1 = \frac{2500}{100}\,\frac{dT}{dP}\,e_1\,(\text{F}) \times \frac{100}{500}\,\frac{(\%\,\text{SPAN2})}{(\text{F})} = \frac{2500}{500}\,\frac{dT}{dP}\,e_1\,(\%\,\text{SPAN2})$$

Figure 4

Question 10

Sheet 10 of the loop error analysis includes a discussion on the methods used to normalize the range of each loop component to the range of the final elements of the loop. For example, the range of modules 9 and 10, 2500 psi (corrected for gain errors), was divided by 500°F to provide a 5.0 psi/°F correction factor. It is the staff's concern that this method may not be appropriate. Typically normalization is achieved by summing the signal errors (mA or mV) rather than creating a psi/°F unit in an equation that sums error in percent span. Accordingly, we request that you supply additional information to support the use of this method.

Response

See the response to Question 9.