Design Analysis

RCS Sub Cooling Margin Monitoring System

Error Analysis

Rochester Gas and Electric Corporation

89 East Avenue

Rochester, New York 14649

EWR 2604

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Prepared by: Carl J. Reinhardt, P.E. 1/23/80
Electrical Engineer DATE

Reviewed by: G. W. Daniels 1/23/80
Manager, Electrical Engineering DATE

Approved by: G. W. Daniels 1/23/80
Manager, Electrical Engineering DATE

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Sub-Cooling Margin Monitoring System
Error Analysis

I. Purpose

The purpose of this analysis is to compute the uncertainty in the value of RCS subcooled margin, as computed and displayed to the plant operator. This value of subcooling margin is computed by a Foxboro Spec 200 analog computer, utilizing as inputs RCS hot leg temperature and pressurizer pressure.

II. Referenced Documents

A. Westinghouse bulletin 43-252D WE A

B. Foxoboro Company Product Specification Sheets:

1. PSS 2C-2A1B 06-77
2. PSS 2C-2A1C 04-77
3. PSS 2C-2A1W 07-77

C. Letter dated 12/27/79 to Westinghouse Owner's Group Representatives from R. A. Newton of Wisconsin Electric Power Company

D. Rosemount Engineering Company drawing 176JA, Rev. C dated 12/23/66.

E. "Signal Characterizer Calibration", Rev. 0, Foxboro Company.

F. RG&E drawing 21489-297, Rev. 0

G. RG&E drawings 21489-303, Rev. 1, and 21489-302, Rev. 1

H. 1967 ASME Steam Tables

I. Letter dated 2/15/78 from J. D. Woodward W, to J. Arthur

J. Foxboro Instruction Sheet 18-232 for 66B Current Repeater

III. Computer Programs

A. "Curvfit" BASIC - least squares polynomial curve fitting program.

B. "Rootr" - BASIC - cracsk polynomials.

IV. <u>Assumptions</u>

A. Only the pressure transmitter (PT) and temperature transmitters are located inside containment, and are therefore subject to the accident environment. All other equipment is therefore assumed to be functioning under normal conditions of temperature, humidity, radiation, electrical voltage and frequency.

B. Reference D above, states that all material used in construction of the RTD's can withstand temperatures to 650°F. In addition leadwire resistance compensation is included in the resistance to voltage converter. Therefore, the accident environment has a negligible effect on the RTD, and conversion circuitry.

C. Errors due to calibration error are considered negligible, for the Foxboro Spec 200 equipment, since these units were factory calibrated, and have better accuracy than that stated in reference B. The calibration errors for the Foxboro 66BR are assumed to have a negligible effect on system accuracy.

D. Accuracy and repeatibility values are in terms of calibrated span, unless otherwise noted.

E. Accuracy and repeatibility errors are summed for conservatism.

V. <u>Analysis</u>

A. This analysis utilizes some of the procedures outlined in reference C above.

B. Instrument accuracies (refer to attached diagram #1).

1. Pressure transmitters (Foxboro E11GM) from ref. C. page B-2

Maximum normal instrument error =

$$\sqrt{5(4)^2 + 3^2 + 2(8)^2} = \pm 14.7 \text{ psi}$$

Maximum instrument error under accident conditions = ± 68 psi, (from ref. I).

2. Isolation amplifiers (Foxboro 66BR-OH) from ref. J accuracy ± 0.5%, repeatability = 0.1%
   Total error = ± 0.6%
   ± 0.6% (2500-1700) = ± 4.8 psi

3. Current to voltage converter (Foxboro Spec. 200 2AI-I2V) from ref. b
   accuracy = ± 0.25% repeatability < 0.1%
   Total error = ± .35%
   = ± .35% (2500-1700) = ± 2.8 psi

4. Therefore the total normal error present at the input of the function generator is:

$$= \sqrt{(14.7)^2 + (4.8)^2 + (2.8)^2} = \pm 15.72 \text{ psi}$$

   Under accident conditions total error = 15.72 + 68 = ± 83.72 psi

This error in the pressure signal must now be transformed into equivalent error present at the output of the function generator. To do this, the steam tables between 1700 psig and 2500 psig must be modeled. Using the "Curvfit" program and steam table data (ref. H) the following polynomial was developed:

$$T_{SAT} = 1.4172591E{-4} + .96584976 \times P - 6.1328799E{-4} \times P^2 + 1.8916803E{-7} \times P^3 - 2.2256878E{-11} \times P^4$$

maximum error = + .0291% in modeling the steam tables

The first derivative of this equation may be used to compute the error in the saturation temperature as a function of the error in the pressure signal, hence:

ΔT_{SAT} (max) = $\Delta P \times f'$ (Pm)
ΔP = Pressure error
Pm = 2000 psig (S.I. termination)

$$\therefore \frac{dT_{SAT}}{dP} = .96584976 - 1.22657598E{-3} \times P + 5.670409E{-7} \times P^2 - 8.9027512E{-11} \times P^3$$

hence $\Delta T_{SAT} = 83.72 \times f'(2000 + 14.7)$
$= 5.87°F$

This would be the error in the output of the function generator if: 1) the steam tables were modeled with no error, and 2) there were no inaccuracies in the function generator.

Reference E, defines the function that was programmed into the function generator by Foxboro. To compare this curve with the steam tables, it is necessary to develop the polynomial for the steam tables adjusted for scaling, spanning and zeroing. This new function can then be used to compare the Foxboro calibration points with equivalent values from the steam tables. The results of these computations are shown on page 7.

The result of this computation shows that the maximum error is -2.24%, (note: all errors are negative and therefore conservative). This error also occurs at approximately 1710 psi and therefore will be used for conservatism.

$$\text{error} = -2.24\% \,(669-614.3°F) = -1.23°F$$

The error due to inaccuracies of the function generator are:

$$\text{accuracy} \pm 0.5\% \quad \text{repeatability} = 0.25\%$$

$$\text{total error} = \pm 0.75\% \,(669-614.3°F) = \pm .41°F$$

The errors present are therefore

a) ± 5.87°F due to errors propagated by the pressure signal

b) -1.23°F due to error in steam table modeling

c) ±.41°F due to "electronic" drifting

These errors are each generated by a separate random process, therefore, the total error at the output of the function generator is:

$$\sqrt{(5.87)^2 + (1.23)^2 + (.41)^2} = \pm \underline{6.01°F}$$

5. Temperature transmitter (RTD) (Rosemount 176JA) Reference D lists the accuracy as

Temperature °F	Accuracy ± °F
32	.011
525	.055
625	.065

Repeatability ∴ 2°F or 1% of span whichever is greater

∴ error = .065 + 1.0% x (700-500) =±2.065°F

6. Resistance to voltage converter (Foxboro 2AI-P2V) from ref. B, accuracy ± .25%, repeatability <0.1%
error = ± .35% (700-500)
= ± .7°F

Total error at input of summer from temperature measurement and conversion =

$$\sqrt{(2.065)^2 + (.7)^2} = 2.18\ °F$$

7. The signal present at summer inputs are

1) T_{HOT} ± 2.18°F
2) T_{SAT} ± 6.01°F

Since both these errors are generated by separate, random processes, the total error as a result of the summing function is

$$\sqrt{(6.01)^2 + (2.18)^2} = \pm 6.39°F$$

8. The error introduced by the summer itself is:
accuracy ± 0.5%, repeatability < .25% (Ref. B)

error = ± .75% (100°F)
= ± .75°F

10. The error from the indicator (W V252) is accuracy ± 1.5%, readability ± 1/2 of division

error = 1.5% (100-0°F) = ± 1.5°F (accuracy)

$$\text{error} = \pm 1/2 \text{ division} \times \frac{2°F}{\text{division}} = \pm 1°F$$

11. The total process error is therefore the square root of the sum of the squares of the errors computed in sections 7,8,9, and 10 above

Total system error =

$$\sqrt{(6.39)^2 + (.75)^2 + (1.5)^2 + (1.0)^2} = \pm 6.71°F$$

VI. Conclusion

From the foregoing analysis, the maximum error in the value of subcooling margin is 6.7°F.

```
X          Y             FNA(X)        FNA(X)-Y         % ERROR
 0         5.71          5.584865      -.125135         -2.2406092
 1.25      6.11          5.9911195     -.11888052       -1.984279
 2.5       6.48          6.3713626     -.10863742       -1.7050892
 3.75      6.84          6.7333361     -.1066639        -1.5841167
 5         7.19          7.0821079     -.10789215       -1.5234468
 6.25      7.52          7.4200717     -9.9928261E-02                   -1.346729
 7.5       7.84          7.7469477     -9.3052297E-02
-1.2011479
 8.75      8.15          8.0597818     -9.0218245E-02
-1.1193634
 10        8.45          8.352946      -.09705404       -1.1619139
 0         0             5.584865       5.584865         100

END AT 0120
* LIST
0010 DIM A(50)
0020 DEF FNA(X)=5.584865+.33800739*X-.011585362*X^2+.001002896*X^3-.000045635274
*X^4
0030 DIM B(20),C(20),D(20)
0035 LET I=1
0040 PRINT 'TYPE IN X,Y PAIRS.... 0,0 TO END'
0045 INPUT A(I),B(I)
0050 IF B(I)=0 THEN GOTO 0100
0060 LET I=I+1
0070 GOTO 0045
0100 PRINT 'X     ','Y     ','FNA(X)','FNA(X)-Y','% ERROR'
0110 FOR K=1 TO I
0115   LET Y=FNA(A(K))
0117   PRINT A(K),B(K),Y,Y-B(K),((Y-B(K))/Y)*100
0120 NEXT K
* SAVE'COMPARE
* B
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NOTE: X&Y values from Reference E
FNA(x) is value for Y computed using steam table polynomial approximation.