MASTER

LOFT TECHNICAL REPORT LTR 115-47

JULY 27, 1978

REVISED ERROR ANALYSIS OF LOFT
SECONDARY CALORIMETRIC POWER EQUATION

D. H. Van Haaften

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LOFT TECHNICAL REPORT
LOFT PROGRAM

TITLE		REPORT NO.
Revised Error Analysis of LOFT Secondary Calorimetric Power Equation		115-47
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LOFT APPROVAL		
<i>D. H. Van Haaften</i> <i>7/24</i> <i>7-27-78</i>		
PSE	RCSS Supvr.	PSB Mgr.
		P&CSB Mgr.
<i>ECC</i>		
RSB Mgr.		

Summary

A second-order error analysis of the LOFT secondary calorimetric power equation was performed to determine a figure for system accuracy for use in safety analysis and program evaluation. A realistic figure of accuracy for the Secondary Coolant System (SCS) was developed reflecting the relative importance of each measured parameter. This analysis was performed using SOERP, a second-order error propagation computer code. The final 2 σ tolerance band on calculated calorimetric power was found to be 0.720% of the mean calculated power in the full power (55MW) range.

The second order error analysis contained in this report is valid provided the following assumptions are met:

- 1) SCS is at steady state as stated in LTR 111-74, H G. Kraus, and
- 2) Errors in instruments are normally distributed.

ACTION ITEM - Prior to use of the RTD instrument for Power Range Testing ensure that the RTD and temperature transmitter are compatible.

INTEROFFICE CORRESPONDENCE

date July 13, 1978

to R. E. Polk

from D. H. Van Haaften *D. H. Van Haaften*

subject REVISED ERROR ANALYSIS OF LOFT SECONDARY CALORIMETRIC POWER EQUATION - DHV-2-78

- Ref:
- (a) D. H. Van Haaften ltr to R. E. Polk, Error Analysis of LOFT Secondary Calorimetric Power Equation, DHV-1-78, June 27, 1978
 - (b) R. E. Polk ltr to N. E. Pace, Request for Analysis of Calorimetric Power Equation, POLK-2-78, Feb. 24, 1978
 - (c) N. D. Cox and C. F. Miller, "User's Description of Second-Order Error Propagation (SOERP) Computer Code for Statistically Independent Variables," TREE-1216, Feb. 1978

A second-order error analysis of the LOFT secondary calorimetric power equation was described in Ref. a. This analysis has been revised to include improved instrumentation for the measurement of $\dot{m}_s$ and Q_{PCC} . SOERP, a second-order error propagation computer code (Ref. c), was used to evaluate the overall uncertainty in the secondary calorimetric power calculation and the relative contribution of the uncertainty associated with each measured parameter. The final 2σ tolerance band on calculated calorimetric power was found to be 0.720% of the mean calculated power in the full power (55 MW) range.

A report documenting this analysis is forthcoming, but a short discussion of the analytical techniques used is included in this letter for your information.

The calorimetric power equation used is:

$$Q = (\dot{m}_s - \dot{m}_{BD}) [x h_g + (1-x) h_f - h_i] + \dot{m}_{BD} (h_f - h_i) - Q_{PP} + Q_{PSL} + Q_{PCC}$$

where

- Q = Reactor power, Btu/hr
- $\dot{m}_s$ = SCS feedwater flow, lbm/hr
- $\dot{m}_{BD}$ = Steam generator blowdown flow, lbm/hr
- x = Steam generator vapor quality, lbm/lbm
- h_i = SCS feedwater enthalpy, Btu/lbm

- h_f = Saturated liquid enthalpy, Btu/lbm
 h_g = Saturated vapor enthalpy, Btu/lbm
 Q_{pp} = Power input to primary coolant pumps, Btu/hr
 Q_{PSL} = Primary and secondary system piping and structural heat losses, Btu/hr
 Q_{PCC} = Heat rejected in the Primary Component Cooling System (PCCS) heat exchangers, Btu/hr

The calorimetric parameters and measured values used as input to this calculation and their percent contributions to the 2σ uncertainty are shown below. On the basis of the information presently available, the nominal values for full power range operation are also shown.

Calorimetric Parameter	Nominal Value	Instrument Identifier	Contribution to 2σ , %
$\dot{m}_s$	2.31×10^5 lbm/hr	FE-P4-72 PT-P4-10A TE-P4-4	13.335 0.050 34.717
$\dot{m}_{BD}$	1.89×10^3 lbm/hr	FRC-202 PT-P4-10A	0.002 0.050
Q_{pp}	2.54×10^6 Btu/hr	PCP-1-P PCP-2-P	2.194
Q_{PSL}	5.84×10^5 Btu/hr	TE-P139-28-2 TE-P139-29 TE-P139-32 TE-P139-33 TE-P139-34 TE-T055-022	
Q_{PCC}	2.98×10^6 Btu/hr	FT-P141-022 TE-CAL-TC-1 TE-CAL-TC-2	
x	0.9975	input as constant	
h_g^1	1196.8 Btu/lbm	PT-P4-10A	
h_f^1	524.8 Btu/lbm	PT-P4-10A	1.927×10^{-5}
h_i^1	361.94 Btu/lbm	PT-P4-10A TE-P4-4	0.040

*These parameters are looked up in a table on pressure and/or temperature. The percent uncertainties listed are those contributed by the enthalpies, not the pressure and temperatures.

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$\sqrt{\gamma}^2$	7.36 (lbm/ft ³) ^{1/2}	PT-P4-10A TE-P4-4	2.687
γ_2^2	47.10 lbm/ft ³	PT-P4-10A	3.830 x 10 ⁻⁶

The instrument signals are amplified and transmitted to the Data Acquisition and Visual Display System (DAVDS). Each channel has a total associated error, which includes that due to the sensing element, transmitter, amplifiers, filters, and the DAVDS. The total channel error was propagated from the measured variables through the calorimetric parameters into the calorimetric equation to obtain the overall uncertainty in the measured reactor power.

For further clarification, the statement in Ref. a that FE-P4-72 contributed 51% to the total uncertainty and that TE-P4-4 contributed 38%, for a total of 89% of the total uncertainty is not directly comparable to the numbers cited in this letter. These percentages refer to percent of total variance, or σ^2 . The components of total variance are additive if the parameters are independent. The interdependencies are relatively small in this case and can be considered unimportant. The numbers listed in this letter are the percent contributions to the 2σ uncertainty. These are not additive, even in the case of total independence, and are therefore not directly comparable to the figures in Ref. a. However, the percentage variance number may be transformed into an equivalent percent of 2σ number. Therefore, for purposes of comparison, it can be said that, from Ref. a, the percentage contributions to the 2σ uncertainty of FE-P4-72 and TE-P4-4 are 30% and 22%, respectively. By improving the accuracy of FE-P4-72 and calculating Q_{pcc} , the percent contribution of FE-P4-72 has decreased to 13% and that of TE-P4-4 has increased to 35%. At the same time, however, the magnitude of the 2σ uncertainty has decreased from 0.891% to 0.720% of nominal full power.

It became apparent during this analysis that the atmospheric pressure, p_{atm} , is not added to the gauge pressure, PT-P4-10A, to obtain absolute steam generator pressure in the current instrument configuration. This introduces a bias into the table look-up of the enthalpies and densities. The result is that the nominal value of the calculated power is 91,800 Btu/hr (0.05%) higher than it should be.

²These intermediate parameters are used in calculating the calorimetric parameters. They are the mass densities of water, looked up in a table on pressure and/or temperature, and are used as input into flow rate calculations. The percent uncertainties listed are therefore the contribution of $\sqrt{\gamma}$ or γ_2 to the total 2σ uncertainty.

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