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To	E. OELKERS, SYSTEM RELIABILITY & CONTROLS UNIT	
From	Thomas L Wilson 1:15 PM T. L. WILSON, SYSTEM RELIABILITY & CONTROLS UNIT	BDS 663-5
Cust.	TMI-2	File No. or Ref.
Subj.	RELIABILITY AND UNCERTAINTY OF THERMOCOUPLES FOLLOWING LOSS OF FEEDWATER TRANSIENT	Date APRIL 5, 1979

This letter to cover one customer and one subject only.

Acknowledgement:

I have gathered the following information through conversations with several individuals having experience with thermocouples that have been subjected to extremely high temperatures. I am indebted to P. E. Mamola, R. H. Stoudt, and Tom Kollie of ORNL for their help and cooperation.

Description of the Problem:

The incore thermocouple design at the TMI-2 core is a grounded junction Chromel-Alumel detector. The wire diameters are approximately 10 mils, the sheath is 62 mils OD Inconel tubing, and the insulation material is Al_2O_3. I have gathered information on reliability and uncertainty of this type of thermocouple after being subjected to extremely high temperatures (> 2000°F). The problem of gross failure (open circuit, sheath failure, new junction or other failure) would be indicated by no reading or extremely low, erratic reading. No detectors are giving indication of gross failure. Given the survival at present conditions, the prospect for continued operation is excellent. The primary questions are the following:

1. Are the readings accurate?
2. Are the errors in the readings consistent with the hypothesized scenario of the transient?

Decalibration Phenomenon:

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A phenomenon observed by Dr. Kollie in thermocouples having experienced extremely high temperatures is a deteriorated state in which the thermocouple gives a stable but inaccurate reading. The effect is called decalibration.

The decalibration error is random but does follow some trends. The primary dependencies are the following:

1. Sheath diameter — The larger the detector, the less susceptible to decalibration.
2. Sheath material — Inconel is better than stainless. The decalibration

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	error for Inconel is usually negative. Measured temperature is lower than actual.
3. Temperature	Decalibration error increases with temperature. (10°C roughly doubles the reaction rate of the mechanism.)
4. Time of exposure	Decalibration error is roughly linear with exposure time.
5. Temperature profile	Decalibration occurs along the length of the thermocouple. Hence, the error depends on the profile of the elevated temperature and on the profile of a subsequent measurement with the thermocouple.

Other dependencies which are not known specifically but are expected to be small are insulation material, length of detector, and wire diameter.

Experience with smaller diameter detectors (20 mils OD) but similar in other characteristics (grounded junction Chromel/Alumel thermocouple with Inconel sheath) show essentially zero probability of survival at 1100°C for 10 to 100 hrs. without a measurable decalibration. The decalibration error tends to be negative (reading lower than actual) for this test; however, one sample gave a positive error. The magnitude for worst case error (remembered) was -50°C. Larger decalibration errors would be expected for higher temperatures.

The primary mechanism for decalibration is migration of constituents primarily chromium in the detector through vapor phase transfer. The chromel lead loses chromium and the alumel lead gains chromium. Belfab tests indicating little decalibration for 4 hour period at 7000°F are not necessarily conclusive since the temperature gradient of the high temperature state does not simulate the transient environment nor did the test condition simulate the present environment.

Conclusions:

If it can be determined that the thermocouple is reading accurately now (for example, if it agrees with outlet RTD's), this implies that its readings are believable throughout the transient.

If thre is reason to believe a thermocouple is decalibrated, there is a high probability that actual temperature is greater than its indication. Hence, the cluster of high readings should not be disregarded.

Since a high percentage of detectors survived the transient, the maximum temperature did not attain a level for widespread failure.

Recommendations:

1. Perform testing simulating transient conditions to determine the temperature threshold for gross failure in TMI-2 design detectors.
2. Perform testing to quantify magnitude and direction of decalibration errors for a range of temperatures simulating reactor environment.

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