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429 1

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OTHER		PROJECTS Development and Test of Components involving High Thermal Stress Assemblies; Development of Moderator Can	DATE 27 March 1959
			PAGE 1 OF 6
TO: R. J. Allen			
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SUBJECT: Large Components Test Loop System Temperature Limit of Error			
CONTENTS: I STATEMENT OF PROBLEM PAGE 1 II SUMMARY OF RESULTS AND RECOMMENDATIONS PAGE 1 III METHOD USED, DESCRIPTION OF EQUIPMENT, SAMPLE CALCULATIONS . . . PAGE 4 IV REFERENCES AND APPENDICES PAGE 6			
I STATEMENT OF PROBLEM A. To determine the limit of error of the temperature measuring system for the high thermal stress tests on the moderator cans. B. To determine the means of calibration of the chromel-alumel thermocouples after installation.			
II SUMMARY OF RESULTS AND RECOMMENDATIONS A. Limit of Error 1. Results (See chart, page 2) 2. Recommendations a. Thermocouple wire (stainless steel sheathed) (1) Fabrication: Prior to installation, the thermocouple material should be baked to eliminate moisture in the Mg O packing. While a longer bake-out is probably beneficial, the manufacturer recommends a minimum of one-half (½) hour at 250° to 300°F. The ends should be sealed immediately leaving the wires extended. (2) Calibration: The two thermocouples tested in the laboratory when spot welded to the moderator skin, had small corrections. Consequently, a 10% random sampling of the thermocouple material should prove whether or not we can narrow the +7°F uncertainty to a closer tolerance. +2°F is the figure possible based on the two test pieces. Calibration should be done after the splice to flexible lead has been made.			

429 2

TECHNICAL DATA RECORD

PROGRAM Hallam Nuclear Facility PROJECT See Page 1 of 6

TOR NO. 3669
DATE 27 March 1959
PAGE 2 OF 6

1. Results:

ITEM	MGFR.	TYPE	LIMITS OF ERROR	
			MANUFACTURER'S SPEC.	WITH CALIBRATION
a. Chromel-alumel thermocouple wire, 304 stainless steel sheathed, 1/16" OD 3DGA	Aero-Research Instrument Co.	Reg. grade	$\pm 4^\circ$ (0° to 530°) $\pm 3/4\%$ (530° to 2300°) Max. error @ 1000°F $\pm 7^\circ\text{F}$	Based on the corrections for two test samples calibrated in the Standards Laboratory $\pm 2.0^\circ\text{F}$
b. Chromel-alumel thermocouple wire glass-asbestos ins. duplex type 28ga	Leeds & Northrup	Reg. grade	Same as "a"	Calibration of "a" included this material and the splice connecting it to the st.st.sh.ch.al.
c. Cannon connectors with chromel and alumel inserts	Cannon Electric Co.	Hermetically sealed Ch-Al	Not specified by Mfg. (measured value $\pm 0.7^\circ\text{F}$)	Evaluation in the Standards Lab $\pm 0.7^\circ\text{F}$
d. Chromel-alumel extension wire, 16 ga, poly vinyl insulated	Thermoelectric	Reg. grade	$\pm 2\frac{1}{2}\%$ of $\pm 4^\circ\text{F}$ This limit applies to the temperature difference between the connection at the cannon plug and the reference junction	The evaluation of this item is included with "c".
e. Reference junction temperature box, 100 channels each, chromel-alumel	Pace Engineering		Stability $\pm 0.2^\circ\text{F}$ Accuracy of chromel alumel channels not specified by manufacturer (measured value $\pm 0.3^\circ$)	Evaluation in Standards Lab indicated 1. Stability $\pm 0.2^\circ\text{F}$ 2. Accuracy $\pm 0.3^\circ\text{F}$
NOTE: The totals given here include only the assembly from the hot junction of the thermocouples to the output of the reference junction box.			TOTAL $\pm 5.3^\circ\text{F}^{**}$	TOTAL* $\pm 1.5^\circ\text{F}$
			*Totaling of the uncertainties is treated as a standard deviation calculation. **Temperatures are reported in $^\circ\text{F}$ rather than $^\circ\text{C}$ at your request.	

730-D-6

429
3

TECHNICAL DATA RECORD

PROGRAM Hallam Nuclear Facilities PROJECT See Page 1 of 6

- b. Flexible duplex chromel-alumel
 - (1) The splice connecting the thermocouple wires in the stainless steel sheath to the flexible lead should be spot welded, insulated and reinforced to protect the small wires. The AI R&D Shop regularly fabricates a satisfactory connection.
- c. Cannon connectors (Receptacle: #GS02-22-14P-110(F9)
Plug: #CA3106E-22-14S(F9))
 - (1) Spot weld connection from the chromel-alumel flexible lead to the plug and from the chromel-alumel extension lead to the receptacle.
- d. Chromel-alumel extension wire
 - (1) No special recommendations.
- e. Reference box
 - (1) Monitor reference box temperature at set intervals (perhaps once a complete cycle) while scanning the thermocouples. The thermistor for this read-out should be calibrated before the reference boxes are installed. A random 10% check on the accuracy of the channels should be made.

B. Means of Calibration

- 1. Results: Due to the lack of equilibrium conditions in the tank, no true calibration of the chromel-alumel thermocouples can be attempted after they are installed. The drift (Figure 1) of the emf of chromel-alumel thermocouples can be monitored throughout the length of the experiment if protected Pt vs Pt 10% Rh thermocouples are installed.

Drift results for chromel-alumel thermocouples at 600°C (1112°F)

429 4

TECHNICAL DATA RECORD

2. Recommendations: Several Pt vs Pt 10% Rh thermocouples should be included in the temperature measuring system. Since part of the Ch-Al thermocouples will be in vacuum and others outside the tank, monitoring Pt vs Pt 10% Rh couples should be placed in both areas. The ones inside the moderator cans should be placed so that various temperature areas are monitored. They should be welded immediately adjacent to a particular chromel alumel couple so that during data processing the temperatures indicated by the two can be readily compared. The Pt vs Pt 10% Rh hot junction should be closed for protection from possible contamination, particularly from graphite. The monitoring couples for the outside should be attached in the same manner and the data handled similarly.

Stainless steel sheathed Pt vs Pt 10% Rh is recommended (available from Aero Research). For the thermocouples inside the cans, a splice can be made to compensated lead wire (L & N Part # 16-60-2) at the top of the instrument tube prior to connecting it to the connectors containing Pt and Pt 10% Rh contacts. Compensated extension wire (L & N Part # 16-60-3) can be used from the outside connection to the reference junction. The thermocouples attached to the outside of the tank can be spliced to the extension wire (L & N Part # 16-60-3) directly. This junction should occur in an area as close to ambient temperature as possible.

All Pt vs Pt 10% Rh thermocouples should be calibrated after the splices are constructed. For the ones going into the moderator cans, the cannon connectors should be included also.

III METHOD USED, DESCRIPTION OF EQUIPMENT, SAMPLE CALCULATIONS (Limit of Error)

A. Method Used

1. Thermocouple calibration data.

- a. Test # 1 - - Calibration was conducted with spot welded, crossed-wire hot junctions on the two sample thermocouples (Aero-Research). The hot junctions were touching the hot junction of two Pt vs Pt 10% Rh secondary standard. All were at 32°F reference temperature.

(1) Run # 1.

Temp. °F	Test Thermocouple #1 (Corr.)	Test Thermocouple #2 (Corr.)
1067.7°	+4.0°F	+0.4°F
978.4°	+4.3°	+0.7°
882.9°	+2.3°	-0.9°

- (2) Run #2 - - The sample thermocouples were allowed to cool ambient temperature. Another calibration check was made

Temp. °F	Test Thermocouple #1 (Corr.)	Test Thermocouple #2 (Corr.)
1090.0°	+4.3°	+1.3°
975.9°	+3.1°	+0.4°
974.6°	+4.2°	+2.0°
979.0°	+3.7°	+1.3°

TECHNICAL DATA RECORD

PROGRAM Hallam Nuclear Facilities PROJECT See Page 1 of 6

TDR NO. 3669

DATE 27 March 1959

PAGE 5 OF 6

- b. Test #2 - - The repeatability of calibration was rechecked as follows:

- (1) The chromel-alumel wires were welded separately to a piece of moderator can skin.
- (2) The hot junctions of the standards were welded immediately adjacent, no more than 1/32" away.
- (3) This assembly was placed in a muffle furnace.
- (4) Reference temperature was 32°F for all leads.
- (5) The data is summarized:

Temp. °F	Test Thermocouple #1 (Corr.)	Test Thermocouple #2 (Corr.)
Run #1		
661°	-0.1° F	-0.2° F
792°	+1.0°	-0.1°
844°	+1.0°	+0.3°
Run #2 (Spot weld redone; annealing time - - zero)		
1078°		+2.6°
Run #3 (Welds redone again and the assembly allowed to anneal overnight)		
1075°	-0.1°	-0.1°

- (6) Conclusion: Repeatability of calibration is more consistent when both the standards and the sample thermocouples are spot welded to a piece of material with good thermal conductivity characteristics than when arranged with the beads only touching. The stainless steel moderator can skin was used in this test since the sample thermocouples will be installed in this manner during the thermal stress experiment.
2. Evaluation of the error introduced to the system by the Cannon connections and the Ch-Al extension wire:
 - a. The calibration was rechecked again immediately prior to this test. The assembly was the same as described for Test #2.
 - b. The standard Pt vs Pt 10% Rh reference leads and the test thermocouple leads remained at 32.0°F for the calibration recheck.
 - c. Next, the duplex leads of the sample thermocouples were spot welded to receptacle.
 - d. The extension wires were then spot welded to the cannon connector pins and the connector assembled.
 - e. The extension wire leads were placed in the 32°F reference.
 - f. The change of the calibration of the sample thermocouples against the standards measured 0.7°F. During the assembly of the cannon connectors and extension leads, the assembly of hot junctions in the furnace was not moved or disturbed in any way.
 3. Evaluation of the Pace Reference Junction Box (Nominally 150°F):
 - a. Test #1 - - The temperature stability of the reference box was tested at three different time intervals using ice for a reference temperature to determine the actual temperature inside

429 6

TECHNICAL DATA RECORD

PROGRAM Hallam Nuclear Facilities PROJECT See Page 1 of 6

- the block. The readings varied by hundreths of degrees but when rounded to tenths, always came to 149.8°F.
- b. The accuracy of various channels of the reference box were tested by first rechecking the calibration of the test thermocouples, as described in #2, a and b.

- (1) Next, the leads for the test thermocouples were removed from the 32°F reference and attached to binding posts on the reference box.
- (2) The leads for the standards remained at 32°F reference.
- (3) The calibration comparison was made. 2.66 mv (corresponds to 150°F in Ch-Al) were added to the indication from the test thermocouple to facilitate direct temperature comparison with the standards.
- (4) Conclusion: The changes in calibration averaged $\pm 0.3^\circ\text{F}$. Thirty per cent of the channels were tested. Again, no mechanical movement or change of temperature affected the assembly of test thermocouples and standards in the furnace between calibration checks.

B. Description of Equipment

The secondary standard thermocouples used are platinum vs platinum 10% rhodium. These are standardized regularly against National Bureau of Standards calibrated thermocouples of the same material.

Rubicon "B" potentiometers with an accuracy of $\pm 0.015\%$ were used to take the thermocouple readings. Eppley standard cells used in this set-up are regularly calibrated by the Electrical section of the Standards Laboratory.

C. Sample calculations (See reference #C for complete calculations)

Emf of Test TC (mv)	Emf of Std. TC (mv)	Corr. for Std. TC (Using ice for reference temp.)	Corrected Emf of Std. (Using Pace Ref. box for test TC)	Temp. of Std. 1067.7°F	Temp. of Test TC 1063.8°F	Corr. for Test TC +4.1°F
23.767	4.9869	-0.0125 mv	4.9745 mv			
21.107	4.9869	-0.0125 mv	4.9745 mv	1067.7°F		
+2.66						
23.767					1063.8°F	+4.1°F

IV. REFERENCES AND APPENDICES

- A. "Temperature - - Its Measurement and Control in Science and Industry"
- B. ORNL 2467 - - Thermocouple Research Report for the Period November 1, 1956, to October 31, 1957, Progress Report No. 1, David L. McElroy
- C. Laboratory Notebook A010701, pages 010716 through 010723