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EFFECT OF HEAT TREATING AND
BRAZING PROCESSES ON INSTRUMENTATION

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EFFECT OF HEAT TREATING AND
BRAZING PROCESSES ON INSTRUMENTATION

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ABSTRACT

As the result of a series of experiments it was found that short time exposures of sheathed copper-constantan thermocouples to localized temperatures as high as 1525°F does not affect their emf output or function.

Similarly, exposure of sheathed chromel-alumel thermocouples to temperatures as high as 2150°F for 30 minutes (in Argon) resulted in no detrimental effects with regards to function.

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INTRODUCTION

Structural components must, on occasion, be so designed that thermocouples are exposed to various heating cycles during fabrication of the component. Brazing is frequently employed to secure a thermocouple or may be performed as a part of the component fabrication after the thermocouple is secured in the assembly, as part of a step brazing cycle. The effect of such exposures on the operation of thermocouples was investigated in this program.

MATERIALS

Thermocouples involved were of the metallic sheathed compacted magnesia oxide insulation type. Nominal outside diameters varied from .040 to .090 inch with sheath thicknesses of .006 to .010 inch and wire diameters of .006 to .011 inch.

The sheathing material was AISI 347 with thermocouple wire combinations of either copper-constantan or chromel-alumel. The composition (nominal) of these wire combinations are as follows:

Copper	99.900% copper
Constantan	50-65% copper, 50-35% nickel
Chromel	90% nickel, 10% chromium
Alumel	94% nickel, 3% magnenese, 2% aluminum, 1% silicon

INDUSTRY LITERATURE SURVEY

In order to learn what work might have been carried out relative to the effects of over temperaturing thermocouple material, a literature survey was made. Major producers of thermocouple materials and the National Bureau of Standards were contacted.

The consensus is that chromel-alumel thermocouples may be exposed intermittently up to approximately 2400°F and used continually up to approximately 2190°F.^(1,2) In a reducing atmosphere the emf is subject to change and therefore bare wire chromel-alumel thermocouples are not used in such atmospheres.⁽¹⁾

Little information was available relative to the effects of temperature on the performance of copper-constantan thermocouples. Exposing copper-constantan to 1500°F for up to 15 minutes would very likely have no detrimental effects on the thermoelectric output provided the conductors are adequately protected from oxidation.⁽³⁾

As noted, damage seems to relate to effects such as hydrogen absorption or oxidation. Such effects occur mainly with bare wire thermocouples. It would be safe to assume that insulation such as swaged magnesia oxide protecting thermocouple wires, would not permit such reaction, and exposure to temperatures higher than those listed would be permitted.

The literature survey revealed the fact that inhomogenities due to microstructure and/or chemical differences in the thermocouple material could affect thermocouple accuracy.⁽²⁾

EXPERIMENTS

To verify that properly protected thermocouples could be exposed to high temperatures encountered in fabrication and with the thought in mind of providing background information for reliability studies, several experiments were carried out. They were conducted using the more common types of thermocouple materials.

1. Effect of High-Temperature, Vacuum, Step-Brazing Procedures on Chromel-Alumel Thermocouples Experiment

One of the reactor components requires a step brazing process which involves securing chromel-alumel thermocouples by brazing followed by a lower temperature braze. The initial braze is accomplished at 2050°F and the second braze at 1950°F. Prior to making a simulated braze run, two .040 inch O.D. AISI 347 sheathed chromel-alumel full length thermocouples were calibrated in the following manner.

- a) carry out low temperature measurement in an ice bath at 32°F
- b) carry out elevated temperature measurement in boiling water at 212°F
- c) carry out precision resistance measurement leg-to-leg for total loop reading
- d) carry out precision resistance measurement for each leg to junction (chromel to ground, alumel to ground).

The two thermocouples were coiled into a 4" diameter coil, to be placed in furnace, and heated as follows:

- a) Place in a vacuum furnace, pump down to 1.0 micron or better, heat to 2150°F, hold 30 minutes at heat, cool to 1600°F, back fill vacuum furnace with argon, and cool to below 400°F. (The 2150°F temperature was used to provide added severity to the test.)
- b) Without removing parts from the furnace, reheat to 1950°F hold 30 minutes at heat and repeat the cooling cycle, cooling to room temperature.

The two thermocouples were then calibrated in the same manner as prior to the heating cycle. As reported by WANL Experimental Engineering, no calibration changes were noted.

2. Effect of Localized Temperatures on Instrumentation in Seal Blocks

That component which probably requires the most careful scrutiny because of any localized heat effect is the instrumentation support seal block. This part requires a pressure tight joint wherein the instrumentation (thermocouples or pressure probe tubes) pass through a block made of AISI 304 material. To braze the stainless steel thermocouple sheath or pressure tube to the block it is necessary to gold plate the instrumentation (method of brazing, etc., as reported in TME-624). Brazing heat is applied by an induction coil while the brazement is protected in an argon atmosphere.

- a) To determine what effect this brazing process might have on instrumentation, a number of thermocouple sections approximately 12 inches long, were calibrated and subjected to the brazing cycle temperature and over temperature.

The sections tested were six (6) unplated .040 inch O.D. copper-constantan and five (5) gold plated .062 inch O.D. copper-constantan pieces. Prebrazing calibration consisted of checking for an extraneous emf induced by inhomogeneities present in the wires and/or dissimilarities with well annealed wires. This test was performed by joining the copper leg with an .010 inch diameter copper thermocouple conductor from an unsheathed thermocouple and recording the output resulting from the copper-copper junction in liquid nitrogen as measured on a Leeds and Northrup potentiometer. (Ideally no output will be seen unless the thermocouple conductor is inhomogeneous or dissimilar.) The constantan leg of each test thermocouple was tested in exactly the same manner.

- b) The normal induction brazing process involves temperatures of 1325-1350°F in argon for approximately 10-15 minutes. To simulate this cycle several of the 12 inch unplated lengths were placed through holes into a seal block (without brazing alloy) and heated to 1400°F, holding approximately 12 minutes at heat. Although the 1400°F is higher than the temperature normally used,

this maximum acceptable temperature was selected. To simulate reheating due to possible rebrazing in production, the parts were cycled three times to this temperature, cooling to 400°F after the first and second heating, and to room temperature after the third heating.

A second group of plated 6 inch lengths was similarly placed into a seal block and heated to 1525°F, held approximately 1 minute and allowed to cool. This cycle would simulate an inadvertent over heating during a production braze.

Subsequent to these heating cycles all samples were re-calibrated with results as shown in Table I. Data shown in this table were developed in the WANL Experimental Engineering Laboratory and were reported in letter EE-1561 (dated December 23, 1963).

3. Microstructure Examination of Exposed Instrumentation

Because homogeneity of thermocouple wire structure is essential to proper thermocouple functioning, a microstructural examination was made. This experiment called for a comparison of brazed and unbrazed instrumentation thermocouple wires.

Pieces used for comparison were taken from a seal block which had been subjected to the brazing cycle heat of 1350°F for 6-10 minutes. These parts consisted of both .042 and .062 inch O.D. copper-constantan and chromel-alumel thermocouples. In each case a transverse section for metallographic examination in areas where high temperature would be encountered (e.g., under the braze fillet and 3/4 inch away from the fillet) was prepared. As a control, a section 1-1/2" away from the braze was examined and compared with pieces of unbrazed .062 inch O.D. copper-constantan and chromel-alumel thermocouples.

No microstructural differences between brazed and unbrazed specimens were noted, and likewise, no evidences of recrystallization were noticed as a result of the 1350°F to

TABLE I

Thermocouple Number	Temperature Calibration Made Before Braze Cycle			Measured Extraneous EMF Produced When a Temperature Gradient of 400°F was Present Along the Sheath (in micro-volts)				Calibration in Liquid N ₂ (320°F) After Brazing: with 400°F & 820°F Temperature Gradient Along Sheath	
				Before Braze		After Braze			
	32°F	-108°F	-320°F	Copper	Constantan	Copper	Constantan	400°F	820°F
1	32°F	-109°F	-322°F	20	8	23	5	-319°F	-321°F
2	32°F	-110°F	-322°F	24	9	22	12	-320°F	-320°F
3	32°F	-109°F	-322°F	20	5	20	2	-320°F	-319°F
4	32°F	-109°F	-322°F	20	5	21	0	-320°F	-320°F
5	32°F	-109°F	-322°F	26	14	26	10	-318°F	-316°F
6	32°F	-109°F	-322°F	28	10	26	0	-320°F	-322°F
7				not tested	not tested	15	15	-318°F	not tested
8				" "	" "	19	19	-318°F	" "
9				" "	" "	20	0	-318°F	" "
10				" "	" "	14	10	-318°F	" "
11				" "	" "	15	25	-317°F	" "

which exposed. These findings are in agreement with metallurgical characteristics of the material which would predict that no change would take place inasmuch as normal thermocouple fabrication includes several high temperature intermediate anneals of the stainless sheathing during swaging operations. Annealing of stainless is normally carried out in the range of 1950-2050°F, far exceeding the 1350°F braze temperature.

CONCLUSIONS

1. Exposing sheathed copper-constantan and chromel-alumel thermocouples to localized temperatures up to 1350°F does not change the microstructure and/or the homogeneity of the material.
2. Subjecting sheathed copper-constantan and chromel-alumel thermocouples to three 1400°F (10-15 minute) cycles and one 1525°F (1 minute) cycle does not affect thermocouples emf output or function.
3. Results of experiments bear out the information developed in the literature survey. That is, exposing copper-constantan thermocouples to approximately 1500°F for minutes will have no detrimental effect on the thermoelectric output.
4. Exposing chromel-alumel thermocouples to 2150°F had no detrimental effect on the function of the thermocouple. The sheathing and magnesia oxide insulation would tend to add a margin of safety over bare thermocouple wire.

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