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FINAL REPORT - PT-105-514-A, INSTALLATION
OF THERMOCOUPLES IN PROCESS CHANNELS

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FINAL REPORT
PRODUCTION TEST 105-514-A
INSTALLATION OF THERMOCOUPLES IN PROCESS CHANNELS

INTRODUCTION

When this production test(1) was written the piles were operating under a graphite temperature limit of 410 C. Operation was controlled by as-read temperatures of the originally installed G thermocouples, by thermocouples installed on vertical safety rod thimbles, and by thermocouples in graphite cylinders installed in the C test holes. Since the thimble thermocouples were to be removed under the Ball 3X program, it was planned to install thermocouples in some of the process tube channels to help monitor the graphite temperatures.

As discussed in HW-23986(2), in order to ensure maximum production levels based on graphite temperatures, the proper temperature relationships between the channel thermocouples and the G and/or C test hole thermocouples were needed. The expected maximum allowable channel thermocouple temperature reading would be higher than the burnout temperature limit of the graphite in the pile. The reason being the difference in the heat flow paths as a result of removal of a process tube from the tube channel. The accuracy of the theoretical calculation for the temperature relationship between the channel thermocouples and the burnout temperature limit of the graphite in the undisturbed lattice was not high. This was due to the inherent errors in the calculation caused by differences in the assumed and actual thermocouple locations in the graphite lattice, method of attachment of thermocouples to the graphite, composition and size of the thermocouple wires, local heat generation or neutron flux in the graphite, graphite conductivity, size of the gas gaps and heat flow paths.

In view of the above considerations, the production test to determine the proper temperature relationship between the channel thermocouples and the graphite burnout temperature limit was authorized.

SUMMARY

Two channel thermocouple assemblies were installed in tube channels 2166 and 2182 at D Pile on December 4, 1952, along with a new C hole thermocouple stringer. The tempera-

- (1) HW-24195, "PT-105-514-A, Installation of Thermocouples in Process Channels", H. H. Greenfield, 7-7-52.
- (2) HW-23986, "Preliminary Report on Use of Process Tube Channel Thermocouples For Monitoring Graphite Temperatures", H. H. Greenfield, 4-2-52.

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ture relationships between channel thermocouples and C hole thermocouples were determined. These were in agreement with the expected results reported in Reference 2. The channel thermocouple readings over the temperature range of 300 to 450 C were found to be from 8 to 10% higher than the temperature in the filler block of a normal adjacent lattice, and 3 to 5% higher than the temperature of the filler block in the same lattice.

Wire size was determined to have no effect on thermocouple readings when the thermocouple wires and hot junction are in a radiation field as long as the hot junctions of the couples are in good contact with the graphite. The iron-constantan thermocouples read from 6 to 50 C higher than the chromel-alumel thermocouples in 12 of the 14 thermocouple locations in the stringers and C hole. These comparisons were generally in agreement with those obtained in the permanent channel stringers at B Pile.⁽³⁾ However, the comparisons were not as good as those found at DR Pile,⁽⁴⁾ or at C Pile between iron-constantan and chromel-alumel thermocouples. A comparison of the readings between the thermocouples of different wire composition during equilibrium, shutdown and startup operation are summarized in Table 1.

The type of channel thermocouple stringers used in the production test were found to be desirable and were recommended for use as the prototype for the Project CG-502, "Permanent Channel Thermocouples Installation at the B,D,F and DR Piles".

DISCUSSION

Objective of Test

The purpose of the production test was to obtain data to establish the maximum allowable temperature readings for use with the permanent channel thermocouples at the B, D and F Piles. Additional information and data to be obtained were as follows:

1. The effect of the temperature readings caused by irradiation of the thermocouple wires which are of different composition and size.
2. Stability of the different wire composition and sizes under irradiation.
3. An evaluation of the desirability of this type of installation which was proposed for monitoring graphite temperatures after the vertical thimbles were removed.
4. Relative front to rear graphite temperature distributions.
5. Relative front to rear lattice conductance distributions.

Details of Test

The test authorized the installation of channel thermocouple assemblies into two central zone tube channels. It also provided for the removal and replacement of the old C test hole thermocouple stringer.

Two channel thermocouple stringers were charged into tube channels 2166 and 2182 at D Pile on December 4, 1952. Each of these stringers contained fourteen thermocouples, six 26 gage iron-constantan, six 24 gage chromel-alumel and two 30 gage chromel-alumel thermocouples. There were five thermocouple stations in the tube channels. The loca-

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- (3) HW-27175, "Technical Activities Report - Heat Transfer Studies - February, 1953", M. W. Carbon, 3-10-53.
 - (4) HW-38542, "Final Report, PT-105-514-A, Supplement A, Installation of Thermocouples in Process Channels at DR Pile", H. H. Greenfield, 8-8-55.

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tions were ten and five feet upstream of the centerline of the pile, on the centerline of the C hole (18-7/8 inches downstream of the centerline of the pile), and five and ten feet downstream of the centerline of the pile. Four of the stations had two thermocouples each consisting of one iron-constantan and one 24 gage chromel-alumel thermocouple spaced one inch apart in graphite cylinders. Six thermocouples were located opposite the C hole. Three of these thermocouples were about one inch apart and were composed of 26 gage iron-constantan, 24 and 30 gage chromel-alumel wires. The other three thermocouples were of the same gage size and composition as the above but had a common hot junction.

The old C test hole stringer was removed on the October 30 and December 4, 1952 shutdowns. The new stringer was charged on the December 4 shutdown, and had twelve thermocouples in four locations. These locations were such that sets of thermocouples in the C hole were in the same lattice and one lattice unit away from the corresponding sets in the tube channel stringers 2166 and 2182. Each set consisted of three thermocouples composed of one 26 gage iron-constantan, one 24, and one 30 gage chromel-alumel wires. The thermocouple hot junctions were one inch apart at each location.

RESULTS OF TEST

Comparison of Channel and C Hole Thermocouple Readings During Equilibrium Operation

The readings from the chromel-alumel channel thermocouples located opposite the C hole were compared with those obtained from the C hole chromel-alumel thermocouples. The results showed that the readings of the channel thermocouples over the temperature range of 350 - 450 C were about 8 to 10% higher than the readings from thermocouples located in the filler block of a normal adjacent lattice, and from 3 to 5% higher than the readings from thermocouples located in the same lattice filler block. These results were in good agreement with the theoretical calculations reported in Reference 1.

Comparison of Iron-Constantan and Chromel-Alumel Thermocouple Readings

1. During Equilibrium Operation

Good agreement in the readings from the 24 and 30 gage chromel-alumel thermocouples at the same channel locations were obtained. It was concluded that the thermocouple wire size does not affect the thermocouple readings in the pile.

Large differences in the temperature readings were obtained between the iron-constantan and chromel-alumel thermocouples for the same channel location. This was also true for the common hot junction thermocouples. During the operating period from December 6, 1952 to January 30, 1953, the iron-constantan couples read 6 to 50 C higher than the chromel-alumel couples at all locations in the two channel stringers except at two locations in which the chromel-alumel readings were about 30 C and 10 C higher. The respective locations were in tube 2166 - 5 feet upstream and 10 feet downstream of the centerline. The relative readings between the iron-constantan and chromel-alumel thermocouples in tube 2166 at the location five feet upstream of the tube centerline, reversed themselves on December 21, 1952. The chromel-alumel thermocouple in the same position in tube 2182 failed on or about December 16, 1952. The relative readings of the iron-constantan and chromel-alumel thermocouples at the most downstream position in both channels reversed themselves on December 18, 1952. However, the readings reversed again in both channels after January 14, 1953. The temperature comparisons between the two types of thermocouples material obtained at D Pile were in good agreement with

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those obtained at B Pile.⁽³⁾ Differences of 30 - 40 C were obtained at each of the 5 locations in each of the seven stringers. The comparisons were not as good as those obtained at DR Pile⁽⁴⁾ or C Pile where differences in the readings of iron-constantan and chromel-alumel were about 10 C.

Good agreement between the couple readings were obtained for three of the four C hole couple locations. At one location in the C hole, the iron-constantan couple read about 40 C higher than the chromel-alumel couple.

2. Thermocouple Shutdown Readings

During the January 8 and 30 pile shutdowns, temperature readings of all the thermocouples were taken at 5 minute intervals. In all locations where the iron-constantan thermocouples were reading higher during equilibrium, the readings declined faster than that of the corresponding chromel-alumel thermocouples until the temperatures were in the range of 175 to 270 C. From this temperature range on down, the iron-constantan and chromel-alumel thermocouple temperatures were about the same.

An interesting phenomena was noted during the reduction of the power level from 50 MW to zero power on the readings from iron-constantan thermocouples in the channel and C hole stringers. The readings were decreasing about 7 C per 5 minute interval prior to and after the reduction of the power level to zero. However, during the time which the reactor power level was reduced from 50 MW to zero (almost instantaneously) the iron-constantan readings dropped about 27 C in a five minute period. On subsequent in-pile testing at D Pile it was found that the flux induced an emf in the constantan wire of the iron-constantan thermocouples which could explain the higher readings obtained from these type thermocouples when used in radiation fields.

3. Thermocouple Start-up Readings

Temperature readings from all the couples were taken on the February 1, 1953, startup. The readings were taken at five minute intervals for five hours until pile turn-around was reached. Most of the temperatures were near equilibrium at this time. The temperature comparisons between the iron-constantan and chromel-alumel couples located together were very different during start-up than the temperature comparisons taken during shutdown. Table 1 shows the comparison of the couple readings at equilibrium during pile operation and at turn-around. The last column of the table is based on the assumption that the chromel-alumel couples were reading correctly. The comparison readings of the C hole couples are also shown in the Table.

The two channel stringers were turned over to Operations as part of the permanent channel thermocouple installation under Project CG-502 at the conclusion of the test.

CONCLUSIONS

The conclusions obtained from the production tests were the following:

1. The readings of the channel thermocouples over the temperature range of 350 to 450 C were about 8 to 10% higher than the readings from thermocouples located in the filler block of a normal adjacent lattice, and from 3 to 5% higher than the readings from thermocouples located in the same lattice filler block.

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2. The thermocouple wire size does not affect the thermocouple readings in the pile.
3. Iron-constantan thermocouple readings indicate higher graphite temperatures than do chromel-alumel thermocouples in the same locations.
4. The channel thermocouple stringers used in this production test were found to be desirable for use as prototypes for the Project CG-502, "Permanent Channel Thermocouple Installation at the B,D,F and DR Piles".
5. Sufficient data was provided for use by the pile engineers to obtain relative front to rear graphite temperature distributions and lattice conductance distributions.

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TABLE I

COUPLE LOCATION	AVERAGE TEMPERATURE DIFFERENCE BETWEEN IRON-CONSTANTAN AND CHROMEL-ALUMEL FROM 12-6-52 TO 1-29-53		APPARENT DISCREPANCY IN IRON-CONSTANTAN READINGS, °C
	Equilibrium Operation	Start-up Turn-Around	
Tube 2166 10 feet upstream* 5 feet upstream 1-1/2 feet downstream 5 feet downstream 10 feet downstream	Iron-Constantan 10 C higher Chromel-Alumel 30 C higher Iron-Constantan 46 C higher Iron-Constantan 46 C higher Chromel-Alumel 10 C higher	Chromel-Alumel 10 C higher Chromel-Alumel 48 C higher Iron-Constantan 6 C higher None Chromel-Alumel 38 C higher	20 C low 18 C low 40 C low 46 C low 28 C low
Tube 2182 10 feet upstream 5 feet Upstream** 1-1/2 feet downstream 5 feet downstream 10 feet downstream	Iron-Constantan 6 C higher Iron-Constantan 40 C higher Iron-Constantan 50 C higher Iron-Constantan 48 C higher Iron-Constantan 14 C higher	Chromel-Alumel 10 C higher ----- Iron-Constantan 10 C higher Iron-Constantan 10 C higher Chromel-Alumel 14 C higher	16 C low ----- 40 C low 38 C low 28 C low
C Hole Between 21-22, 83-84 Between 21-22, 82-83 Between 21-22, 65-66 Between 21-22, 64-65	None Iron-Constantan 34 C higher Chromel-Alumel 6 C higher Iron-Constantan 6 C higher	None Iron-Constantan 10 C higher None Iron-Constantan 14 C higher	None 24 C low 6 C high 8 C high

* Distances measured from pile centerline

** Chromel-Alumel thermocouple inoperative on December 16, 1952.

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