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FINAL REPORT

PRODUCTION TEST IP-285-C AND SUPPLEMENT A
MEASUREMENT OF OPERATING TEMPERATURES
OF UNCOOLED THERMAL SHIELD COOLING TUBE

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FINAL REPORT
PRODUCTION TEST IP-285-C AND SUPPLEMENT A
MEASUREMENT OF OPERATING TEMPERATURES OF
UNCOOLED THERMAL SHIELD COOLING TUBE

July 20, 1960

INTRODUCTION

The iron thermal shields of the Hanford reactors are cooled by means of water flow through thermal cooling tubes embedded in the shield blocks. The flow rate, temperature rise, and allowable pressure in the tubes and the conditions under which some of the tubes may be out of service are specified in the process standards. Shield heat formation and heat transfer calculations are necessarily based on broad assumptions and are therefore usually reliable only for order of magnitude and trend predictions. In order to specify condition of shield cooling under which the reactors may be safely and economically operated data must be available regarding shield operating temperature as related to the flow of cooling water through the shield.

Some of the data on which the current standards are based have been determined by extrapolation to present conditions of measurements taken several years ago. The purpose of this test was to establish current data that may be used in updating the thermal shield coolant standards.

Measurements were taken of the operating temperatures experienced in an uncooled thermal shield cooling tube in relation to the specific power of the adjacent process tube. Conditions were varied by adjusting the flow in the thermal shield cooling tube next to the uncooled one.

SUMMARY

At the highest fringe tube power levels experienced (approximately 580 kw) the maximum

temperatures reached in the uncooled tube were 243°C with normal flow conditions in the adjacent thermal shield cooling tubes, and 285°C with no flow in one adjacent tube and normal flow in the other adjacent one. (Changes in other variables such as inlet water temperature and pile gas composition will cause small variations in thermal shield temperatures.) Although these temperatures would probably cause excessive deterioration rates in an adjacent uncooled biological shield, they are below the melting point of lead (327°C); therefore operation under these conditions - up to two adjacent uncooled thermal shield cooling tubes - should not significantly damage the thermal shield structure under present operating conditions.

It was also determined that at present equilibrium conditions fairly large variations in fringe tube power will cause relatively small changes in temperature in an uncooled thermal shield cooling tube (about 20°C resulted from variations of 125 kw.)

Some additional temperature and flow data which were taken for various conditions of shield cooling are included in the discussion section of this report.

DISCUSSION

Temperatures In Uncooled Tube

Recently the thermal shield cooling tube B70* in the H-reactor became plugged and was removed from service for maintenance work. This tube is located near the vertical centerline of the reactor and is therefore in a good location for use in making shield temperature measurements. After the stoppage was removed, a thermocouple stringer was installed in the tube arranged so as to provide temperature measurements at five points along the tube axis. The temperatures taken with this first TC stringer and the related pile data are recorded in Table 4. Note that the highest temperature recorded in the uncooled tube was 243°C. This was for adjacent process tube powers up to 553 kw. (Other variables such as the inlet water temperature and the helium concentration in the reactor gas will cause variations in the thermal shield temperatures; however these effects are relatively small.)

Under supplement-A to the PT the first TC stringer was replaced with a second similar one. In addition the following equipment was installed:

1. The front pigtail of tube B71 was replaced with a 3/8" Potter flowmeter connected with 3/8" copper tubing and a 3/8" valve.
2. The front pigtail of tube T72 was replaced with a 3/4" Potter flowmeter connected with 3/4" copper tubing and a 3/4" valve.
3. Strap-on thermocouples were placed on the rear pigtails of tubes B69, B71, B76, FS24 and T72.

Temperatures in the uncooled tube and related pile data were again taken and are recorded in Table 5. (This time the flow in tube B71 was restricted by the flowmeter installation to a maximum of 2.7 gpm.) Under these conditions the maximum temperatures recorded in the uncooled tube was 257°C with adjacent fringe tube powers up to 580 kw.

*In this discussion the thermal shield cooling tubes are designated as follows:

B bottom shield section
T top " "
FS farside " "

Number indicates the process tube row or column in line with the tube

Thus tube B70 refers to the bottom thermal shield cooling tube opposite process tube column #70.

Figure 1 shows the maximum temperatures measured in the uncooled tube - B70 plotted against the specific power for process tube O170. The helium percentages are also shown as evidence that there may be some slight correlation between lower He concentration and higher thermal shield temperatures. (Some correlation between higher inlet water temperatures and higher thermal shield temperatures can also be seen by comparing the points on Figure 1 with the inlet temperature data in Table 5.) From this chart it is seen that rather large changes in fringe tube powers have a relatively small effect on the temperature of the uncooled tube.

Temperature vs Flow Measurements

In the two tubes equipped with flowmeters flows were varied within the range of the flowmeters, and the outlet temperatures of the tubes were observed. The results of this test are shown in Figure 2.

In another test the total flow to the thermal loop was varied and the effect noted for:

1. T72 tube flow
2. B71 tube flow
3. Outlet temps. of tubes B69, B71, B76, FS24 and T72
4. Thermal loop bulk outlet temperature

The results of this test are plotted on Figure 3.

Temperatures In Uncooled Tube With Partial Flow In Adjacent Tube

A series of flow settings were made to tube B71 and each time after the system reached equilibrium temperature readings were taken from the thermocouples in the uncooled tube. Although these temperatures will change somewhat with changing pile conditions, the values shown in Table 1 are representative of this temperature vs flow effect.

Table 2 shows representative outlet temperatures for the tubes equipped with strap-on thermocouples. B76 is a bottom tube with normal flow. B69 and B71 are tubes carrying somewhat different flows and located adjacent to the uncooled tube B70. FS24 and T72 show the lower temperatures resulting from fringe poison protection in these locations.

Temperatures In Uncooled Tube Adjacent To Another Uncooled Tube

By stopping completely the flow in tube B71 the condition of two adjacent uncooled tubes was established. Periodic temperature measurements were then taken from the thermocouples in tube B70 until the system reached equilibrium. These data are recorded in Table 3. The maximum temperature reached under these circumstances was 285°C. Extended operation in this manner would probably cause excessive deterioration in an adjacent uncooled biological shield. However this temperature is well below the melting point of lead (327°C). Therefore operation with two adjacent thermal shield cooling tubes without flow should not damage the thermal shield structure under present conditions of fringe tube powers and reactor gas composition.

Application of Results to Other Shield Sections

Comparing other reactor shield sections with the H reactor bottom thermal shield for similar operating and flow conditions, it would appear that:

1. All reactor side thermal shields and the B, D, DR and F bottom thermal shields would have slightly lower temperatures. Therefore, the results reported here can be applied conservatively in these cases.

2. All reactor top shields, the C reactor bottom thermal shield, and possibly the KE and KW bottom thermal shields would have somewhat higher temperatures. For these cases the results of this test can be used only as a rough guide; further tests are needed to establish more accurate data.

The results obtained here are not directly applicable to other shield sections at the H reactor or at other reactors because of differences in shield construction. Some of the variables for other shield sections as compared to the H reactor bottom shield are:

1. Bottom Shield Sections

The bottom reflectors at B, D, F, DR, KE and KW are thicker. C, KE and KW bottom shields contain ball channel penetrations.

2. Top Shield Sections

Top shields have VSR penetrations; they do not have instrument riser penetrations. Air gaps are included in the C, DR, H, KE and KW top shields. The DR top reflector is slightly thinner. The B, D, F, KE and KW top reflectors are somewhat thicker. The top thermal shields are thinner.

3. Side Shield Sections

All side reflectors are thicker. All side shields contain air gaps. They do not have instrument riser penetrations; they do have HCR or test hole penetrations. The B, C, D, DR, F and H side shields are thinner.

W. Smalley

Operational Physics Sub-Section
Research and Engineering Section

WL Smalley:gs

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Figure - 1
Uncooled Thermal Shield Cooling Tube
Maximum Temperature Vs.
Corresponding Adjacent Fringe Tube Powers H-Ref.

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Figure - 2
Outlet Temperature Vs. Flow
For Two Thermal Shield Cooling Tubes
H-Reactor

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Figure - 3

Some Effects Noted as Result of Varying
The Flow to the He-Resistor Th. and Lines

TABLE I

REPRESENTATIVE TEMPERATURES
FOR AN UNCOOLED THERMAL SHIELD COOLING TUBE
WITH VARIOUS FLOW SETTINGS IN AN ADJACENT TUBE
(NORMAL FLOW IN THE OTHER ADJACENT TUBE)

<u>Flow Settings</u> <u>Gal/Min</u> (Bottom tube #71)	<u>Thermocouples</u> (Uncooled Bottom Tube #70)				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Off	116	235	283	259	153
0.5	112	217	248	228	138
1.0	108	208	240	221	135
1.5	104	204	237	217	134
2.0	102	203	235	215	133
2.7	101	202	234	214	132
Normal*	101	201	233	213	132

* Normal flow estimated at 4.5 gpm

Thermocouple Locations

- #1 - 10' downstream from reactor center
- #2 - 5' downstream from reactor center
- #3 - reactor center
- #4 - 5' upstream from reactor center
- #5 - 10' upstream from reactor center

Reactor Data

Pile power - 1856 MW
Power, tube 0170 - 565Kw
Inlet temp. - 7.3°C
He con. - 72%

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TABLE 2

REPRESENTATIVE OUTLET TEMPERATURES
FOR THERMAL SHIELD COOLING TUBES

<u>Thermal Shield Cooling Tube</u>	<u>Outlet Temp.*</u>		<u>Flow Conditions</u>
	<u>Case 1.</u>	<u>Case 2</u>	
Bottom 69	34	45	Normal flow and next to uncooled tube
Bottom 71	46	60	2.7 gpm flow and next to uncooled tube
Bottom 76	29	42	Normal flow
Far 24	22	30	Normal flow
Top 72	14	22	Normal flow

	<u>Case 1</u>	<u>Case 2</u>
* Pile power	1855 MW	1725 MW
Inlet temp.	6.8° C	16.7° C
He con.	72%	64%

TABLE 3TEMPERATURES IN UNCOOLED THERMAL SHIELD COOLING TUBE
AFTER WATER SHUT-OFF IN ADJACENT TUBE

<u>Time</u>	<u>Thermocouples</u> <u>(Uncooled Bottom Tube #70)</u>				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
8:00 AM	104°C	201°C	235°C	214°C	135°C
8:30	105	203	240	217	137
9:00	109	210	250	225	142
9:30	112	212	255	233	146
10:00	113	216	262	235	146
10:40	114	218	264	240	149
11:00	115	221	269	244	150
11:30	115	224	273	245	150
12:00	115	226	272	250	154
12:30	119	228	280	254	155
1:00	119	230	280	255	155
1:30	119	230	282	255	155
2:00	120	234	283	256	156
2:30	120	233	285	256	156
3:00	120	236	283	259	156
3:30	120	236	285	260	155

Thermocouple Locations

- #1 - 10' downstream of tube center
- #2 - 5' downstream of tube center
- #3 - center of tube
- #4 - 5' upstream of tube center
- #5 - 10' upstream of tube center

Reactor Data

Pile power - 1845 MW
Power, tube 0170 - 616 Kw
Inlet temp. - 11.6°C
He con. - 68%

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TABLE 4

Shield Temperature Study Data Taken At H-Reactor

Date	Reactor Power-MW	Helium %	Loop Outlet °C	Loop Outlet °C	Loop Flow GPM	OL70 Power kW	T.C. 2-S - °C	#1 Stringer TC's				
								C-10'	C-5'	C	C + 5'	C + 10'
11-6-59	1000	37	13.0	15.7	745	382	--	70	120	147	117	53
11-7-59	1385	40	12.8	18.5	1246	453	72	114	174	200	163	74
11-8-59	1520	43	12.5	19.6	1228	485	84	138	211	225	185	91
11-9-59	1630	43	12.4	19.1	1367	472	84	134	209	231	195	100
11-10-59	1650	45	12.5	19.2	1349	485	82	130	195	229	193	102
11-11-59	1645	46	12.5	19.5	1349	490	85	135	208	236	186	106
11-12-59	1655	45	12.3	19.3	1367	518	89	140	220	241	167	105
11-13-59	1675	49	11.2	18.3	1367	508	87	145	223	243	180	107
11-14-59	1680	48	11.2	18.3	1354	470	86	137	215	238	165	105
11-15-59	1690	51	10.0	17.8	1349	513	83	140	208	233	154	99
11-16-59	1690	51	9.8	16.9	1349	456	83	133	208	228	159	94
11-17-59	1700	52	9.5	17.1	1280	458	84	145	222	238	176	101
11-18-59	1700	53	9.4	17.0	1280	504	86	131	216	233	172	97
11-19-59	1715	53	10.0	17.0	1280	536	84	135	217	238	177	101
11-20-59	1720	54	10.8	18.1	1315	470	85	128	217	236	177	87
11-23-59	1725	56	11.5	18.2	1367	538	86	127	220	236	181	96
11-24-59	1730	57	11.5	18.8	1315	520	86	105	194	212	168	77
11-25-59	1735	58	10.7	18.0	1298	546	83	118	211	229	187	94
11-26-59	1735	58	10.5	18.0	1228	553	87	130	224	235	186	95

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TABLE 5

Shield Temperature Study Data Taken At H-Reactor

Date	Reactor Power - Mw	Helium g	Loop Inlet - °C	Loop Outlet °C	Loop Flow - gpm	OL70 Power - kw	TC 2-S - °C	C-10'	#2 Stringer TC's				Strap-on TC's				
									C-5'	C	C + 5'	C + 10'	B-69	B-71	B-76	T-72	FS-24
4-12-60	1855	72	6.8	15.3	1280	559	65	131	213	228	193	95	34	46	29	22	14
4-13-60	1855	73	6.8	15.8	1211	565	54	128	209	230	199	99	29	43	24	20	--
4-15-60	1860	72	7.2	16.0	1246	558	67	132	215	231	198	101	29	33	23	18	--
4-16-60	1860	72	7.2	15.5	1280	549	68	143	225	237	198	100	28	42	24	19	--
4-17-60	1860	72	7.5	16.3	1246	577	69	138	221	236	200	100	30	46	26	21	--
4-22-60	1815	71	8.6	17.4	1159	480	64	117	195	218	192	98	27	37	20	17	--
4-27-60	1840	71	9.4	17.6	1228	508	63	126	201	225	197	98	26	38	21	18	--
4-29-60	1850	67	10.4	--	1246	560	66	131	210	232	200	100	28	42	24	21	--
4-30-60	1850	67	10.7	19.4	1246	530	66	132	212	236	205	103	30	43	25	22	--
5-1-60	1850	68	11.2	19.6	1280	537	66	134	215	236	203	103	29	41	24	21	--
5-7-60	1835	69	11.5	19.6	1263	545	53	132	212	235	202	103	31	45	25	23	--
5-8-60	1830	69	11.3	19.0	1298	544	67	134	214	236	204	102	30	44	24	22	--
5-9-60	1830	68	12.0	20.8	1176	534	53	135	215	238	206	107	35	50	29	25	--
5-10-60	1825	69	12.5	21.3	1176	534	68	134	212	236	201	104	35	50	30	25	--
5-14-60	1735	62	11.7	19.2	1246	481	66	150	231	243	196	97	26	38	24	19	--
5-15-60	1800	61	11.5	20.2	1159	561	65	135	219	247	214	106	34	50	33	24	15.4
5-18-60	1840	67	10.2	19.6	1159	538	67	135	217	240	207	105	31	44	29	21	--
5-22-60	1840	67	11.0	20.4	1125	563	67	139	220	248	214	110	34	49	30	23	--
6-11-60	1765	64	13.8	23.0	1176	568	65	134	217	245	215	113	42	54	36	28	19.8
6-12-60	1765	64	13.8	22.8	1176	580	68	140	224	249	215	110	43	54	37	29	20
6-15-60	1765	63	13.6	22.6	1176	579	68	142	226	250	216	114	39	51	31	25	--
6-16-60	1765	63	14.2	23.1	1159	576	68	142	225	249	215	113	37	53	31	24	--
6-20-60	1600	54	13.8	21.5	1138	532	58	126	208	235	202	105	41	52	35	28	17
6-21-60	1750	57	14.5	23.8	1090	582	72	146	228	257	220	117	45	54	38	30	20

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