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UNITED STATES ATOMIC ENERGY COMMISSION

HRT SPACE COOLER HEAT LOAD

By
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October 5, 1955

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HRT Space Cooler Heat Load

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Work performed under Contract No. W-7405-Eng-26

OAK RIDGE NATIONAL LABORATORY

Operated By

UNION CARBIDE NUCLEAR COMPANY

POST OFFICE BOX P

OAK RIDGE, TENNESSEE

The total heat load within the reactor cell is divided into five sources as follows:

1. Equipment and Piping
 - A. H. P.
 - B. L. P.
2. Cell Walls and Structures
3. Blast Shield
4. Thermal Shield
5. Pipe Flanges

1. Equipment and Piping

Heat losses by radiation and convection are as follows:

High pressure system

Ambient cell temperature = 150°F

Piping and equipment temperature = 600°F $\Delta T = 450^\circ\text{F}$

$$(1) \quad h_r = \frac{0.173 \epsilon \left[\left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right]}{T_1 - T_2}$$

$$(2) \quad h_c = 0.4 \left(\frac{\Delta T}{d_o} \right)^{0.25}$$

$$T_1 = 1060^\circ\text{R}$$

$$T_2 = 610^\circ\text{R}$$

$$h_r = \frac{0.173 \epsilon \left[(10.6)^4 - (6.10)^4 \right]}{450} = 4.32 \text{ E Btu/hr ft}^2 \text{ } ^\circ\text{F}$$

Assume d_o for 3-1/2" pipe (average for system) .°. $d_o = 4"$

$$h_c = 0.4 \left[\frac{450}{4.0} \right]^{0.25} = 1.30 \text{ Btu/hr ft}^2 \text{ } ^\circ\text{F}$$

$$h_c + h_r \text{ (for } \epsilon = 1) = 5.62 \text{ Btu/hr ft}^2 \text{ }^\circ\text{F}$$

If we assume ϵ to be 0.8 (which is high for stainless steel)

we have $h_c + h_r = 4.74 \text{ Btu/hr ft}^2 \text{ }^\circ\text{F}$ for bare pipe

Low Pressure System

$$\text{Ambient cell temperature} = 150^\circ\text{F}$$

$$\text{Piping and equipment temperature} = 220^\circ\text{F} \quad \Delta T = 70^\circ\text{F}$$

$$T_1 = 680^\circ\text{R}$$

$$T_2 = 610^\circ\text{R}$$

$$h_r = \frac{0.173 \epsilon [(6.8)^4 - (6.10)^4]}{70} = 1.86 \epsilon \text{ Btu/hr ft}^2 \text{ }^\circ\text{F}$$

$$h_c = 0.4 \left[\frac{70}{4.0} \right]^{0.25} = 0.816 \text{ Btu/hr ft}^2 \text{ }^\circ\text{F}$$

$$h_c + h_r \text{ (for } \epsilon = 1) = 2.68 \text{ Btu/hr ft}^2 \text{ }^\circ\text{F}$$

$$\text{For } \epsilon = 0.8 \quad h_c + h_r = 2.3 \text{ Btu/hr ft}^2 \text{ }^\circ\text{F}$$

These coefficients are slightly higher than those given in Table 11, page 402 of Marks (4th Ed.) however, we wish to be on the conservative side.

Using 4.7 and 2.3 as our coefficients we have the following heat losses based on using an insulation having an efficiency of 90 % (HRT aluminum foil insulation has an efficiency of ~ 94 %) ⁽³⁾

Heat Loss/ft² of Surface for 90 % Efficiency Insulation

	$450^\circ\text{F } \Delta T$		$70^\circ\text{F } \Delta T$	
	BtuH	Kw	BtuH	Kw
1" to 6" pipe	212	.062	16.1	.0047
Equipment and larger pipe	186	.055	13	.0038

On this basis the heat losses of the piping and equipment as reported in CF 55-1-93 ⁽⁴⁾ would be:

	<u>H. P. System</u>	<u>L. P. System</u>
Total	<u>34 Kw</u>	<u>3.5 Kw</u>

2. Cell Walls and Structures

Heat generation in the cell walls and structures from fission product gammas and delayed neutrons will be 76 Kw⁽⁵⁾.

3. Blast Shield

Assuming a radiation coefficient of 1 Btu/hr ft² °F, a cell temperature of 120°F and a shield temperature of 180°F we obtain a radiation heat loss of ~ 3 Kw from the outside of the 77" O.D. blast shield. The major heat load is taken by the water cooling coils surrounding the blast shield.

4. Thermal Shield

On the basis of a multi-group calculation by P. N. Haubenreich the heat generated in the thermal shield due to neutrons and gammas from the reactor proper is as follows:

For D ₂ O blanket at 10 Mw operation	12.8 Kw
For Uranyl sulfate blanket operation	30 Kw

The thermal shield cooler has been designed to take a flow of 50 gpm⁽⁶⁾, not only to remove the heat load, but to prevent the formation of hot spots within the shield which is composed of a water and sand mixture having a boiling point of 180°F at 7-1/2 psia.

If we assume a radiation coefficient of 0.5 Btu/hr ft² °F, a cell temperature of 120°F, and a shield temperature of 180°F the total heat loss from all surfaces of the shield (~ 950 ft²) is ~ 475 Btu/min or 8.5 Kw.

5. Pipe Flanges

An attempt will be made to determine the heat losses to the cell with bare and also insulated flanges.

If we assume an average air velocity of 400 ft/min (this is much higher than expected) and use the curve shown in figure 4⁽⁷⁾ of The Piping Handbook we would expect an increase in heat loss at 450°F ΔT of $\sim 50\%$, and at 70° $\Delta T \sim 25\%$. On this basis our H.P. and L.P. system coefficients would be ~ 3180 Btu/hr ft² and 200 Btu/hr ft² respectively. H.P. = 0.933 Kw, L. P. = .059 Kw.

The following table indicates the size and approximate number of flanges in the L.P. and H.P. systems, the area of each flange and the bare flange heat losses in each system.

Flange Size(in)	No. in High Pressure System	No. in Low Pressure System	Area of Each Flange*	Bare Pipe Loss Kw	
				H.P.	L.P.
6		2	3.7		0.434
4	5	4	3.0	14.2	.72
3-1/2	14		2.7	34.6	
3		4	2.3		.53
2-1/2	1		1.7	1.63	
1		64	0.6		2.26
3/4		9	0.48		0.25
1/4 and 1/2	58		0.44	23.79	
Totals				74.22	4.19
Grand Total:				78.41 Kw	

$$* \text{ Area} = \pi DT + \frac{\pi D^2}{2}$$

where D = O.D.
T = Thickness
A = ft²

Summary (At 10 Mw core power)

1. Equipment and piping in cell	<u>Kw Load</u>
A. H.P.	34
B. L.P.	3.5
2. Cell Walls and Structure	76
3. Blast Shield	3
4. Thermal Shield (D ₂ O Blanket)	12.8
5. Pipe Flanges (bare)	
A. H. P.	74.2
B. L. P.	4.2
	<hr/>
Total	207.7 Kw

Assuming that we insulate the flanges with aluminum foil and have an efficiency of 90 o/o. The total heat losses are 137 Kw.

Using a uranyl sulfate blanket and bare flanges we have a load of 225 Kw. Insulated flanges reduce this load to 154 Kw.

The present design of the space coolers is based on the following conditions (8):

Inlet water	75°F
Outlet water	95°F
Inlet air	150°F
Outlet air	95°F
Water flow rate	17 gpm
Air flow rate	6500 cfm at 1/2 atmos.
	= 3250 cfm at STP

There are four units, each operating at a load of 170,000 Btu/hr, or a total capacity of 200 Kw.

* Based on 90°F inlet water and a flow rate of 25 gpm the ambient temperature would be 163°F as compared to 150°F. The motor capacity may have to be increased for this application.

If we increase the size of the unit to obtain the original 150°F ambient temperature and use 90°F water the surface area increases by 34 %. This increases the size of the units by 2" in width and 1" in height. A larger fan and diffuser may be required. The air flow would be 7100 cfm at 1/2 Atmos. (9.2 % increase) or 3550 cfm at STP.

It appears that the present unit using 90°F inlet water could be used if the flanges are insulated. The ambient temperature would be less than 163°F (proportional to the heat load).

* S. E. Beall recently requested that we attempt to use 90°F cooling water for the space coolers in order to eliminate the need for process water within the reactor cell. This plan would confine all cooling water in the reactor cell to the closed cooling tower loop and therefore no water break would be required in the process water cooling line coming from the X-10 site (line 503).

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