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Loop HN-1
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1.0 Summary

A mock-up of a proposed cooler for removing gamma heat from the ORR loop core walls was constructed and tested for heat transfer characteristics. This mock-up cooler consisted of 1/4" stainless steel tubing double (reverse) wrapped around an eight inch length of two inch stainless steel pipe and cast in an aluminum jacket. As compared with the 88 inch long double-wound cooling coil, the 44 inch single-wound coil appeared better for the particular application of removing gamma heat from the core walls. Extension of the data to 4000 watts of heat removal gave a heat transfer coefficient of 240 Btu/hr ft² °F for a water flow of 75 cc/min and an air flow of 3.6 scfm.

A similar core cooler was constructed and operated on in-pile development loop DV9. A report from D. B. Weaver to H. C. Savage on the results of tests performed with this cooler is included in the appendix of this report, section 8.6.

2.0 Introduction

Radiation heating from the reactor will result in increased temperature in the core wall of the ORR HN-1 loop. This increase in wall temperature will be sufficient to cause boiling of solution inside the core adjacent to the core wall unless the heat is removed by means of a core cooling device. Cooling of the core is discussed in more detail in a recent memorandum from R. A. Lorenz to H. C. Savage, which is included in the appendix of this report, section 8.5.

One of the most promising coolers consists of stainless steel tubing wrapped around the core and cast in an aluminum jacket. The coolant consists of a mixture of air and water. The use of air-water mixtures provides a satisfactory combination of film coefficient and heat removal capacity.

3.0 Description of Core Cooler Mock-up

The experimental cooler consisted of approximately $7\frac{1}{2}$ feet of $1/4$ " diameter x .035" wall stainless steel tubing double-wound around an eight inch length of 2" schedule 80 stainless steel pipe. The inlet and outlet were at the same end of the pipe, with the "middle" of the tubing exposed at the other end. A $3/8$ " thick aluminum jacket was then cast around the pipe and tubing. Figure 1 shows the construction details of the cooler.

Six thermocouples were equally spaced along the length of the aluminum jacket. One thermocouple was placed on the stainless steel pipe at the center of the cooler. Duplicate thermocouples were used at the "middle" and "out" locations on the $1/4$ " tubing.

An electric heater was placed inside the 2" pipe. The assembly was insulated except for the ends. Heat input was determined by measuring the heater voltage and amperage. Rotameters were used to measure the air and water flow rates.

4.0 Description of Tests

Two series of tests were run. One used the entire length of double-wound tubing, and the other used only half the tubing, the coolant entering at one end of the cooler and leaving at the other end. Each series of tests included air coolant alone at several different flow rates, and air-water mixtures at several different water flow rates with the air held constant at approximately 3.6 scfm. For each coolant setting the heater power was adjusted to maintain the stainless steel pipe at 280°C at the center of the core. Plant air supply and process water were used for the coolant.

5.0 Results

A summary of the data and calculations is given in Table I.

6.0 Discussion

Cooling by the use of air-water mixtures proved very effective. No operational difficulties were encountered with the air-water apparatus. However, fluctuations in line pressure of both air and water proved to be a minor nuisance. The use of pressure regulators in both air and water lines is essential for accurate control of the coolant.

Examination of the data shows that the 44" single-wound cooler removed as much heat as the 88" double-wound cooler. This is a result of the high heat transfer coefficient.

Tests performed at Y-12 with a similar core cooler on in-pile development loop DV-9 gave comparable results. A report from D. B. Weaver to H. C. Savage on the results of tests performed with this cooler is included in the appendix, section 8.6.

7.0 Recommendations for In-Pile Core Cooler

A reasonable operating condition for the in-pile core cooler will be the removal of 4000 watts of heat from the core walls and cooler jacket. The exact amount of heat to be removed will depend upon the desired core wall temperature and the observed jacket temperature during in-pile operation.

The following tabulation summarizes the recommended core cooler and the predicted operating conditions for 4000 watts of heat removal.

Construction: 44 inches of 1/4" x .035" wall stainless steel tubing wrapped around core and cast in 1/4" to 3/8" aluminum jacket, inlet at nose, exit at reducer end. Approximately 10 to 14 inches of this tubing should be on the core cap.

TABLE I

SUMMARY OF DATA:

CORE COOLER MOCK-UP

SINGLE-WOUND COOLER

(44.1 inches of 1/4" Stainless Steel Tubing)

Air flow, scfm	0	1.2	3.35	7.35	3.62	3.66	3.56	3.82	3.68
Air pressure, psig	0	5.2	27	74.5	33	35	35	40	41
Water flow, cc/min	0	0	0	0	10.3	21	39.2	40	50
Water pressure, psig	0	0	20	47	22	22	28	33	36
Stainless Steel pipe, °C	280	280	280	280	280	280	280	280	280
Air in	21	21	21	21	21	21	21	21	21
Air out	133	260	261	247	260	259	238	223	211
Heat Input, watts	180	375	630	1100	985	1490	2050	2740	3720
q (calculated), watts	0	176	494	1020	1032	1553	1916	2367	2768
Δt_m , °C	0	82.2	78.2	87.2	74.8	78.7	94.8	102.3	110.3
U (Al to Air), Btu/hr·ft ² ·°F	0	17	50	92	109	156	159.5	183	198.2

Temperature of Aluminum from "In" End to "Out" End, °C.

"IN" End	276	259	242	227	208	189	191	188	192
↓	277	264	250	236	226	205	206	202	203
	278	272	262	250	249	236	230	225	222
	278	277	273	265	270	268	262	251	245
	277	278	278	272	279	283	280	273	269
"OUT" End	273	276	277	273	280	287	284	280	277

DOUBLE (Reverse)-WOUND COOLER (88.2 inches of 1/4" Stainless Steel Tubing)

Air flow, scfm	0	1.18	3.8	7.5	3.86	4.04	4.32
Air pressure, psig	0	7.5	40	87	41	47	55
Water flow, cc/min	0	0	0	0	10.5	20.2	30.0
Stainless Steel pipe, °C	280	280	280	280	280	280	280
Air In	21	21	21	21	21	21	21
Air middle	208	258	261	253	264	268	271
Air out	188	248	247	244	230	221	221
Heat Input, watts	100	350	670	1175	990	1470	2080

TABLE I (Cont'd)

SUMMARY OF DATA: CORE COOLER MOCK-UP

Temperature of Aluminum from "In-Out" End to "Middle" End

"In-Out" End	280	261	243	232	211	194	193
↓	280	266	250	240	229	209	207
	280	272	262	252	251	238	231
	280	278	273	264	270	268	266
	278	268	277	268	277	281	284
"Middle" End	276	267	269	259	270	273	275

237
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Air flow = 3.6 scfm

Water flow = 75 cc/min. (demineralized water)

Pressure drop = 40 psi

q = 4000 watts = 13,670 Btu/hr

U = 240 Btu/hr ft² °F (aluminum to air-water)

A = 0.24 ft² outside area of tubing

Δt_m = 131°C = 236°F

t in, air-water = 21°C

t out = 210°C = 410°F

t , inside wall of core at all points = 280°C

t , outside wall of core at nose = 256°C

t , outside wall of core at reducer = 274°C

8.0 Appendix

8.1 Calculations:

Experimental Data - The heat transferred to the air-water coolant, q , was calculated from the flow rates and enthalpy changes of the air and water. This was considered to be better than using the electrical energy input because the heat losses from the system could not be measured.

The heat transfer coefficient, U , was calculated for the distance from the aluminum casting to the air-water mixture. The coefficient was based on the outside surface area of the 1/4" tubing.

The following typical calculations are for the single-wound cooler operating with 50 cc/min water flow and 3.68 scfm air flow.

Length of 1/4" x .035" wall tubing = 44.1 inches

Outside surface area of tubing = 0.24 ft²

$t_m = (277-211)-(192-21)/\ln(277-211)/(191-21) = 110^\circ\text{C} = 199^\circ\text{F}$

Heat removed by air:

$$c_p = 0.24 \text{ Btu/lb}^\circ\text{F}$$

$$\rho = .0808 \text{ lb/scf}$$

$$\text{flow} = 3.68 \text{ scfm}$$

$$\Delta t = (211-21)(1.8) = 342^\circ\text{F}$$

$$\text{air} = 3.68(.0808)(0.24)(342)(60) = 1465 \text{ Btu/hr}$$

Heat removal by water:

$$\text{flow} = 50 \text{ cc/min} = 6.61 \text{ lb/hr}$$

$$\text{enthalpy of water at } 21^\circ\text{C} = 38 \text{ Btu/lb}$$

$$\text{enthalpy of steam at } 211^\circ\text{C and 1 atm. pressure} = 1246 \text{ Btu/lb}$$

$$\text{water} = 6.61(1246-38) = 7985 \text{ Btu/hr} = 2340 \text{ watts}$$

$$\text{Total heat removed} = 1465 + 7985 = 9450 \text{ Btu/hr} = 2768 \text{ watts}$$

$$U = q / A \Delta t_m = 9450 / 0.24(199) = 198 \text{ Btu/hr ft}^2 ^\circ\text{F}$$

4000 Watt Cooler - By extension of the experimental data, a heat transfer coefficient, $U = 240$, was estimated. The following calculation uses the equation $hD = .023 k (Re)^{.8} (Pr)^{.4}$ to obtain a rough comparison.

$$t_{\text{air-water in}} = 21^\circ\text{C} = 70^\circ\text{F}$$

$$t_{\text{air-water out}} = 210^\circ\text{C} = 410^\circ\text{F}$$

$$\text{air flow} = 3.6 \text{ scfm} = 17.45 \text{ lb/hr}$$

$$\text{water rate} = 75 \text{ cc/min} = 9.92 \text{ lb/hr}$$

$$\text{Total heat removed} = 4000 \text{ watts} = 13650 \text{ Btu/hr}$$

$$\text{Avg. } c_p = 13650 / (17.45 + 9.92)(410-70) = 1.47 \text{ Btu/lb}^\circ\text{F}$$

$$K_{\text{air, } 21^\circ\text{C and } 210^\circ\text{C}} = .015 \text{ and } .023 \text{ Btu ft/hr ft}^2 ^\circ\text{F}$$

$$\text{avg. } K = .018 \text{ Btu ft/hb ft}^2 ^\circ\text{F}$$

$$\mu_{\text{air, } 21^\circ\text{C and } 210^\circ\text{C}} = .044 \text{ and } .0635 \text{ lb/ft hr}$$

$$\mu_{\text{steam, } 100^\circ\text{C and } 210^\circ\text{C}} = .0317 \text{ and } .0412 \text{ lb/ft hr}$$

$$\text{avg. } \mu = .0475 \text{ lb/ft hr}$$

$$D = .015 \text{ ft}$$

$$\text{cross sectional area} = .000177 \text{ ft}^2$$

$$G = (17.45 + 9.92)/.000177 = 1.545 \times 10^5 \text{ lb/hr ft}^2$$

$$\text{Avg. Re} = DG/\mu = .015 (1.545 \times 10^5)/.0475 = 4.88 \times 10^4$$

$$\text{Avg. Pr} = cp\mu/k = 1.47(.0475)/.018 = 3.88$$

$$\text{Avg. h} = .023(.018)(4.88 \times 10^4)^{.8}(3.88)^{.4}/.015 = 268$$

$$h_{\text{tube}} = 3500 \text{ Btu/hr ft}^2 \text{ } ^\circ\text{F}$$

$$U = (3500)(268)/(3500 + 268) = 249 \text{ Btu/hr ft}^2 \text{ } ^\circ\text{F}$$

8.5 Core Cooler for ORR Loop HN-1*

Gamma heating from reactor radiation will raise the core wall temperature and create thermal stress. The purpose of the core cooler is to control the temperature and the thermal stress in the wall. A perfect cooler design will include the following features:

- (1) Local heat transfer proportional to heat generation,
- (2) Overall heat removal controllable from the loop control panel,
- (3) Low thermal neutron cross-section, and
- (4) No danger of spreading activity in case of core rupture.

The core cooler may also be used to remove heat generated in the core after reactor scram in case of circulation failure. For example, ten seconds after reactor scram from 20 Mw operation, the gamma heating from the reactor would total about 1200 watts. Fission product decay within the core would amount to 150 watts. Radiation and air convection cooling of the core wall would be about 400 watts.

Several proposed cooler designs are as follows. The overall heat transfer of each of these coolers is controlled by changing the coolant flow rate. The inlet temperature could be changed in the case of pressurized water coolant.

- (1) Water coolant in small tubes with heat transfer area controlled by tack-welding tubes to core.

- (2) Air coolant blowing through annulus surrounding core. Local heat transfer controlled by annulus thickness or by fins.
- (3) Stainless steel tubes wrapped around core and cast in aluminum. Local heat transfer controlled by pitch of coils. Coolant either air, air-water mixtures, low pressure water, or high pressure water. D. T. Jones is having a mock-up of this cooler constructed for heat transfer tests.
- (4) Water coolant in jacket separated from core by a thermal insulation. Local heat transfer controlled by annulus thickness or by insulation thickness. The Chemical Technology group is constructing a mock-up of this type for heat transfer measurements.

The following calculation of the inside wall temperature shows the need of a core cooler for normal operation. Assuming no external cooling and the solution to be at 280°C flowing in an annulus, the heat transfer coefficient may be calculated from:

$$\left(\frac{hD_e}{k}\right) = .023 \left(\frac{D_e G}{\mu}\right)^{.8} \left(\frac{C_p \mu}{k}\right)^{.4}$$

where:

D_e	$= D_o - D_i = 1.939" - .905" = 1.034" = 0.0863 \text{ ft.}$
k	$= .332 \text{ Btu ft/hr-ft}^2\text{-}^\circ\text{F}$
μ	$= .24 \text{ lb/ft-hr}$
C_p	$= 1.24 \text{ Btu/lb-}^\circ\text{F}$
ρ	$= 46.7 \text{ lb/ft}^3$
Flow rate	$= 5.8 \text{ gpm} = 46.5 \text{ ft}^3\text{/hr}$
G	$= 135,800 \text{ lb/ft}^2\text{-hr}$
Re	$= 48,700$
Pr	$= 0.896$

then:

$$h = 456 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

Along the core shell at the knuckle radius of the core cap, the gamma heating at 20 Mw reactor operation is 3.5 watts/gram. This amounts to a heat flux of 49,200 Btu/hr-ft². Without external cooling the temperature drop through the solution at the knuckle radius of the core cap will be 49,200/456 = 108°F = 60°C. This is sufficiently above the solution temperature to cause boiling.

According to calculations by J. R. McWherter, a hot spot of 295°C may initiate boiling if the bulk solution temperature is 280°C and the loop is operating at 10 kw of fission power. The exact temperature at which a particular portion of solution will boil depends upon the total system pressure, the dissolved oxygen pressure, and the radiolytic gas pressure. The amount of radiolytic gas in a particular portion of solution is difficult to calculate accurately since it depends on the time, temperature, and radiation history of the solution.

The high velocity of solution near the center of the core cap will result in a heat transfer coefficient roughly double that at the knuckle radius if the coupon holder is located 3/8 inch from the core cap. This more than makes up for the higher gamma heat at the center.

Stresses in the pipe wall may be calculated from equations in Perry's Chemical Engineering Handbook, Section 18. For hoop stresses,

$$S = \frac{P}{R^2} \frac{(R_o^2 + R^2)}{(R_o^2 - 1)}$$

where P = 2000 psi
 $R_o = r_o/r_i = 1.1875/.9695 = 1.225$; $R_o^2 = 1.500$
 $R = r/r_i$

then $S_i = 2000(1.5 + 1)/(1.5 - 1) = 10,000$ psi
 $S_o = 2000(1.5 + 1.5)/1.5(1.5 - 1) = 8,000$ psi

Thermal stresses are:

$$S_i = \frac{\alpha E \Delta t}{2(1-m)} \left(\frac{2R_o^2}{R_o^2 - 1} - \frac{1}{\ln R_o} \right)$$

and

$$S_o = \frac{\alpha E \Delta t}{2(1-m)} \left(\frac{2}{R_o^2 - 1} - \frac{1}{\ln R_o} \right)$$

At 20 Mw reactor power the temperature drop through the core wall at the knuckle radius is 40.8°F if all of the gamma heat is removed from one side. Then for Sch. 80 stainless steel pipe $\alpha = 10.1 \times 10^{-6}/^\circ\text{F}$ at 280°C, $m = 0.3$, and $E = 28 \times 10^6$ psi.

From the above equations the thermal stress at the inside wall will be 8820 psi compression if the wall is externally cooled. Thermal stress at the outside wall will be 7660 psi tension.

Total stress at the inside wall will be $10,000 - 8820 = 1180$ psi tension. At the outside wall the total stress will be $8000 + 7660 = 15,660$ psi tension. During 30 Mw reactor operation the thermal stresses will increase proportionately. Total S_i will be 3230 psi compression. Total S_o will be 19,490 psi tension at the knuckle radius.

If all the heat generated in the core wall flows into the core, the signs of the thermal stresses will be reversed. At 20 Mw, $S_i = 18,820$ psi tension and $S_o = 340$ psi compression. At 30 Mw, $S_i = 23,230$ psi tension and $S_o = 3490$ psi compression at the knuckle radius.

According to the ASME code for unfired pressure vessels, the allowable working stress for 347 stainless steel seamless pipe at 280°C is 15,050 psi combined hoop and thermal stresses. Although some of the above calculated stresses are higher than the ASME allowable working stresses, the core should be safe to operate under any of the above conditions.

Suppose a core cooler consists of $1/4"$ x $.035"$ wall stainless steel tubes wrapped around the core and cast in aluminum. If the average coil spacing is $3/4"$ per turn, the total length will be about 6.4 feet. To examine the cooling by air alone, assume an air flow rate of 50 lb/hr at an average pressure of 50 psig.

$$\begin{aligned}\text{Then the flow rate} &= 10.3 \text{ scfm} \\ G &= 2.83 \times 10^5 \text{ lb/hr-ft}^2 \\ \text{Re} &= 77,000 \\ \text{and Pr} &= 0.69\end{aligned}$$

$$\text{From } \frac{hD}{k} = .023 (\text{Re})^{.8} (\text{Pr})^{.4},$$

$$h = 215 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

If the tube wall temperature is 464°F (240°C) and the air inlet temperature 70°F , the outlet temperature will be 462°F and the heat removal will be 4700 Btu/hr or 1380 watts. If sufficient water is injected into the air stream to keep the "air" temperature at 100°C , the heat removal will be at least 16,400 Btu/hr or 4800 watts.

With air coolant, most of the heat transfer occurs near the inlet end of the tube. Therefore a single wound tube with the inlet at the core nose will be better than a double wound cooler having inlet and exit at the rear of the core.

The core cooler for each loop will probably be calibrated by measuring the amount of heat it removes from the loop. The over-all heat transfer coefficient for the above cooler removing heat from the circulating solution may be calculated as follows:

$$\begin{aligned} h_{\text{solution}} &= 456 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F} \\ h_{\text{core wall}} &= k/L = 10.9 \times 12/.218 = 600 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F} \\ h_{\text{aluminum}} &= k/L = 130 \times 12/.2 = 8000 \\ h_{\text{tube}} &= k/L = 10.2 \times 12.035 = 3500 \\ h_{\text{air}} &= 215 \\ A_{\text{solution}} &= 0.273 \text{ ft}^2 \\ A_{\text{core wall}} &= 0.31 \text{ ft}^2 \\ A_{\text{aluminum}} &= 0.346 \text{ ft}^2 \\ A_{\text{tube}} &= 0.36 \text{ ft}^2 \\ A_{\text{air}} &= 0.302 \text{ ft}^2 \\ 1/U_{\text{Am}} &= 1/h_s A_s + 1/h_c A_c + \text{-----} \\ U_{\text{Am}} &= 33.4 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F} \end{aligned}$$

If $A_m = 0.31 \text{ ft}^2$, then $U_m = 108 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$ using 50 lb/hr air as coolant. If air-water cooling is used in the core cooler, the air flow rate will be closer to 10[#]/hr.

* Memo to H. C. Savage from R. A. Lorenz, September 17, 1956.

8.6 Test Results on Core Cooler Mock-up for ORR Loop HN-1*

The following information should be of help in designing the core and loop coolers for ORR Loop HN-1. The information was obtained from a mock-up cooler mounted in development loop DV-9 at Y-12. The core as installed was similar to the proposed core; however, it contained only a core coupon holder and coupons. Because of availability, it was constructed of 2-in. Sch 40 rather than Sch 80 pipe. This difference in wall thickness would affect the over-all coefficient of heat transfer slightly, but in a comparison of reactor conditions to test conditions, this effect would be negligible.

The cooler consisted of 5 1/2 ft of 1/4-in. by 0.035-in. wall stainless steel tubing double wound on the core with the inlet and outlet at the reducer end. The tubing was tack welded to the core in as few places as possible, and was approximately 1/16-in. away from the core. The whole assembly was preheated with a torch before casting in aluminum to insure a sound casting. The aluminum when poured was about 1500°F. The casting was turned down to 3-1/4-in. OD by 5-1/2-in. long and x-rayed for faults. The coupons and holder were inserted, the core reducer welded to the body, and the assembly was installed in the loop.

Tests were run using process water, building air, and a mixture of the two as coolants. The heat removal was measured by electrical input to the pressurizer and loop heaters at steady state conditions before and during cooling. Thermocouples were placed on the inlet and outlet coolant lines, inlet and outlet core lines, on the outside of the aluminum casting, and in holes drilled through the aluminum to the core wall. These last thermocouples were held in place by aluminum pins pressed in the holes and it is believed that they were indicating aluminum temperature at some

point close to the core wall.

The following are values obtained from a series of tests on this cooler. The over-all coefficient of heat transfer, U , is based on the mean area between the inside of the core (0.25 ft^2), and inside of the coolant tube (0.26 ft^2).

It appeared from operation of these tests that the pressure drop through the coolant system will be a limiting factor in the amount of cooling that can be accomplished. In the core cooler this should not be too critical; however, some development will be necessary to overcome this if the in-line coolers are of a similar type.

* Memo to H. C. Savage from D. B. Weaver, November 23, 1956.

TABLE II

MOCK-UP TEST DATA - ORR CORE COOLER, DV-9

WATER COOLANT

Test No.	Loop Temp. (°C)	Coolant Flow gpm	Coolant		Heat Removal btu/hr	Aluminum Temp. Outside Surface °C		Aluminum Temp. Interior °C		U btu/hr-ft ² -°F
			Inlet Temp. °C	Outlet Temp. °C						
			°C	°C		min.	max.	min.	max.	
A	155	0.19	22.2	84.5	11,126	87	95	89	111	234
E	150	0.246	22.6	75.5	11,870	79	84	82	98	252
B	180*	0.18	23.7	100.1	13,037	102	112	105	131	234

* Maximum loop temperature that could be obtained with water at 0.18 gpm.

TABLE III
AIR COOLANT

		scfm									
F	152	2.85	28	136	655	137	143	141	141		26
G	151	13.5	23	125.5	2,960	124	129	130	133		97.6
H											
N	253	2.2	28	226	860	226	238	236	240		19.3
H	253	8	44.2*	218	3,075	216	225	221	228		66
I	253	11.3	40.5*	211.5	4,110	208	218	215	224		82.3
D	250	11.4	41.9*	217.4	5,080	222	224	222	231		112

* Thermocouple was too close to core on Coolant tube. These readings should be in the range of 25 to 30°C. Assuming 28°C, the U for H, I, and D would then be 63, 79, and 107, respectively.

TABLE IV
AIR-WATER MIXTURE

Test No.	Loop Temp. °C	Air Flow scfm	Water Flow cc/min	Coolant		Heat Removal btu/hr	Aluminum Temperature				U btu/hr-ft ² -°F
				Inlet Temp. °C	Outlet Temp. °C		Outside Surface °C		Interior °C		
							min.	max.	min.	Max.	
L	253	3.7	20	28	211	4,530	189	222	208	227	88
J	253	6.0	19	27	207.5	5,580	192	217	206	233	104
O	253	2.2	39	30	201	6,540	182	209	202	216	116
K	253	5.5	40	27	194.5	8,440	175	205	194	214	143
M	254	4.0	50*	28	191	8,860	172	198	192	207	145
P	254	2.8	51*	30	192	11,100	180	201	192	208	184

* Maximum water-air flow obtainable and still maintain loop temperature.

Fig. 2
8.3 HEAT TRANSFER CHARACTERISTICS OF CORE COOLER MOCK-UP
SINGLE-WOUND COOLER; 44.1 IN. OF $\frac{1}{4}$ " TUBING

CORE COOLER MOCK-UP

9-56 RAL

8.4 FIGURE 1

0-17