NCLASSIFIED

OAK RIDGE NATIONAL LABORATORY
 Operated By
 UNION CARBIDE NUCLEAR COMPANY

UCC

POST OFFICE BOX X
 OAK RIDGE, TENNESSEE

External Transmittal
 Authorized

ORNL
CENTRAL FILES NUMBER
CF- 57-6-66

DATE: June 28, 1957

COPY NO. 68

SUBJECT: Test Results on a Heater-Cooler Unit for the ORR In-Pile Loop

TO: E. G. Bohlmann

FROM: T. H. Mauney, H. C. Savage

Distribution

1. HRP Director's Office	22. R. B. Korsmeyer	43. H. C. Savage
2. G. M. Adamson	23. K. A. Kraus	44. C. L. Segaser
3. S. E. Beall	24. N. A. Krohn	45. I. Spiewak
4. E. G. Bohlmann	25. J. A. Lane	46. R. W. Stoughton
5. S. E. Bolt	26. R. E. Leuze	47. J. A. Swartout
6. F. R. Bruce	27. R. B. Lindauer	48. E. H. Taylor
7. W. D. Burch	28. R. A. Lorenz	49. D. G. Thomas
8. R. D. Cheverton	29. M. I. Lundin	50. D. S. Toomb
9. E. L. Compere	30. R. N. Lyon	51. W. E. Unger
10. J. S. Culver	31. T. H. Mauney	52. R. Van Winkle
11. D. E. Ferguson	32. E. A. Mason	53. C. E. Winters
12. C. H. Gabbard	33. J. P. McBride	54. F. C. Zapp
13. W. R. Gall	34. H. F. McDuffie	55. ORNL Document
14. J. C. Griess	35. H. M. McLeod	Reference Lib., Y-12
15. P. H. Harley	36. R. A. McNees	56. Central Research Lib.
16. P. N. Haubenreich	37. J. R. McWherter	57-58. REED Library (2)
17. J. W. Hill	38. E. C. Miller	59. F. C. Moesel, AEC
18. G. H. Jenks	39. L. F. Parsly	60. M. J. Skinner
19. D. T. Jones	40. R. C. Robertson	61-67. Westinghouse PAR
20. S. E. Kaplan	41. A. M. Rom	Project (7)
21. P. R. Kasten	42. J. A. Russell	68-82. TISE-AEC (15)

NOTICE

This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

UNCLASSIFIED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

TABLE OF CONTENTS

	<u>Page</u>
I. SUMMARY	3
II. INTRODUCTION	3
III. DESIGN SPECIFICATIONS	5
IV. TEST PROCEDURE	6
V. TEST RESULTS AND OBSERVATIONS	12
VI. CONCLUSIONS	20
VII. REFERENCES	22

I. SUMMARY.

Tests have been completed on a combination heater-cooler unit for use in in-pile loops designed to operate in beam hole HN-1 of the ORR facility. The unit is designed to use air-water mixtures as the coolant. The coolant flows through a spiral of 3/8-in. diameter tubing cast in aluminum around the 3/8-in. IPS loop pipe. Four 1000-w calrod-type electric heating elements are cast into the aluminum, along with the cooling coils, to provide loop heating.

The combination unit is designed to remove fission heat generated in the circulating fuel solution during in-pile operation, as well as to supply the heat necessary for loop temperature control. Test results indicate that with a coolant mixture (air-water) of ~ 4 scfm of air and ~ 270 cc/min of water, ~ 8 kw of heat can be removed at a loop temperature of 250°C. The cooling capacity can be varied from <1 kw to ~ 8.5 kw by adjusting the water injection rate. These results are for one 28-in.-long unit. Two of these units will be incorporated in the ORR in-pile loop to provide up to ~ 17 kw of cooling capacity and up to 8 kw of heating.

The heater-cooler unit was used to maintain and control the loop temperature at 250°C, with satisfactory results.

The pressure drop through the cooling-tube circuit, which was of equal length to that planned for the ORR installation, was ~ 33 psi at the air-water mixture rate given above. This value is considered acceptable for in-pile operation.

II. INTRODUCTION.

During the operation of an in-pile loop in the ORR, nuclear fission heat generated in the circulating fuel solution must be removed along with the heat generated in the metal wall of the loop core section by reactor gamma energies. It has been calculated that a maximum of 20 kw of heat will be produced in the loop fuel solution along with an additional 4 kw in the core metal wall. In the present in-pile loops, which operate in the LLTR, a maximum of ~ 3 kw of fission and gamma heat is produced. Therefore the cooler used in the LLTR loops is not adequate for the ORR loops and a new design was required. The heating and cooling units were combined into one unit to take advantage of all available loop-pipe heat-transfer area for both heating and cooling.

Initially it was decided that two types of heater-cooler units would be fabricated and tested. One design, a modification of the cooling unit in use in the LITR in-pile loops, was a 20-in.-long annulus-coolant-passage type with four 750-w calrod-type heating elements cast in aluminum around the 3/8-in. loop fuel line. The second unit consisted of 3/8-in. stainless steel tubing and four calrod-type heating elements of 1000-w each cast in aluminum around the 3/8-in. loop pipe. This unit was made 28-in. long as the maximum length which could be fitted into the ORR loop in any one section of pipe. Two of the 28-in.-long units could be incorporated in the ORR loop package without major design changes to the loop layout. From the standpoint of thermal stress in the pipe wall, ~ 8 kw cooling rate is the maximum allowable for the 28-in.-long unit. The coolant medium of air-water mixtures was chosen on the basis of past experience in the LITR loops and previous test results of a core cooler for the ORR loop¹. Not only could a wide range of cooling capacity be obtained by adjusting the water content of the air-water mixture, but operational control of loop temperature and response to changes in heat loads were very good.

Since the heater-cooler unit with a 3/8-in. stainless steel cooling coils was found to be more efficient than the annulus-type cooler, only test results for the unit with spiral-wound cooling coils are reported.

III. DESIGN SPECIFICATIONS.

a. Loop.

1. Maximum fission heat generated in the ORR loop fuel solution: ~ 20 kw (calculated).
2. Total reactor gamma heating of ORR loop core metal wall: ~ 4 kw, max. (calculated).
3. Loop operating temperature: 250 to 300°C.
4. Loop flow rate: 5 gpm.
5. Pipe size from which fission heat is to be removed: 3/8-in. IPS, Sch 40.
6. Maximum available length of loop pipe for heat removal: ~ 5 ft.
7. Maximum outside diameter of cooler: 2-3/8 in.
8. Length of coolant supply line: 15 ft.
Length of coolant exhaust line: 15 ft.
9. Air supply pressure: 100 psig (plant supply).
10. Water supply pressure: 100 psig.
11. Water injection tube: 1/8-in. x 0.020-in. wall.

b. Heater-Cooler Unit (Ref. Dwg. TD-E-4786).

1. Length: 28 in.
2. Outside diameter: 2-3/8 in.
3. Aluminum casting dimensions: OD, 2-1/4 in.; ID, 0.675 in.
4. Helical cooling-coil dimensions:
Linear length: 144 in.
OD: 2-1/8 in.
ID: 1-1/2 in.
Tube: 3/8 in. x 0.035-in. wall.
5. Cooling coil inside surface area: ~ 1 ft².
6. Cross-sectional area of cooling coil for flow calculations: 0.0005 ft² (3/8-in. x 0.035-in. wall).
7. Heating-element data:
Heating elements: 4 electric calrod type of 1000 w each, GE 4A420 or equal.
Calrod sheath temperature rating: 1500°F.
Volts: 220
Total length: 38 in.
Effective heating length: 24 in.

The heater-cooler unit is designed to remove fission heat from fuel solution. The heat generated in the loop core metal is removed with a separate cooling unit described elsewhere¹. Two of the 28-in. -long heater-cooler units can be incorporated in the loop package. The design data and test results presented are for one unit only. Figure 1 is a drawing of the assembled unit. Photographs of the unassembled and the assembled unit are shown in Fig. 2 and 3.

IV. TEST PROCEDURE.

Tests on the heater-cooler unit described above were conducted in an in-pile type loop facility designated as DV9. Only sufficient alteration was made to permit installing the test heater-cooler units and a second heater which was required to provide a total of 11 kw of loop heat to simulate heat generation during reactor operation. Fig. 4 shows schematically the arrangement of the loop for the tests. Fig. 5 is a diagram of the coolant flow as used in the test unit.

The cooling-air inlet and exhaust lines were 1/2-in. tubes 15 ft long to equal the length planned for the ORR facility. The water injection line was made 15 ft long and was 1/8-in. OD x 0.020-in. -wall tubing. The 1/8-in. water supply line was inserted into the 1/2-in. air line and injected water into the air stream at a point ~ 6-in. from the cooler unit. A pressurized demineralized water supply was built to provide a continuous supply of 100-psig water. Air was obtained from the plant supply, which was at 90 to 100 psig. Measurements of total pressure drop as a function of varied air and water rates were made. Tests were conducted at a loop operating temperature of 250°C and with oxygenated water as the circulating solution in the loop.

Test data was obtained with the loop in thermal equilibrium at 250°C. Cooling rates for the test unit with various air and water mixtures as the coolant media were obtained by wattmeter readings of loop heat load at equilibrium. All test data was obtained at a nominal loop temperature of 250°C while circulating oxygenated distilled water.

Loop temperature control characteristics of the heater-cooler were also observed with the unit heaters on automatic temperature control. In this case, the cooling rate of the unit was compensated by the calrod heaters embedded in the aluminum matrix along with the cooling coils.

7

Fig. 1. Heater-Cooler Unit for ORR In-Pile Loop Package

Fig. 2. 28-Inch Heater-Cooler Unit for the ORR In-Pile Loop, Unassembled

9

UNCLASSIFIED
PHOTO 28619

Fig. 3. 28-Inch Heater-Cooler Unit for the ORR In-Pile Loop, Assembled

Fig. 4. Schematic Diagram, Loop DV9 as Used for Tests of Heater-Cooler Unit

	OPEN VALVE	CLOSE VALVE
TO OPERATE COOLER HALF "A" ONLY	NOS. 1, 4	NOS. 2, 3, 5
TO OPERATE COOLER HALF "B" ONLY	NOS. 2, 5	NOS. 1, 3, 5
TO OPERATE COOLER "A" AND "B" IN SERIES	NOS. 1, 3, 5	NOS. 2, 4
TO OPERATE COOLER "A" AND "B" IN PARALLEL	NOS. 1, 2, 4, 5	NO. 3

Fig. 5. Coolant Flow Circuit, Heater-Cooler Tests

The temperature distribution along the length of the aluminum in which the cooling coils and calrod heaters were embedded was obtained by means of thermocouples. The thermocouple locations and method of attachment are noted in Fig. 6.

V. TEST RESULTS AND OBSERVATIONS.

Cooling-capacity data were obtained on the 28-in.-long heater-cooler unit (described in section III) at a number of coolant flow rates with various mixtures of air and water. With air cooling alone, the 28-in.-long unit removed up to ~ 2 kw of heat at an air flow rate of ~ 20 scfm (20 scfm was the maximum flow obtainable with an air supply pressure of ~ 100 psig). With the 28-in.-long unit divided into two halves of equal length (14 in.) and by using a parallel air flow through both halves, up to ~ 3 kw of heat could be removed with air alone. An air flow rate of ~ 40 scfm (20 scfm through each half) was obtained with the parallel coolant flow. Fig. 7 is a plot of the cooling capacity versus air flow rate for both straight-through and parallel flow of air through the 28-in.-long unit.

With air-water mixtures as the coolant media, the cooling capacity of the unit could be varied and controlled from ~ 1 kw up to ~ 8.5 kw. Air flow rates of 2 to 10 scfm, along with water injection rates varying from ~ 20 cc/min to ~ 270 cc/min, were used. Fig. 8 is a plot of the cooling capacity versus water injection rate for a number of different air flows. It will be noted that the rate of water injection is the controlling factor on cooling capacity.

The data plotted in Fig. 8 were obtained with straight-through or series flow (see Fig. 5) with the exception of two values, which were obtained with the coolant in parallel flow through the two halves of the unit. Only a few tests were made with the air-water mixtures in parallel flow, since initial tests indicated no advantage of the parallel flow over the series flow from the standpoint of cooling capacity. Since the pressure drop through the unit is not excessive, the series flow will simplify the cooling-line connections required for in-pile operation.

The temperature distribution in the aluminum casting along the length of the heater-cooler unit at various cooling rates is given in Table I. Included in Table I are temperatures obtained when the unit was used only as a

13

Fig. 6. Thermocouple Location, Heater-Cooler Test Unit

Method of Thermocouple Installation
in Aluminum

UNCLASSIFIED
ORNL-LR-DWG. -23066

Fig. 7. Cooling Capacity of 28-in. Heater-Cooler Unit with Air Cooling Only

Fig. 8. Cooling Capacity of 28-in. Heater-Cooler with Air-Water Mixtures as the Coolant Media. Loop Temperature at 250°C

TEMPERATURE DISTRIBUTION IN HEATER-COOLER UNIT (SEE FIG. 6)

H ₂ O (cc/min)	Air (scfm)	Heat Removed (watts)	Temp. (°C) in Aluminum 1/8 in. from 3/8 in. Loop Pipe						Loop Temp. (°C)		Coolant Temp. (°C)		ΔT (°C) T.C.17- T.C.15
			T.C.22	T.C.23	T.C.24	T.C.25	T.C.26	T.C.27	In (T.C.4)	Out (T.C.1)	In (T.C.15)	Out (T.C.17)	
UNIT USED AS COOLER ONLY													
25	3.9	1270	149.0	202.5	233.0	230.0	236.0	238.5	250.0	250.0	30.0	159.0	129.0
50	4.1	2720	131.0	165.0	208.5	223.0	232.5	236.0	252.0	250.5	35.0	168.0	133.0
75	4.0	3720	122.0	162.0	191.0	199.0	225.0	231.0	252.0	250.0	37.0	170.0	133.0
100	4.1	4530	115.0	153.0	188.0	187.0	208.0	221.0	253.0	250.0	39.0	153.0	114.0
126	4.0	5760	113.0	149.5	179.5	180.5	189.5	201.5	254.0	250.0	41.0	137.0	96.0
142	4.0	6220	112.0	150.0	178.5	175.0	186.0	176.5	254.0	249.0	41.5	104.0	62.5
269	4.0	7960	112.0	161.0	188.5	185.0	180.5	150.0	254.0	249.5	45.0	105.0	60.0
24	5.5	1560	149.5	201.0	230.5	228.5	234.5	238.0	251.0	250.5	31.0	171.0	140.0
75	4.9	3500	122.0	162.0	191.5	199.5	224.5	230.0	252.0	250.0	39.5	174.0	134.5
134	5.0	5960	111.0	149.0	178.0	176.0	186.0	182.0	253.5	249.0	42.0	124.0	82.0
269	5.0	8020	111.0	161.0	189.0	185.0	181.0	150.0	254.0	249.5	41.5	105.0	63.5
75	6.2	3260	118.5	160.0	190.0	194.5	220.0	227.0	253.0	250.5	37.0	174.0	137.0
134	6.0	6060	110.0	148.0	177.5	175.0	186.0	182.5	254.5	249.5	41.0	125.5	84.5
269	5.9	8360	113.0	163.5	191.0	189.0	184.0	151.0	254.0	249.5	45.0	105.0	60.0
25	7.2	1590	142.5	191.0	227.0	227.0	233.5	236.5	251.0	250.5	29.5	179.0	149.5
75	7.0	3980	118.0	160.0	190.0	193.5	219.0	226.0	253.5	250.5	36.5	176.0	139.5
142	7.0	6310	109.0	148.0	177.0	172.0	183.5	187.5	253.0	249.5	40.0	115.2	75.2
263	7.0	8640	114.0	164.5	192.0	190.0	184.5	151.0	253.5	248.0	43.5	105.0	61.5
25	8.0	1770	140.5	189.0	225.5	226.0	232.5	235.5	251.0	250.5	30.0	182.0	152.0
75	8.2	3870	115.0	158.0	190.0	193.0	217.0	224.0	252.5	250.0	35.0	177.0	142.0
130	8.0	6190	110.0	148.0	178.0	175.0	186.5	188.5	254.0	249.5	38.5	133.0	92.5
269	8.1	8540	111.0	163.0	190.0	189.5	184.0	151.0	254.0	249.0	43.0	105.0	62.0
269	9.9	8550	111.0	162.5	190.0	188.5	184.0	150.0	254.0	249.0	41.0	104.5	63.5
UNIT USED AS BOTH HEATER AND COOLER													
22	3.0	730	171.0	228.0	252.0	249.0	257.0	252.0	250.0	250.5	33.0	152.0	119.0
50	3.0	2260	146.0	186.0	257.0	271.0	283.5	265.0	250.0	250.5	34.5	184.0	149.5
78	3.0	3460	143.0	186.0	232.0	283.0	303.0	275.0	250.0	251.0	35.0	204.0	169.0
86	3.0	4020	140.0	187.0	217.5	288.0	310.0	278.0	250.0	251.0	35.0	209.0	174.0
25	4.0	840	158.0	219.0	251.0	249.0	258.0	252.0	250.0	250.0	34.5	168.0	133.5
50	4.0	2060	147.0	184.0	251.0	266.0	278.0	263.0	250.0	251.0	36.0	188.5	152.5
75	4.0	3180	146.0	285.0	231.0	276.0	294.0	271.0	250.0	251.0	36.5	204.0	167.5
86	4.1	4000	140.0	187.0	213.0	278.0	305.0	275.0	250.0	251.0	36.0	215.0	179.0

cooler (calrod heaters off) as well as when it was used for both heating and cooling. In the latter case, the heat supplied by the calrod units, cast in the aluminum jacket along with the cooling coils, was balanced by the loss to the cooling coils. Figure 9 is a plot of some representative temperature-distribution data from Table I. It will be noted that the temperature in the aluminum reaches a maximum near the mid-section of the cooler and decreases at the coolant exit end for high rates of heat removal. At the relatively high cooling rates, the water injection rate is in excess of the quantity that can be evaporated in passing through the coils. Under these conditions, the temperature of the air-water coolant is controlled by the boiling point of water at a partial pressure which is determined by the total pressure in the cooling coil. Thus the temperature of the coolant mixture does not rise above this boiling point in passing through the cooling coils. In fact, the pressure drop through the coils is such that, under the conditions where excess water is injected, the coolant temperature is observed to reach a maximum and then to decrease. Thus increased cooling rates are encountered as the air-water mixture passes through the unit as a result of increased heat-transfer coefficient of the boiling water and the decreasing coolant temperature.

When lesser quantities of water are injected into the air stream ($\sim < 125$ cc/min), all the water is evaporated before reaching the cooling-coil exit and an increasing coolant temperature is noted. This is evident in the plot of aluminum temperature along the cooler length for a water injection rate of 75 cc/min as shown in Fig. 9.

At water injection rates of 25, 50, 75, 100, and 125 cc/min into an air stream of 4 scfm, the cooling rates are approximately proportional to the water injection rate. A heat balance of the cooling media (air-water) based on the enthalpy change of the water and heat content of the associated air is in good agreement with the cooling rate based on the electrical heat input to the loop as determined from wattmeter readings. Calculated and observed values of cooling capacity at water injection rates of 25, 50, 75, 100, and 125 cc/min are given in Table II.

A series of tests was made with the heater-cooler unit operating simultaneously as both a heater and cooler. In this case, the electrical heat supplied by the calrods was removed by the cooling coils. Cooling-capacity data,

Fig. 9. Temperature Distribution in Heater-Cooler Unit,
Air-Water Mixture Coolant Media

TABLE II
CALCULATED VERSUS ACTUAL HEAT REMOVAL IN HEATER-COOLER UNIT

Air Flow (scfm)	Water Flow (cc/min)	Coolant Temperature (°C)		Heat Removal (watts)	
		Inlet	Exit	Calc.*	Actual**
4	25	30	159	1430	1270
4	50	35	168	2520	2720
4	75	37	170	3620	3720
4	100	39	153	4630	4530
4	125	41	137	5580	5760

* Heat balance on air-water mixture.

** Electrical heat input to loop (wattmeter).

along with temperature of the aluminum casting obtained under these conditions, are also shown in Table I. Since the maximum calrod heater input was 4 kw, the cooling-capacity data were limited to 4 kw. A typical temperature distribution in the aluminum casting obtained under these conditions is shown in Fig. 9, along with the distribution obtained with cooling only. When the unit was used for both heating and cooling simultaneously, the aluminum temperature is above the loop temperature at some points.

Measurements of the pressure at several points throughout the coolant flow circuit were obtained for a number of different coolant flow rates. Table III lists these pressure measurements. A total system pressure drop of 33 psi was observed with 4 scfm of air and 269 cc/min of water, which gave a cooling capacity of ~ 8.5 kw. This pressure drop is well within the capacity of the 100-psig supply pressure of air and water. In fact, present plans are to connect the coolant circuit of two of the 28-in.-long heater-cooler units in series in the ORR loop. This would require possibly a 60 to 70 psi coolant supply pressure, which is still well within the available 100-psig supply pressures of air and water.

VI. CONCLUSIONS.

The 28-in.-long heater-cooler unit as designed and tested is satisfactory for use in the ORR loop package. This unit is capable of supplying 4 kw of heat to the loop. Cooling rates up to ~ 8.5 kw can be obtained by using air-water mixtures as the coolant media. Control of loop temperature and response to changes in loop heat load appear satisfactory. Present plans are to install two of the 28-in.-long heater-cooler units in the ORR loop package, which will provide up to ~ 17 kw of cooling capacity at a loop temperature of 250°C. In addition, 8 kw of heating will be available. These values are considered adequate for the initial in-pile loop experiments in the ORR.

If additional cooling capacity (i.e., 20 kw or more) is required in future loops, design modifications to the loop to add additional heat-transfer area will be required to obtain the increased cooling capacity. Cooling rates above ~ 8.5 kw can be obtained in a 28-in.-long unit, but are not advisable from the standpoint of the induced thermal stress in the loop piping.

TABLE III

PRESSURE DROP THROUGH THE COOLING COIL OF THE 28 IN. LONG HEATER-COOLER UNIT

(Refer to Sketch, Fig. 5)

Air Flow (scfm)	Water Flow (cc/min)	Pressure (psig)					Overall ΔP A-E, (psi)
		A (Inlet)	B	C	D	E (Exit)	
1.8	25	5.5	8.0	5.5	4.5	0	5.5
1.8	134.	17.0	18.0	14.5	18.0	3	14.0
2.0	271	24.5	27.0	23.0	12.0	3	21.5
1.7	72.	13.0	14.0	10.0	6.0	3	10.0
1.9	50.	9.5	10.5	7.0	5.0	3	6.5
2.1	25	6.5	7.0	5.0	4.0	3	3.5
2.0	89	15.0	16.0	13.0	7.0	3	12.0
3.0	263	31.0	32.0	26.0	14.0	3	28.0
3.0	86	20.0	20.0	15.0	8.0	3	17.0
3.0	50	14.5	15.0	11.0	6.0	3	11.5
3.0	22	10.0	11.0	7.0	4.5	3	7.0
3.0	77	18.0	18.0	14.0	7.5	3	15.0
4.0	269	37.0	38.0	26.0	15.0	4	33.0
4.0	25	15.0	16.0	11.0	7.0	3	12.0
4.0	50	19.0	19.0	14.0	7.5	3	16.0
4.0	75	23.0	23.0	18.0	9.5	3	20.0
4.1	86	25.0	25.0	19.5	10.0	3	22.0
5.0	126	30.0	31.0	24.0	12.0	4	26.0
5.0	269	44.0	45.0	35.0	17.0	4	40.0
5.0	269	43.5	45.0	35.0	18.0	4	39.5
6.0	269	48.0	49.5	38.0	20.0	4	44.0
7.0	263	54.0	54.0	41.0	20.0	4	50.0
8.1	269	61.5	63.0	47.0	24.0	4	57.5

REFERENCES

R. A. Lorenz and D. T. Jones, Laboratory Test of a Core Cooler For ORR Loop HN-1, ORNL 56-12-65.