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RESEARCH MEMORANDUM

FORCED-CONVECTION HEAT-TRANSFER CHARACTERISTICS OF MOLTEN FLINAK FLOWING IN AN INCONEL X SYSTEM

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NATIONAL ADVISORY COMMITTEE
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FORCED-CONVECTION HEAT-TRANSFER CHARACTERISTICS OF MOLTEN FLINAK FLOWING IN AN INCONEL X SYSTEM

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SUMMARY

An experimental investigation was made of the forced-convection heat-transfer characteristics of Flinak (NaF-KF-LiF, 11.5-42.0-46.5 mole percent) flowing through an electrically heated Inconel X test section. The range of variables included Reynolds numbers from 2000 to 20,000 corresponding to velocities from 4.1 to 14.7 feet per second, average fluid temperatures from 1005° to 1344° F, average surface temperatures from 1058° to 1460° F and heat flux densities up to about 400,000 Btu per hour per square foot.

Average heat-transfer coefficients for Flinak circulating in an Inconel X system were about 40 percent of the values calculated from the McAdams correlation line. Similar results were obtained by another investigator with Flinak in an Inconel system.

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INTRODUCTION

Because of the potential usefulness of molten salt mixtures as high-temperature heat-transfer media, the NACA Lewis laboratory investigated the heat-transfer characteristics of Flinak, which is one of the more promising of the salt mixtures. The Flinak used in this investigation was obtained from the Oak Ridge National Laboratories, Oak Ridge, Tennessee.

The forced-convection heat-transfer data obtained for Flinak (NaF-KF-LiF, 11.5-42.0-46.5 mole percent) flowing through an electrically heated Inconel X test section are reported herein. Data were obtained over a range of Reynolds numbers from 2000 to 20,000, corresponding to velocities from 4.1 to 14.7 feet per second, average fluid temperatures from 1005° to 1344° F, average surface temperatures from 1058° to 1460° F and heat flux densities up to about 400,000 Btu per hour per square foot.

APPARATUS

A photograph and a schematic drawing of the test setup are shown in figure 1. The apparatus used was similar to that of reference 1. Flinak was circulated by a submerged centrifugal pump (fig. 1(b)) from the sump tank through a welded system consisting of a test section, a pair of heat exchangers acting as heat sinks, and a volume measuring tank. The test setup was so arranged that upon completion of a run the Flinak drained back into the sump tank. Each component of the heat-transfer setup is described in the following paragraphs.

Sump tank. - The sump tank housed the centrifugal pump and served as a storage tank for about 22 pounds of Flinak contained in the system. The tank was made of 1/4-inch Inconel with an inner diameter of 11 inches and a depth of 5 inches. During operation, a helium atmosphere was kept above the liquid surface.

Circulating pump. - The circulating pump was of the centrifugal type driven by a 1-horsepower air motor. The rotor, split rotor housing, and shaft were made of Inconel. The gasket material used at the split rotor housing was two sheets of 0.004-inch nickel. The pump was totally immersed in the molten Flinak and supported from the cover plate. The pump shaft extended through the cover plate to a water-cooled bearing housing. A slinger ring prevented the liquid from climbing the shaft. The flow rate of the Flinak was controlled by varying the air supply to the air motor.

Test section. - The test section was fabricated from Inconel X tubing having an outside diameter of 3/8 inch and a wall thickness of 0.065 inch. A schematic drawing of the test section, which was 24 inches long, is shown in figure 2. Three stainless steel flanges were welded to the test section 12 inches apart. The test section was heated by the direct passage of electricity through it. Electric current was supplied to the flange at the center of the test section and was removed at the two ends of the test section which were attached to a common lead. Inasmuch as the ends of the test section were at the same electrical potential and grounded, no current flowed through the rest of the system. For starting purposes only, guard ring heaters were used on each flange to eliminate cold spots. Baffled mixing cans were located at each end of the test section. A thermocouple totally enclosed in a 1/8-inch Inconel tube measured the mixed temperature at the downstream end of the baffled mixing cans. Outside tube-wall temperatures were measured with 14 chromel-alumel thermocouples spotted at intervals along the test section.

Heat exchangers. - Two heat exchangers were used as sinks for the heat added electrically to maintain constant temperature at the inlet to the test section. Each heat exchanger consisted of two concentric Inconel tubes forming an annulus with Flinak flowing in the inner tube and counterflow air in the outer tube. The length of each exchanger was 24 inches with a 1/2-inch-outside-diameter, 1/16-inch-wall inner tube, and a $1\frac{1}{2}$-inch-outside-diameter, 1/16-inch-wall outer tube.

Volume-measuring tank. - The volume-measuring tank was made of 1/8-inch Inconel plate formed into a cylinder $5\frac{3}{8}$ inches in inside diameter and 11 inches deep. An air-actuated piston operated a plunger valve at the bottom of the tank. When the plunger valve was closed, the fluid level rose and upon reaching the first of a pair of contact points an electric stopwatch was started. The second contact point, located at a known distance above the first, stopped the clock and opened the plunger valve. A thermocouple immersed in the fluid recorded the temperature while the volume measurement was being taken. From the stopwatch reading, the density of the Flinak at the recorded fluid temperature and the known volume between the contact points, the weight flow and velocity through the test section were calculated.

Electric system. - Electric power from a 208-volt 60-cycle line was supplied to the test section, as shown in figure 1(b), through two saturable reactors and a power transformer. A voltage regulator controlling the direct-current supply to the reactor maintained close voltage regulation at the primary of the power transformer for any setting (test-section input) of the variable transformer control. The capacity of the electric equipment was 25 kilovolt-amperes at a maximum input of 10 volts across the test section. The power input was read from a calibrated ammeter, voltmeter, and wattmeter.

Miscellaneous. - Each component of the system was thermally insulated. Nichrome wire in alundum beads wrapped around each element of the setup was used for preheaters to bring the temperature level above 851° F, the melting point of Flinak. Chromel-alumel thermocouples made of 24-gage wire were spotted at intervals along the system. All temperatures were read on a self-balancing, indicating-type potentiometer. The fluid temperature difference across the test section was read with a potentiometer and an external light-beam galvanometer to obtain greater accuracy.

PROCEDURE

Cleaning system. - Prior to welding the various components of the system together, the tanks were cleaned with steel wool. All surfaces to be exposed to the Flinak were cleaned with a solution of carbon tetrachloride to remove any oil.

Water heat-transfer tests. - Heat-transfer tests were made with water before and after the Flinak tests. This procedure with a fluid of well established heat-transfer characteristics was followed in order to check the accuracy of the instrumentation and to determine whether the inside surface of the test section was affected by the flow of Flinak. After the Flinak tests were made, the system was flushed with water for several days prior to making additional water tests. 3144

Charging sump tank with Flinak. - The sump tank was charged by connecting a line from a supply tank to the sump tank. The entire system was then purged with helium. After the system was purged and brought up to a temperature above the melting point of Flinak, flow from the supply tank to the sump tank was caused by pressurizing the Flinak with helium. The height of the Flinak in the sump tank was determined by an electric contact point.

Flinak heat-transfer tests. - The test procedure was as follows: The system was purged with helium prior to starting. Next, all the starting heaters were turned on, and the entire system was brought up to a temperature of 1000° to 1100° F. The pump was then started, which circulated the Flinak through the system. All the starting heaters except the volume-measuring tank heater were then turned off. A helium atmosphere was kept over the free liquid surfaces during operation. The flow rate was set by regulating the speed of the air motor driving the pump, and the desired rate of electrical heat input was set. Air was passed through the heat exchangers in sufficient quantity to maintain a constant temperature at the inlet of the test section. After equilibrium conditions had been obtained, all fluid temperatures, test-section wall temperatures, and power input readings were recorded, and the fluid flow rate was determined. This procedure was repeated for a range of flow rates, power inputs, and average bulk temperatures of the Flinak.

METHOD OF CALCULATION

Water heat-transfer coefficients. - Heat-transfer coefficients for water were calculated in the conventional manner, which is identical to the method used for Flinak explained in the succeeding paragraph.

Flinak heat-transfer coefficients. - Average heat-transfer coefficients were obtained for Flinak from the equation

$$h = \frac{Wc_p(T_2 - T_1)}{S(T_s - T_b)}$$

All symbols used herein are defined in the appendix.

3144 The average outside-tube wall temperature T_w was obtained from a plot of local outside-tube wall temperature against distance along the test section by planimetering the area under the curve and dividing by the tube length. The average inside-tube wall temperature T_s was then calculated by subtracting the temperature drop through the tube wall from the average outside-tube wall temperature. The drop through the wall was calculated by means of the following equation, which assumed uniform heat generation throughout the tube wall:

$$T_w - T_s = \frac{Q}{2\pi l k_I (R_o^2 - R_i^2)} \left(R_o^2 \ln \frac{R_o}{R_i} - \frac{R_o^2 - R_i^2}{2} \right)$$

Physical properties of Flinak. - The physical property data used in this report were obtained from reference 2. The density ρ and the viscosity μ are plotted against temperature in figure 3. The specific heat c_p was reported in reference 2 to be in the range of from 0.4 to 0.5 Btu/(lb)(°F), and for this report a constant value of 0.5 was used. The thermal conductivity k was reported as 2.6 Btu/(hr)(sq ft)(°F/ft) in a temperature range from 932° to 1382° F. The melting point of Flinak is 851° F.

The physical properties reported herein were evaluated at the average bulk temperature of the fluid.

RESULTS AND DISCUSSION

The basic Flinak data obtained in this investigation are listed in table I.

Water heat-transfer tests. - As previously stated, water heat-transfer tests were made before and after Flinak tests. The tests before Flinak were made to check the instrumentation of the test section. The tests after Flinak were made to determine whether or not the inside surface of the test section was affected, so far as heat transfer is concerned, by exposure to the flow of Flinak.

The water heat-transfer data are shown in figure 4 where the Nusselt number divided by the Prandtl number raised to the 0.4 power $Nu/Pr^{0.4}$ is plotted against the Reynolds number Re. There are two sets of data shown: one for water runs before Flinak, and one for water runs after Flinak. It is seen that the data for the water runs before Flinak agree fairly well with the McAdams correlation line (ref. 3). The data for the water runs after Flinak agreed with the McAdams correlation line at the low Reynolds numbers and fell progressively below the McAdams line as the Reynolds number was increased. 3144
This decrease in the heat-transfer coefficients at the higher heat fluxes indicates that a high thermal resistance layer had formed on the inside surface of the test section. A scale can be seen in figure 5, which is a photograph of the inside surface magnified four times.

Figure 6 shows a photomicrograph of a cross section of the Inconel X test section. The presence of a thin scale can be noted. Severe intergranular penetration shown in figure 6 indicates that a reaction between the Inconel X test section and the liquid Flinak had taken place.

Heat balance. - The heat balance for the water tests before Flinak (not shown) check within 5 percent, whereas the water tests after Flinak check to within only 12 percent.

The heat balance for Flinak tests is shown in figure 7, where the heat transferred to the Flinak Q as determined from the flow rate, specific heat, and increase in total temperature is plotted against the electrical heat input Q_p minus the external heat loss Q_L. A 45° line is drawn to represent the perfect heat-balance condition. The external heat loss was determined by supplying various amounts of power to the test section without Flinak flowing. The power input for a given average tube-wall temperature was considered to be the external heat loss for the same average wall temperature with Flinak flowing through the test section. Except for a few points in the low power input range, the data have a maximum deviation of 10 percent from the 45° line.

Tube wall temperature distribution. - Representative axial temperature distributions along the outside-tube wall are shown in figure 8. The end losses are caused by the relatively large mass of metal in the electrical flanges. The dip in the center of the test section is caused by the heat loss to the center electrical flange.

Some of the thermocouples were inoperative for the runs shown, but a sufficient number remained to give a smooth temperature distribution curve.

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Flinak heat-transfer tests. - The Flinak heat-transfer data are compared with the familiar Nusselt relation in figure 9, wherein the Nusselt number divided by the Prandtl number of the 0.4 power, $Nu/Pr^{0.4}$, is plotted against the Reynolds number Re. Three sets of Flinak data, differing only in time at which taken, are shown. The values of the ordinate for the Flinak are approximately 40 percent of the values given by the McAdams line for the same Reynolds number. A slight trend with time appears to exist in that the third set of Flinak data is somewhat lower than the first set of Flinak data. However, the difference is small compared to the difference between the Flinak data and the McAdams correlation line.

A plot of Stanton number times Prandtl number of the 2/3 power $St\, Pr^{2/3}$ against Reynolds number Re is shown in figure 10. Three sets of data are included in this figure: the Flinak data of reference 4 which were obtained in a nickel system, the Flinak data of reference 4 which were obtained in an Inconel system, and the Flinak data of this investigation which were obtained in an Inconel X system. (The same data for the Inconel X system are shown in fig. 9 plotted with different coordinates.) Included for comparison is the Colburn equation (ref. 3) with a suitably faired line into the transition region. If figures 9 and 10 are to be consistent, the McAdams equation on a Stanton number basis in which the Prandtl number is raised to the 0.6 power would be used rather than the Colburn equation in which the Prandtl number is raised to the 2/3 power. The data of reference 4, however, were presented on the basis of the Colburn equation and since insufficient basic data were given to convert the data to a McAdams correlation plot, the data herein are presented accordingly. It is seen that the Flinak data of reference 4 obtained in a nickel system fall in the transition region and in general check the predicted line fairly well. The Flinak data of reference 4 obtained in an Inconel system, and the data of the present investigation obtained in an Inconel X test section fall below the Colburn line. The data of reference 4 fall at about 45 percent of the Colburn line ordinates whereas the data of the present investigation fall at about 40 percent of the Colburn line ordinates. The data of the present investigation show no apparent decrease of the heat-transfer coefficient in the transition range, as is shown by the Flinak data of reference 4 obtained in a nickel tube. No explanation for the difference can be given at this time.

It should be noted that the composition of Inconel and Inconel X are substantially the same. Inconel X contains small quantities of aluminum, titanium and niobium which are not found in Inconel.

Possible reasons for the low heat-transfer coefficients include a change in the physical properties of the Flinak or the formation of a high thermal resistance layer made up of a scale formation on the inside surface of the test section and an intergranular penetration of the tube wall. Reference 4 indicates that the physical properties of the Flinak could not be in error to the extent of the discrepancy of the data. The assumption is therefore made that the low heat-transfer coefficients may be caused by a high thermal resistance layer.

The high thermal resistance layer found in the Inconel X test section was discussed in the water heat-transfer section. A value for x/k_f of 0.000033 $\left[\text{Btu}/(\text{hr})(\text{sq ft})(^{\circ}\text{F})\right]^{-1}$ was computed for the thermal reistance layer, which would bring the water data up to the McAdams correlation line. When the same value of x/k_f was used to calculate a new heat-transfer coefficient for the Flinak data, the data were raised only slightly and still fell approximately 50 percent below the McAdams correlation line. If the scale on the surface of the tube were the major resistance of the thermal resistance layer, this would indicate that the thickness of the scale was reduced before water data were obtained. However, from the best knowledge available, this scale is thought to be insoluble in water. The possibility exists that the thermal conductivity of the layer changes radically with temperature, in that the water data were taken at about 180° F, and the Flinak data were taken at about 1200° F.

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Remarks on test setup. - The test setup was under flow conditions for approximately 40 hours in the temperature range from 1100° to 1500° F. A few leaks occurred because of faulty welds. The action of the molten Flinak which flowed from these leaks was very corrosive on the outside of the component in which the leak occurred.

SUMMARY OF RESULTS

Heat-transfer tests for Flinak (NaF-KF-LiF, 11.5-42.0-46.5 mole percent) flowing through an electrically heated Inconel X test section with Reynolds numbers from 2000 to 20,000, corresponding to velocities from 4.1 to 14.7 feet per second, average fluid temperatures from 1005° to 1344° F, average surface temperatures from 1058° to 1460° F and heat flux densities up to about 400,000 Btu per hour per square foot, gave the following results:

1. The heat-transfer data for Flinak flowing in an Inconel X tube were compared to the familiar Nusselt relation, and were about 40 percent of the values given by the McAdams correlation line. Similar results were obtained by another investigator using Flinak in an Inconel system.

2. The presence of a high thermal resistance layer made up of a scale formation on the inside surface of the test section and an intergranular penetration of the tube wall was noted in the test section.

The low heat-transfer coefficients may be due to the high resistance layer rather than the values used for the physical properties of Flinak.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, December 14, 1953

APPENDIX - SYMBOLS

The following symbols are used in this report:

c_p	specific heat, Btu/(lb)(°F)
D	inside diameter of test section, ft
G	mass flow per unit cross-sectional area, lb/(hr)(sq ft)
h	average heat-transfer coefficient, Btu/(hr)(sq ft)(°F)
k	thermal conductivity, Btu/(hr)(sq ft)(°F/ft)
k_I	thermal conductivity of Inconel X, Btu/(hr)(sq ft)(°F/ft)
l	effective heat-transfer length of test section, ft
Q	rate of heat transfer, Btu/hr
Q_L	external heat loss, Btu/hr
Q_p	electrical heat input to test section, Btu/hr
R_i	inner radius of test section, ft
R_o	outer radius of test section, ft
S	heat-transfer area of test section, sq ft
T_b	average bulk temperature, $(T_1+T_2)/2$, °F
T_s	average inside-tube wall temperature of test section, °F
T_w	average outside-tube wall temperature of test section, °F
T_1	fluid temperature at entrance to test section, °F
T_2	fluid temperature at exit of test section, °F
V	velocity, ft/hr
W	rate of flow, lb/hr
x/k_f	thermal resistance, $[\text{Btu}/(\text{hr})(\text{sq ft})(^{\circ}\text{F})]^{-1}$
μ	absolute viscosity, lb/(hr)(ft)

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ρ density, lb/cu ft

Nu Nusselt number, hD/k

Pr Prandtl number, $c_p\mu/k$

Re Reynolds number, GD/μ

St Stanton number, h/c_pG

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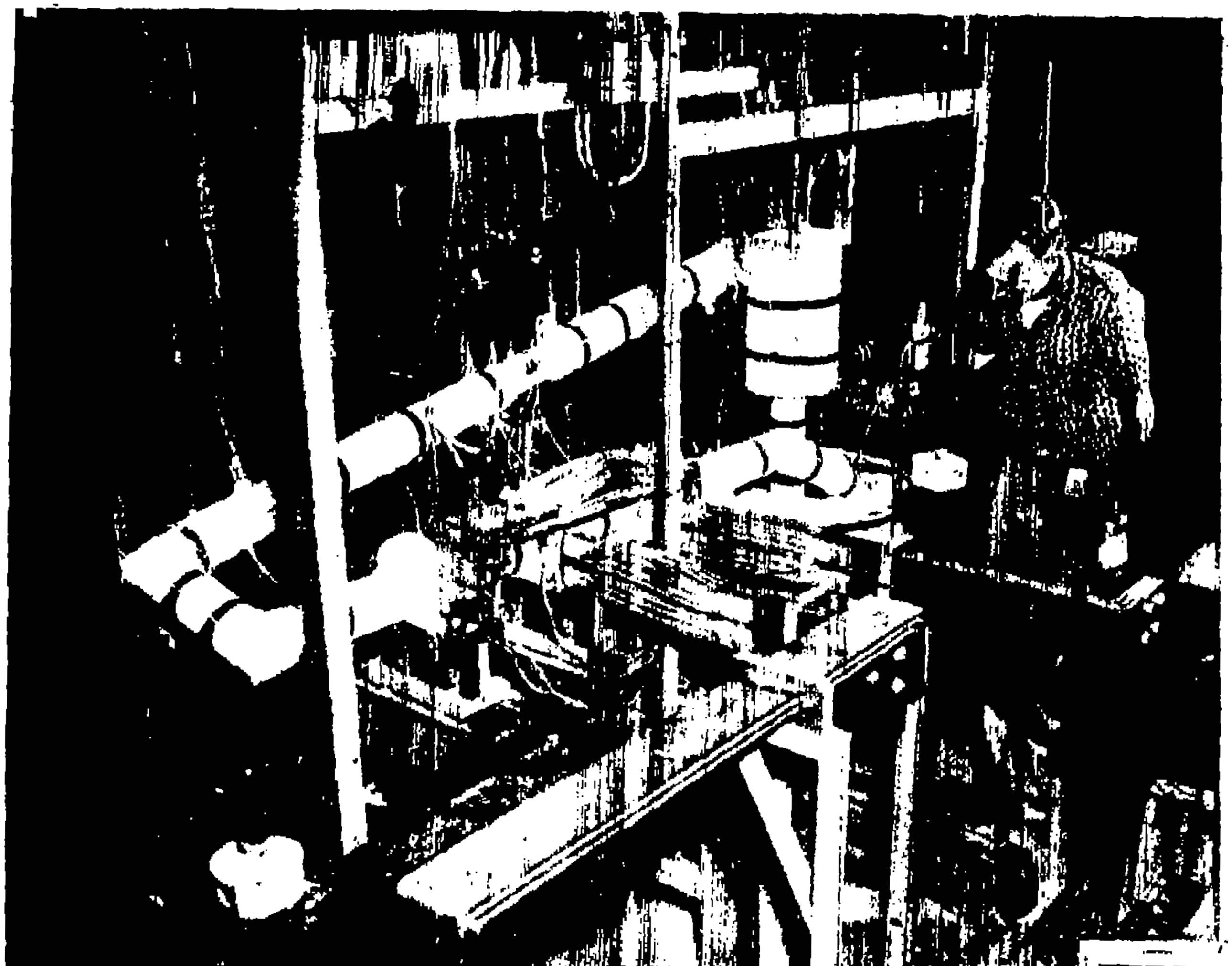
TABLE I. - BASIC EXPERIMENTAL DATA

Run	T_1, °F	T_2-T_1, °F	T_w, °F	T_s, °F	W, lb/hr	V, ft/hr	$G \times 10^{-6}$, lb/(hr)(sq ft)	Q, Btu/hr	$(Q/S) \times 10^{-3}$, Btu/(hr)(sq ft)	h, Btu/(hr)(sq ft)(°F)	Nu	Pr	Re
1	1007	22.2	1089	1076	996	23,359	3.019	11,057	85.8	1480	11.7	4.08	2,919
2	1011	36.0	1150	1129	1003	23,565	3.040	18,059	140.2	1402	11.1	3.91	3,063
3	995	19.7	1075	1058	1213	28,375	3.675	11,946	92.7	1750	13.8	4.33	3,348
4	1118	42.6	1271	1240	1305	31,212	3.956	27,805	215.9	2137	16.9	2.41	6,462
5	1095	42.6	1261	1231	1289	30,696	3.906	27,451	213.1	1853	14.6	2.66	5,797
6	1098	34.9	1245	1215	1571	37,421	4.762	27,421	212.9	2129	16.8	2.67	7,033
7	1107	50.5	1320	1277	1596	38,107	4.836	40,294	312.8	2157	17.0	2.50	7,626
8	1078	25.7	1193	1170	1574	37,327	4.769	20,221	157.0	1987	15.7	2.97	6,339
9	1041	14.4	1107	1094	1539	36,260	4.665	11,084	86.1	1871	14.8	3.61	5,100
10	1103	45.5	1307	1265	1712	40,858	5.189	38,959	302.5	2176	17.2	2.55	8,029
11	1110	31.4	1248	1218	1713	40,868	5.191	26,893	208.8	2270	17.9	2.55	8,031
12	1092	18.6	1174	1156	1716	40,770	5.199	15,957	123.9	2252	17.8	2.85	7,202
13	1055	16.5	1119	1110	892	21,056	2.702	7,356	57.1	1215	9.6	3.38	3,156
14	1051	25.0	1152	1139	891	21,039	2.700	11,138	86.5	1153	9.1	3.38	3,154
15	1098	43.1	1261	1239	913	21,766	2.768	19,682	152.8	1284	10.1	2.62	4,172
16	1050	15.9	1114	1107	750	17,702	2.273	5,964	46.3	945	7.5	3.46	2,589
17	1053	29.8	1171	1158	754	17,808	2.283	11,227	87.2	969	7.6	3.31	2,721
18	1080	46.0	1250	1231	764	18,156	2.315	17,570	136.4	1066	8.4	2.82	3,239
19	1092	24.9	1190	1175	1035	24,594	3.135	12,881	100.0	1408	11.1	2.79	4,426
20	1053	16.7	1116	1110	628	14,819	1.902	5,242	40.7	831	6.6	3.40	2,203
21	1050	30.6	1170	1159	632	14,922	1.914	9,667	75.1	798	6.3	3.36	2,249
22	1087	51.9	1283	1265	646	15,373	1.957	16,759	130.1	856	6.8	2.69	2,866
23	1141	49.4	1323	1237	998	23,971	3.025	24,658	191.4	1461	11.5	2.17	5,488
24	1135	39.1	1289	1262	1265	30,315	3.832	24,725	192.0	1794	14.2	2.27	6,658
25	1135	30.8	1265	1238	1570	37,640	4.759	24,183	187.8	2134	16.8	2.31	8,115
26	1041	24.5	1142	1126	1523	35,915	4.616	18,659	144.8	2166	17.1	3.52	5,165
27	1092	45.6	1304	1269	1443	34,358	4.372	32,898	255.4	1662	13.1	2.68	6,425
28	1066	18.6	1158	1136	2052	48,549	6.218	19,084	148.2	2449	19.3	3.18	7,702
29	1085	35.0	1260	1219	2100	49,916	6.364	36,754	285.4	2441	19.2	2.83	8,857
30	1070	25.1	1197	1171	1801	42,677	5.459	22,608	175.5	1981	15.6	3.09	6,972
31	1093	41.9	1299	1257	1857	44,202	5.627	38,902	302.0	2113	16.7	2.69	8,239
32	1080	17.2	1155	1143	1248	29,587	3.781	10,731	83.3	1545	12.2	3.00	4,969
33	1078	44.3	1278	1248	1247	29,619	3.778	27,614	214.4	1453	11.4	2.86	5,215
34	1059	22.3	1153	1140	1037	24,507	3.142	11,560	89.8	1295	10.2	3.25	3,807
35	1049	40.7	1213	1190	997	23,560	3.021	20,285	157.5	1306	10.3	3.28	3,628
36	1046	31.3	1183	1168	812	19,173	2.461	12,711	98.7	924	7.3	3.40	2,855
37	1028	29.5	1162	1151	625	14,712	1.894	9,219	71.6	660	5.2	3.68	2,027
38	1255	51.0	1472	1438	1363	33,355	4.130	34,756	269.8	1718	13.5	1.45	11,215
39	1273	40.8	1448	1412	1754	43,010	5.315	35,782	277.8	2341	18.5	1.40	15,008
40	1291	32.3	1417	1383	2049	50,366	6.209	33,091	256.9	3372	26.6	1.35	18,184
41	1303	30.7	1426	1393	2079	51,199	6.300	31,913	247.8	3304	26.1	1.31	18,965
42	1315	29.8	1433	1401	2152	53,104	6.521	32,065	249.0	3492	27.5	1.27	20,255
43	1320	34.8	1452	1420	1889	46,668	5.724	32,869	255.2	3105	24.5	1.25	18,081
44	1325	37.8	1465	1433	1718	42,495	5.206	32,470	252.1	2845	22.4	1.23	16,754
45	1296	43.8	1453	1420	1534	37,777	4.648	33,595	260.8	2562	20.7	1.31	13,993
46	1314	51.5	1491	1460	1264	31,242	3.830	32,548	252.7	2106	16.6	1.24	12,212
47	1310	48.6	1469	1442	1130	27,903	3.424	27,459	213.2	1978	15.6	1.26	10,750
48	1301	56.0	1480	1453	981	24,204	2.973	27,468	213.3	1721	13.6	1.27	9,234
49	1283	52.0	1450	1428	848	20,853	2.570	22,048	171.2	1434	11.3	1.34	7,558
50	1132	38.6	1297	1267	1443	34,564	4.373	27,850	216.2	1870	14.8	2.30	7,483
51	1142	35.2	1315	1277	2026	48,598	6.139	35,658	276.8	2364	18.6	2.22	10,906
52	1143	49.5	1384	1331	2062	49,536	6.248	51,034	396.2	2426	19.1	2.16	11,396



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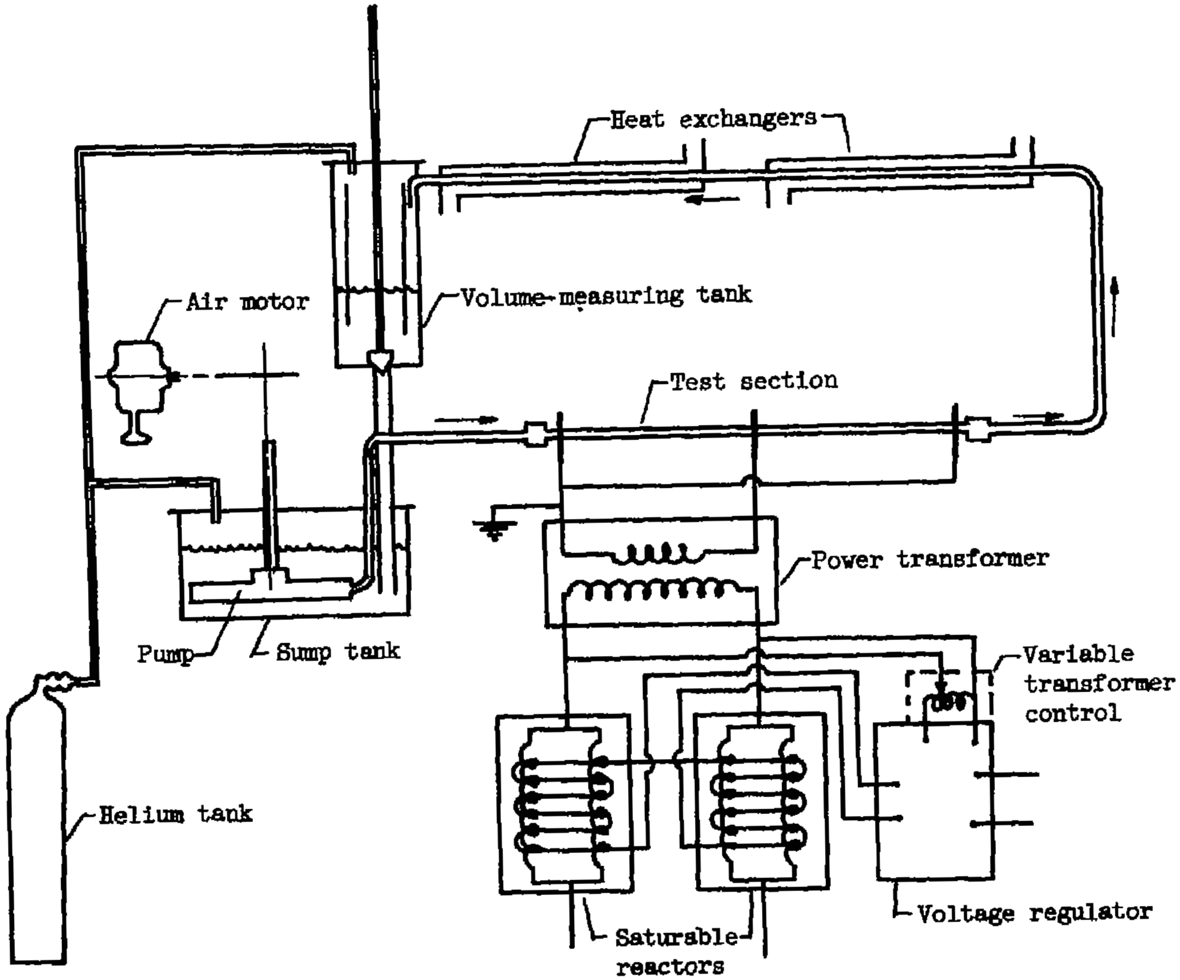
(a) Over-all view.

Figure 1. - Test setup.



(b) Schematic drawing.

Figure 1. - Concluded. Test Setup.

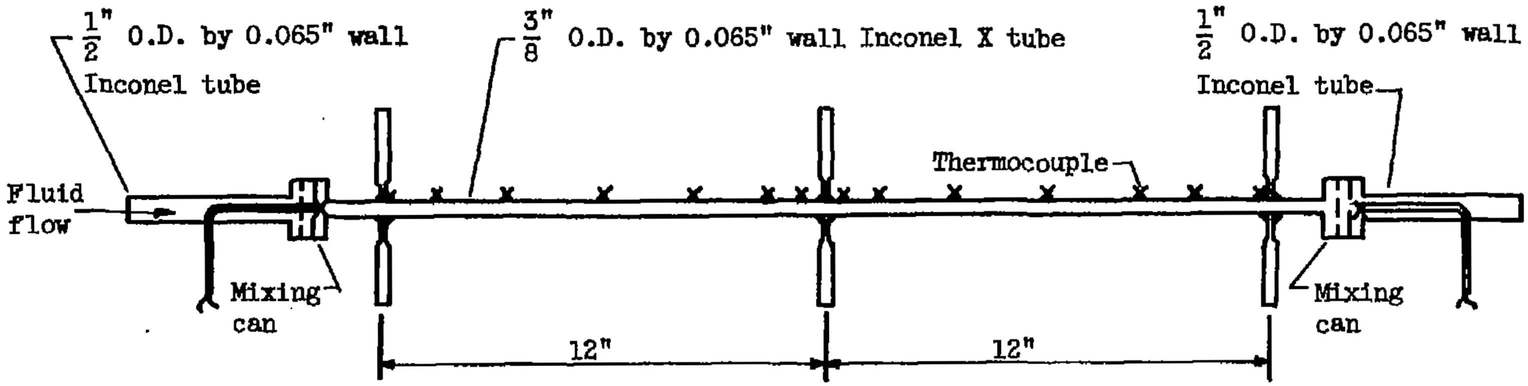


Figure 2. - Schematic drawing of test section.

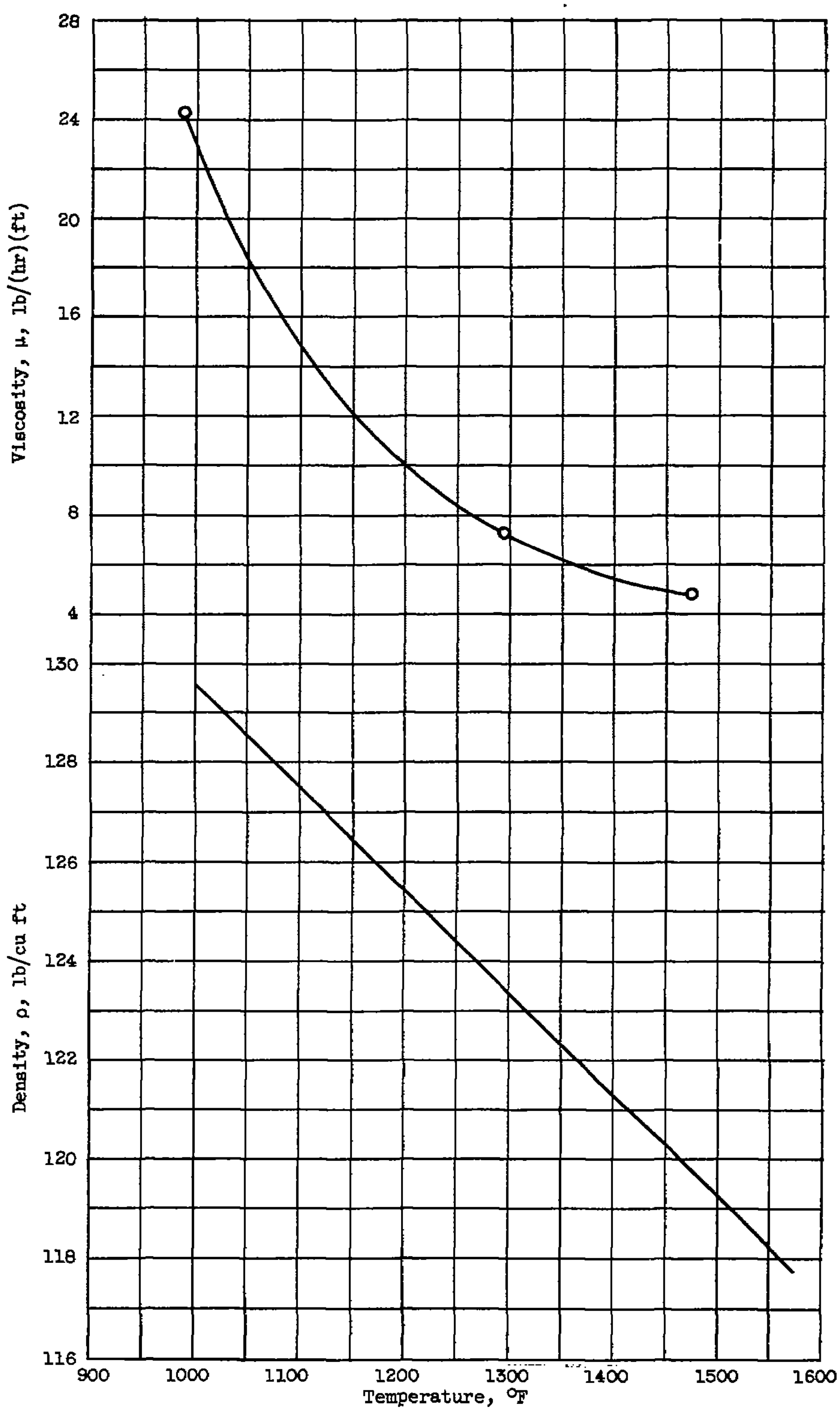


Figure 3. - Variation of viscosity and density of Flinak with temperature.

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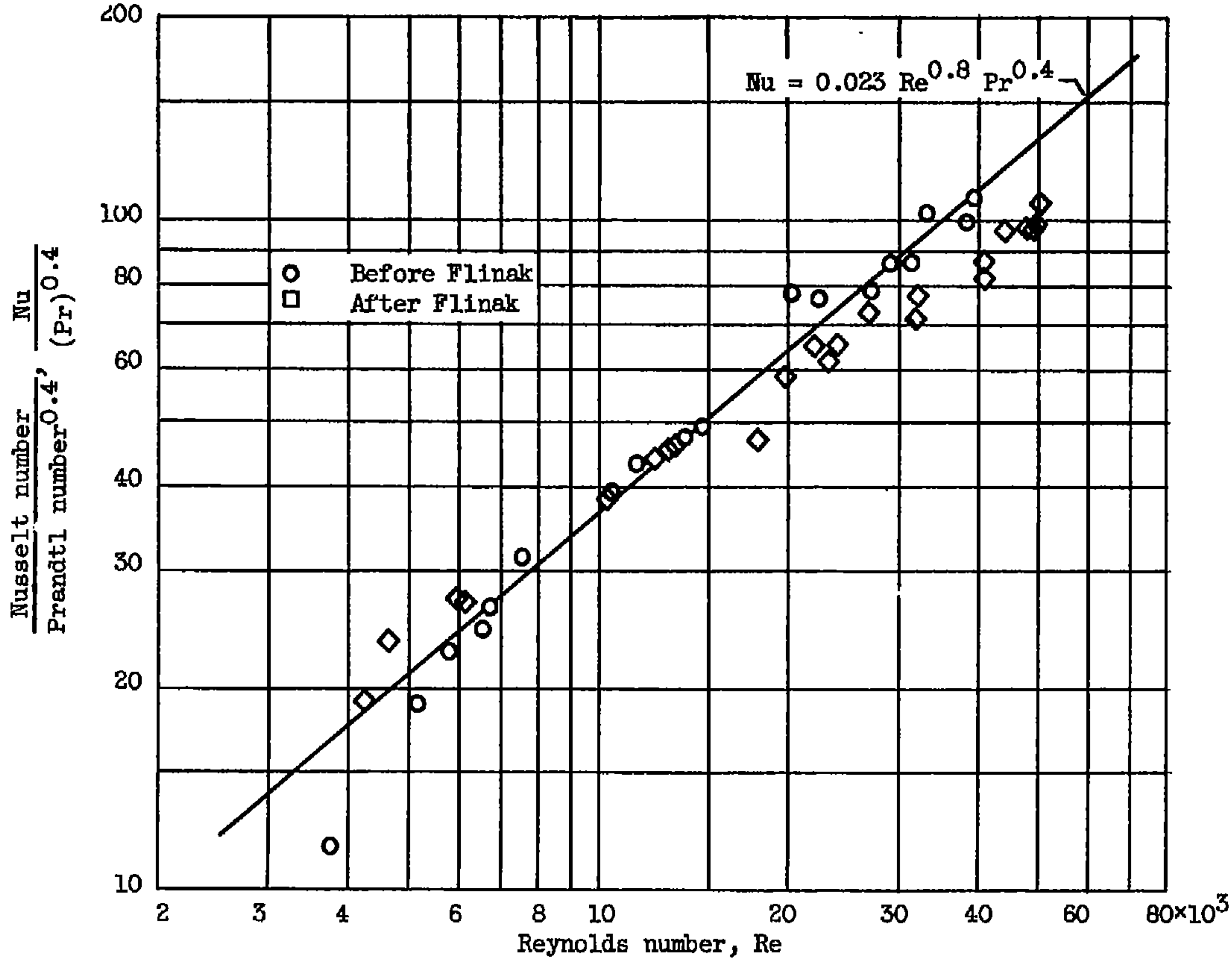

Figure 4. - Water heat-transfer data.

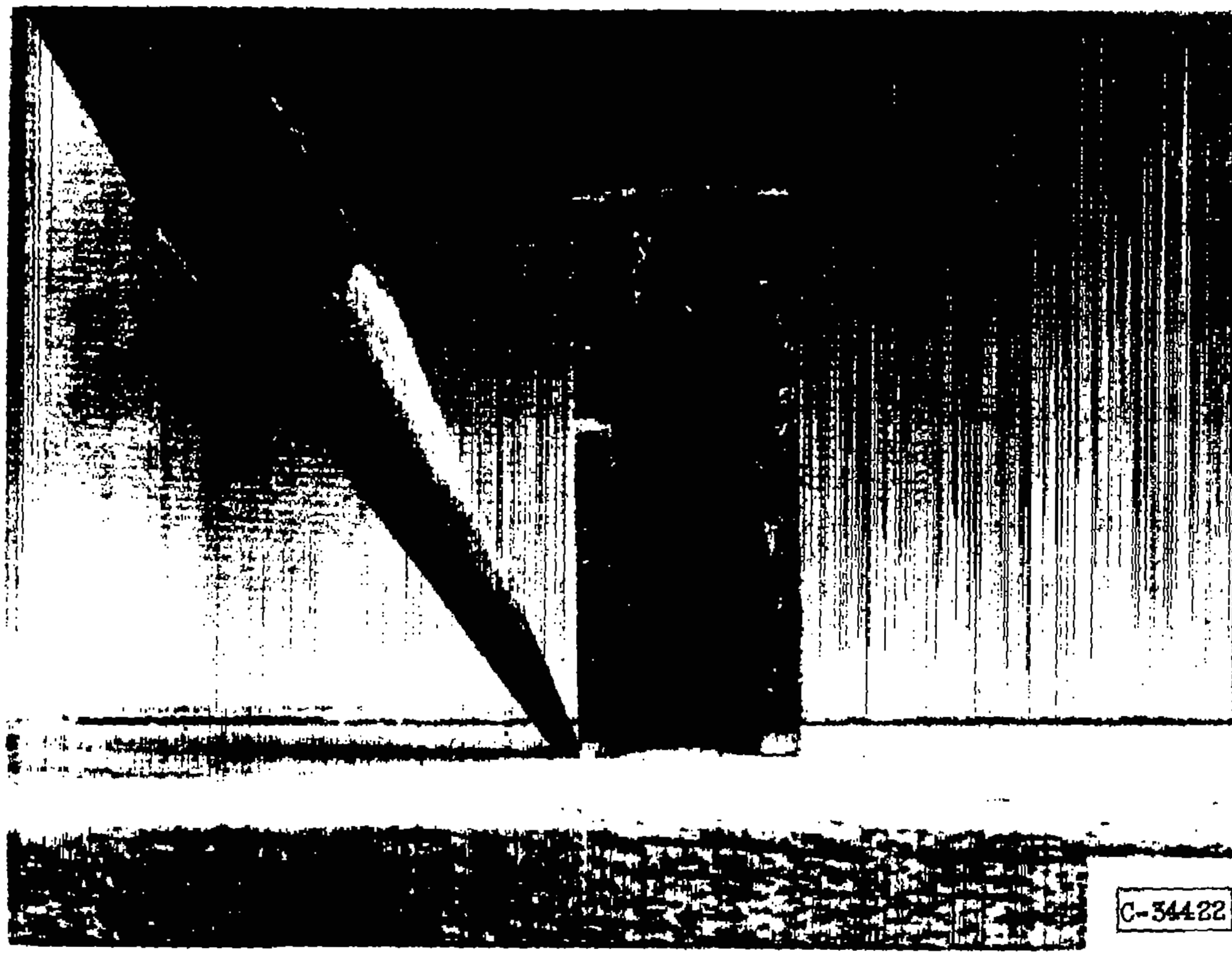

Figure 5. - Portion of test section after completion of tests.

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CO-3 back

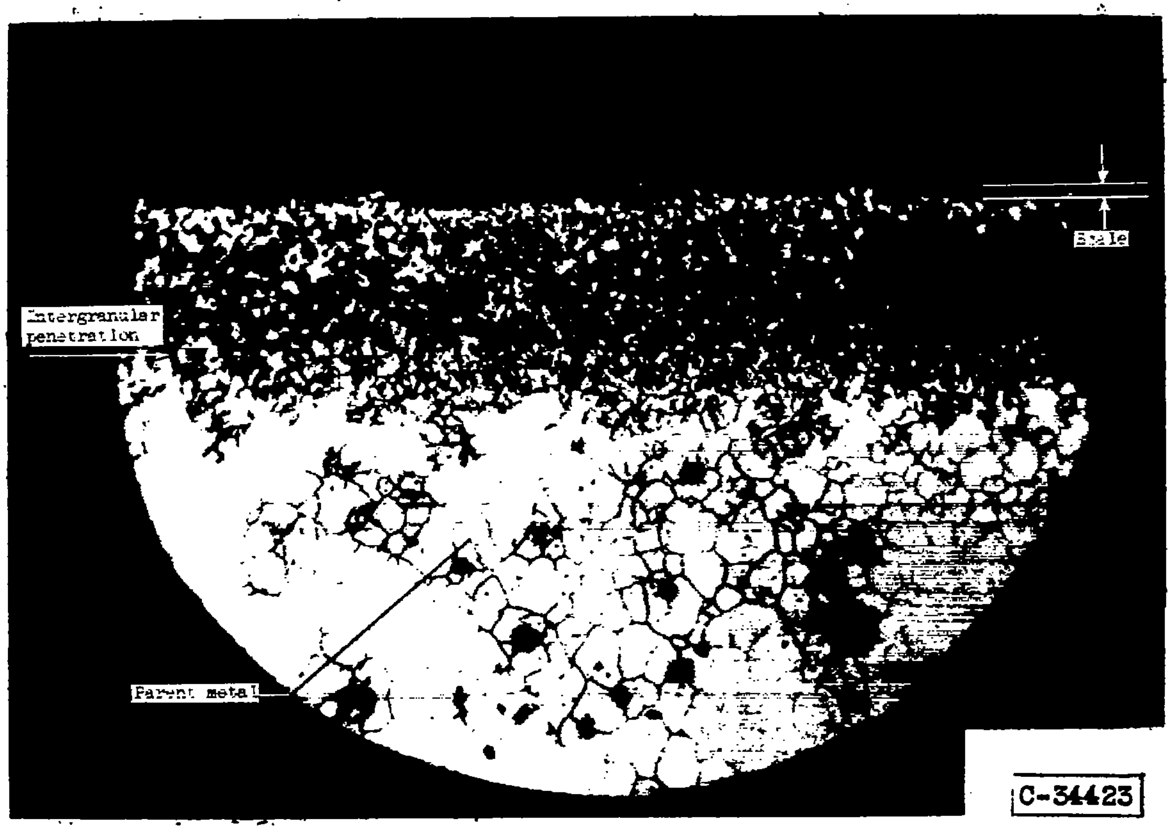

Figure 6. - Photomicrograph of Inconel X test section. X750.

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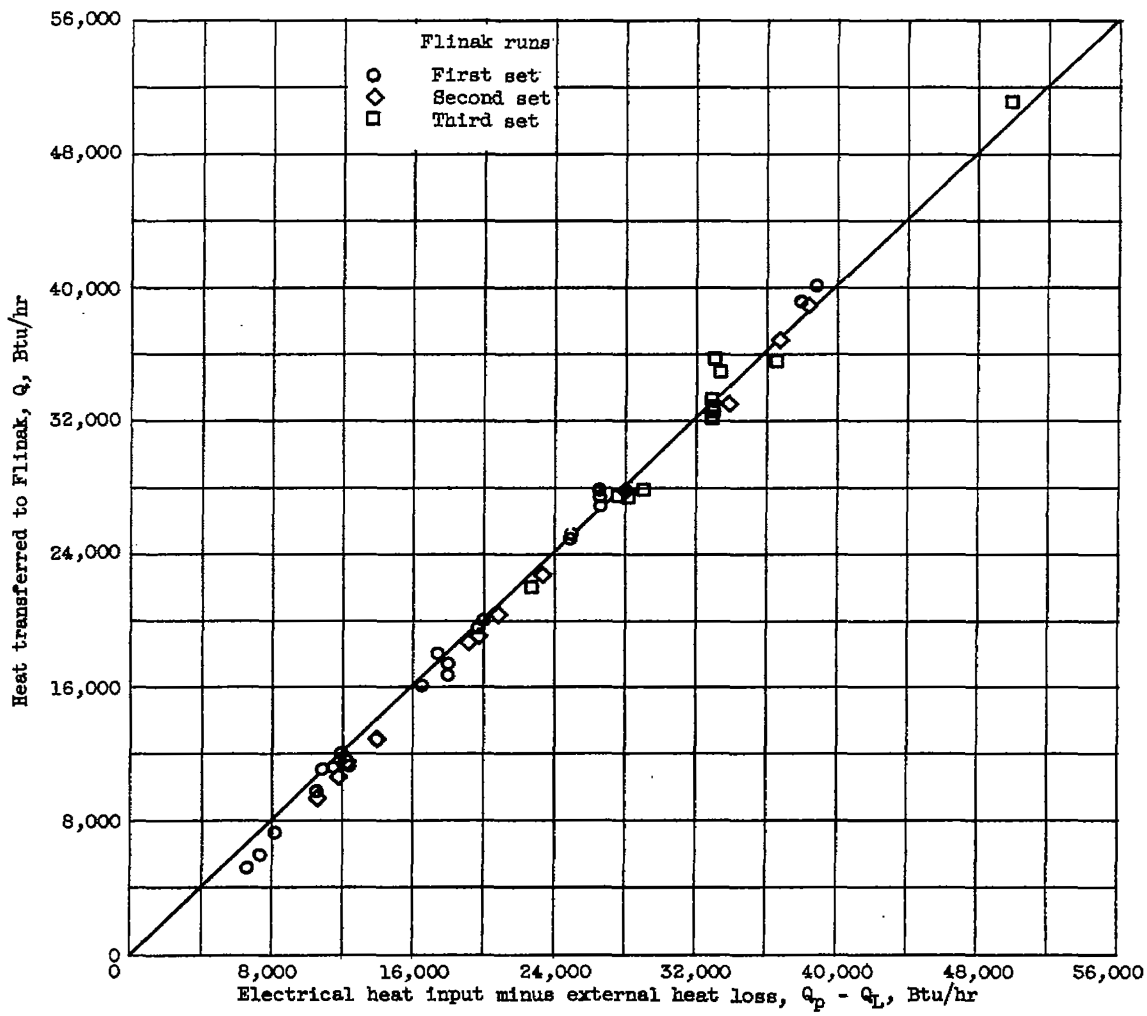

Figure 7. - Heat balance for Flinak.

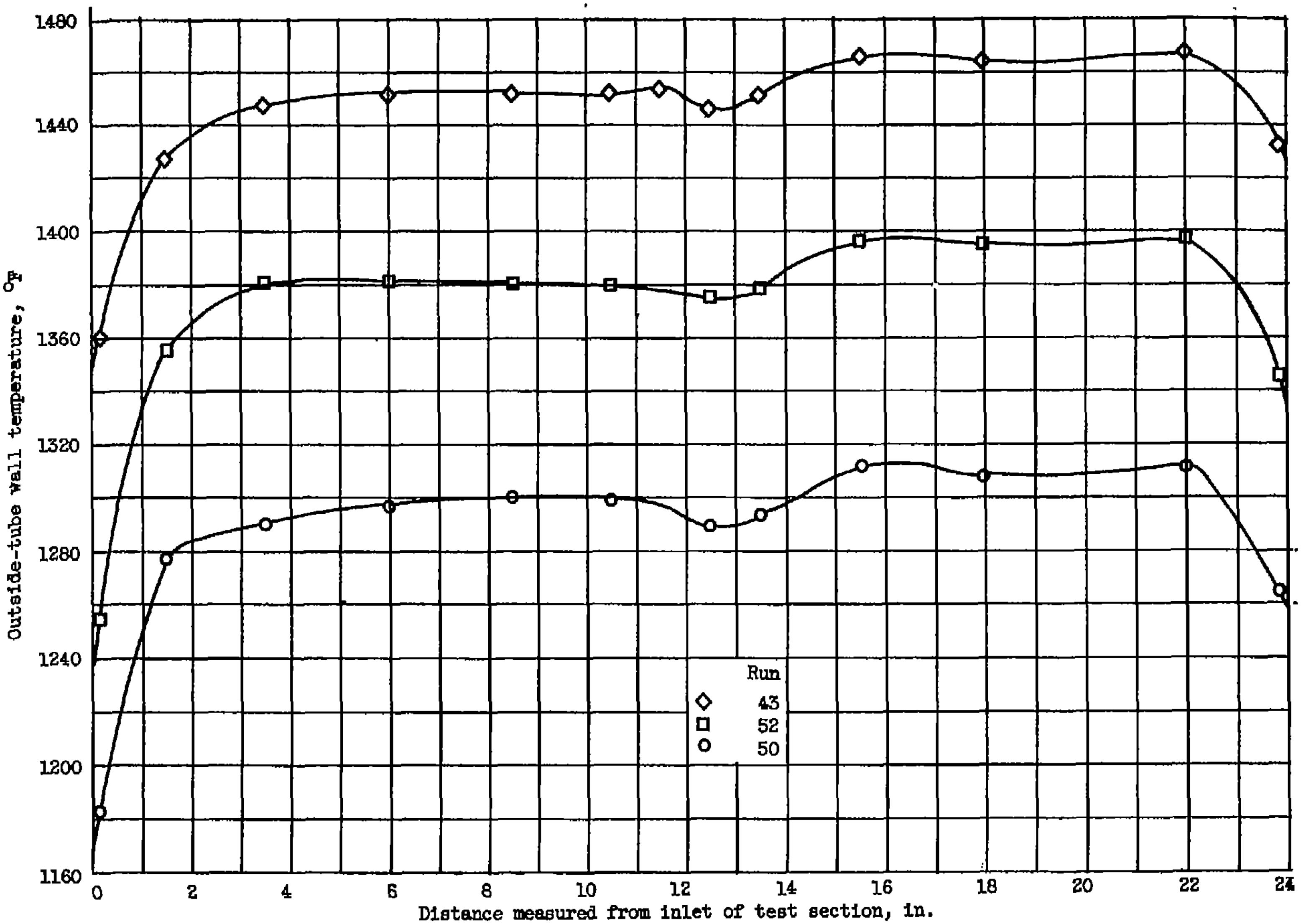

Figure 8. - Representative axial temperature distribution for test section.

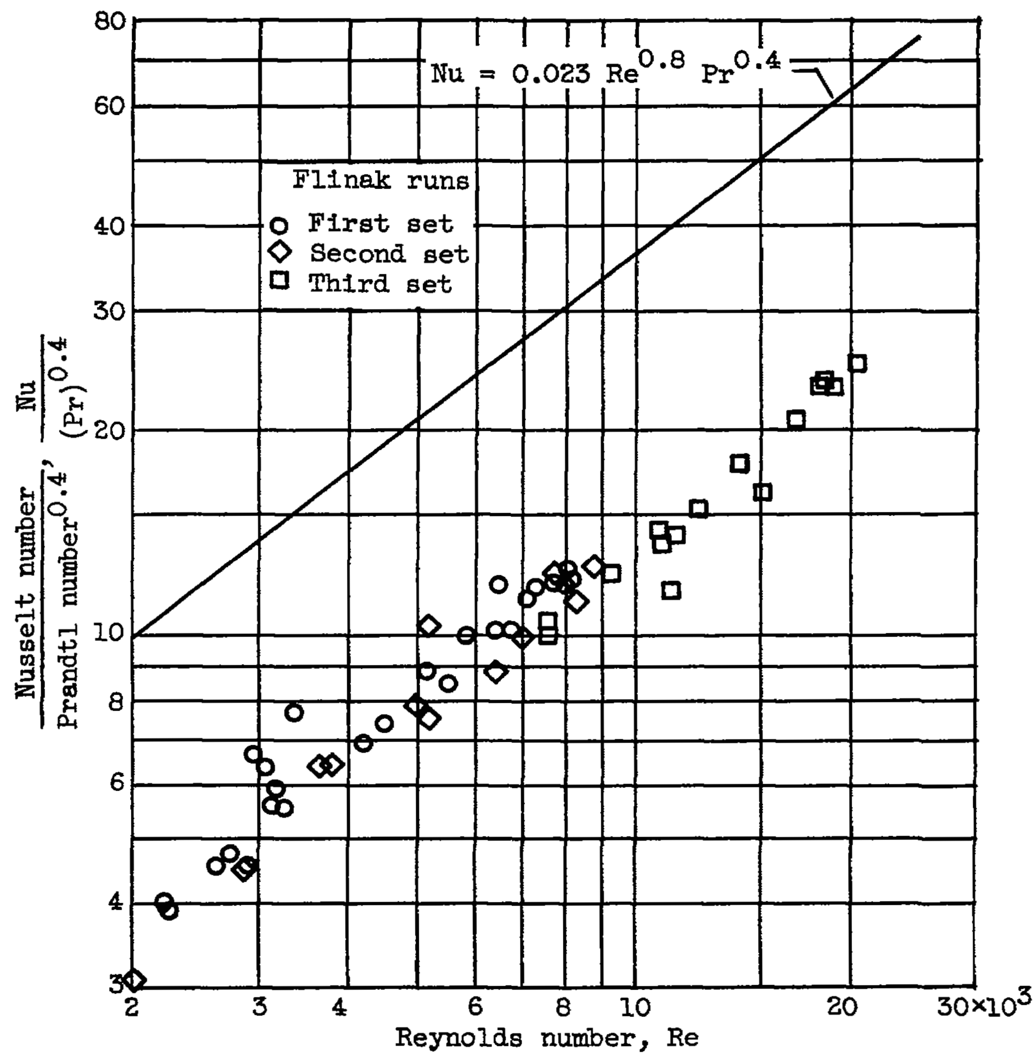

Figure 9. - Flinak heat-transfer data.

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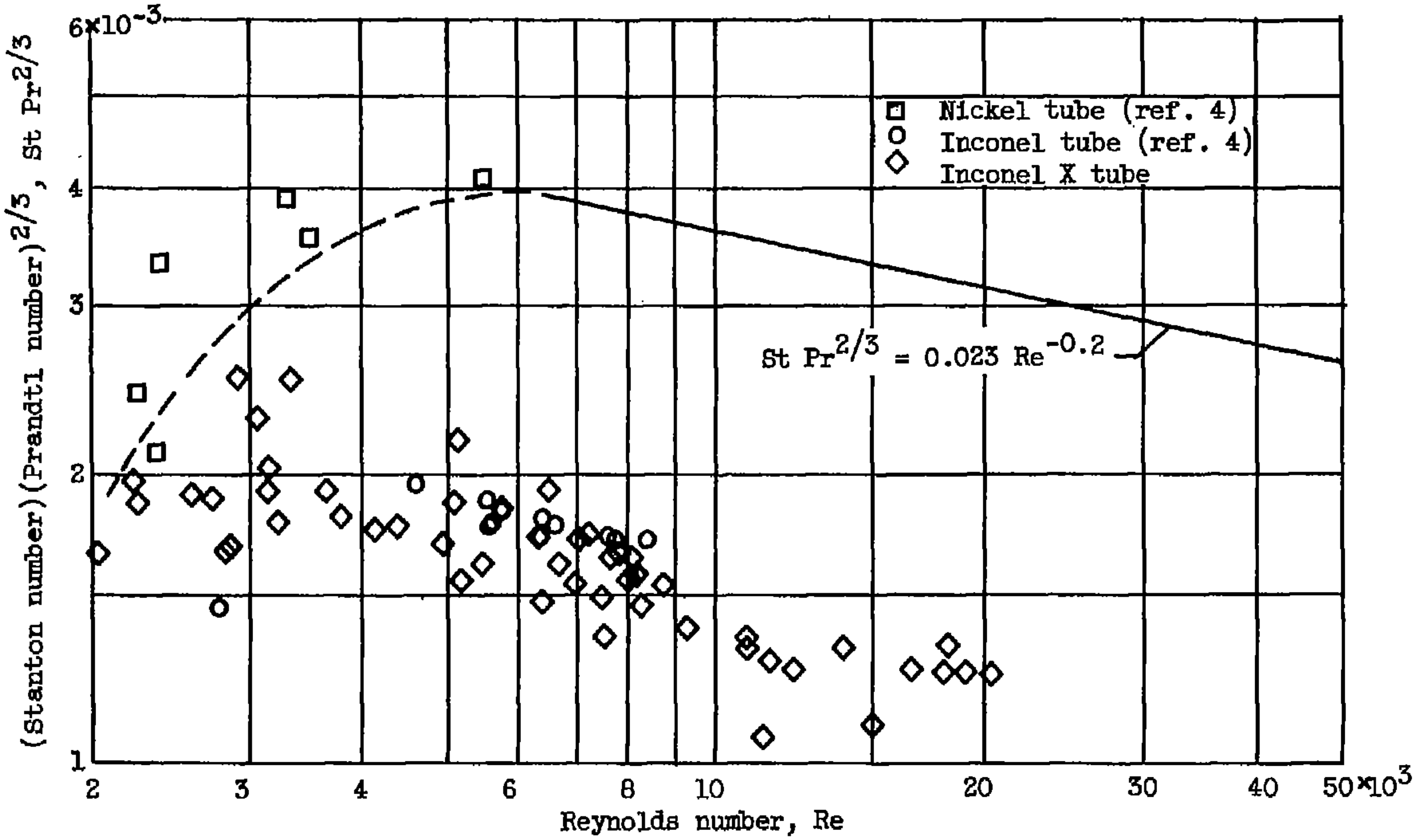

Figure 10. - Comparison of Flinak heat-transfer data.