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FROM: J. C. Amos, R. E. MacPherson, R. L. Senn

Abstract

Heat transfer data are presented over a Reynolds Number range of 400 to 8000 for the test fused salt Mixture No. 130 (62 mol % LiF - 37 mol % BeF_2 - 1 mol % UF_4) and for a calibrating fused salt Mixture No. 30 (50 mol % NaF - 46 mol % ZrF_4 - 4 mol % UF_4) flowing inside round heat exchanger tubes. A preliminary equation is developed for predicting shell-side heat transfer coefficients for liquid metal in turbulent, longitudinal flow over a square tube array having a pitch/diameter ratio of 1.165. An experimental value of the specific heat of fused salt Mixture No. 130 is also determined from the test data.

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Preliminary Report of Fused Salt Mixture No. 130 Heat Transfer Coefficient Test

Table of Contents

1.0 Introduction

The current concept of the Molten Salt Power Reactor involves the use of both fused salts and liquid metals as heat transfer media. Available literature on the heat transfer characteristics of these fluids does not include sufficient data to allow exact definition of heat exchanger design requirements. A series of tests has therefore been initiated to provide the required design data.

This preliminary report presents the results of heat transfer tests conducted on fused salt Mixture 130 (62 mol % LiF - 37 mol % BeF_2 - 1 mol % UF_4), one of several salts of interest for this power reactor application. Additional data are presented for fused salt Mixture 30 (50 mol % NaF - 46 mol % ZrF_4 - 4 mol % UF_4) which was run as a calibration fluid prior to operation with Mixture 130, and for NaK which served as the primary coolant in both the Mixture 30 and 130 tests. Mixture 30 was used as a standard primarily because of the availability of extensive data from other earlier tests.

2.0 Summary

Heat transfer data were obtained for fused salt Mixtures 30 and 130 flowing inside round tubes at Reynolds Numbers from 425 to 8000. The heat transfer performance correlations, based on available physical property values, developed from these data appear to be satisfactory for predicting heat transfer coefficients for these salts within ± 10%. Since the Mixture 130 data were correlated using estimated physical property values, inaccuracies in these values will be reflected in any comparison of the heat transfer correlations of this mixture with Mixture 30, or other more conventional fluids.

The test work was done on a tube and shell heat exchanger with the salt flowing inside round tubes counter-current to NaK (56 wt% Na, 44 wt% K) flowing longitudinally in the shell over closely spaced tubes (pitch/diameter ratio = 1.165) in square array.

Since no reliable means of predicting the shell-side heat transfer performance of the liquid metal was available in the literature, it was necessary to add to the program sufficient independent tests to allow development of a correlation for this purpose. The result was found to be in close agreement with work published by Tidball[1] for NaK in baffled shell heat exchangers.

Analysis of heat balances obtained during this test indicated the specific heat of fused salt Mixture 130 to be approximately 0.57 BTU/lb°F. A value of 0.62 ± 20% BTU/lb°F had been estimated initially.[2]

3.0 Description of Test Facility

3.1 Test Stand

A schematic flow diagram of the test facility is shown in Fig. 1. All components are Inconel. Heat is supplied to the fused salt by a 400 KW resistance heater. The heat is transferred from the salt flowing in the tubes to NaK flowing in the shell side of the test heat exchanger and is removed from the NaK by a 500 KW NaK-to-air heat dump. Salt and NaK flows are measured by venturis equipped with Moore Nullmatic pressure measuring devices. NaK flow is also measured with an electromagnetic flow meter. Temperatures are measured with 20 gage chromel-alumel thermocouples and read on a Brown 48 point temperature indicator. The NaK loop is equipped with a circulating cold trap for oxide control. This test facility, designated Small Heat Exchanger Stand C (SHE-C), is shown in Figs. 2 and 3.

3.2 Test Heat Exchanger

The test heat exchanger contains 25 - 3/16" O.D. x 0.025" wall Inconel tubes arranged in a square array, spaced with .031" x.056" flattened Inconel wire and enclosed in an Inconel shell. This heat exchanger, designated as type SHE-7, is shown in Fig. 4. Dimensional parameters are given in Fig. 5. The heat exchanger was operated as a counter-flow unit with fused salt inside the tubes and NaK outside the tubes.

4.0 Test Procedure

The test operation included the following steps:

A. The NaK loop was filled at room temperature and the NaK and empty fused salt systems brought up to approximately 1200°F with NaK circulating. During system heat-up, the NaK circulating cold trap outlet temperature was maintained at approximately 300°F by water cooling to maintain a low level of oxide in the NaK system.

B. When the system reached 1200°F, fused salt Mixture No. 70 (56 mol % NaF - 39 mol % ZrF_4 - 5 mol % UF_4) was raised into the salt system

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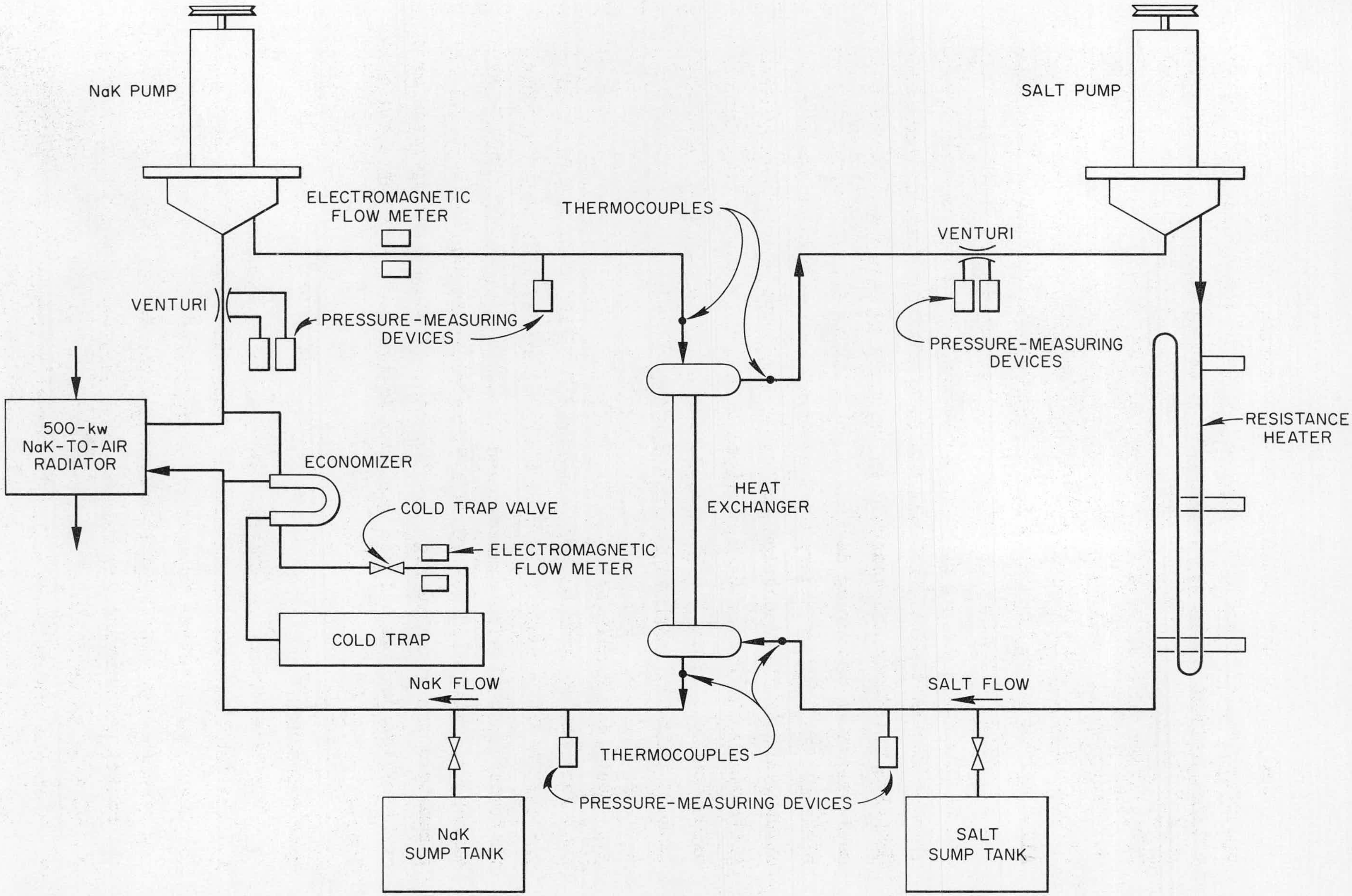

Fig. 1. Schematic Flow Diagram, Small Heat Exchanger Test Stand - C.

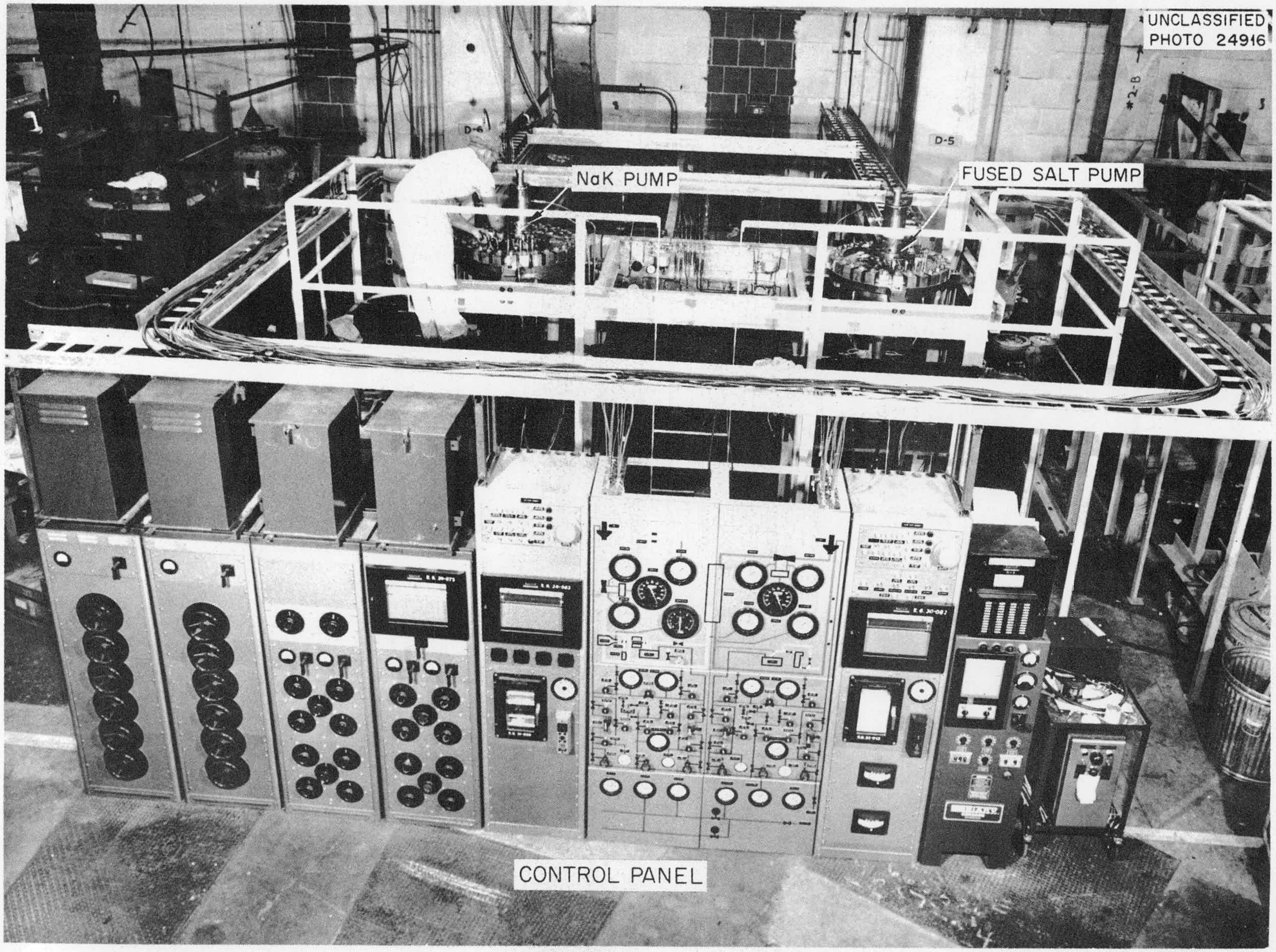

Figure 2 Photograph of Test Stand

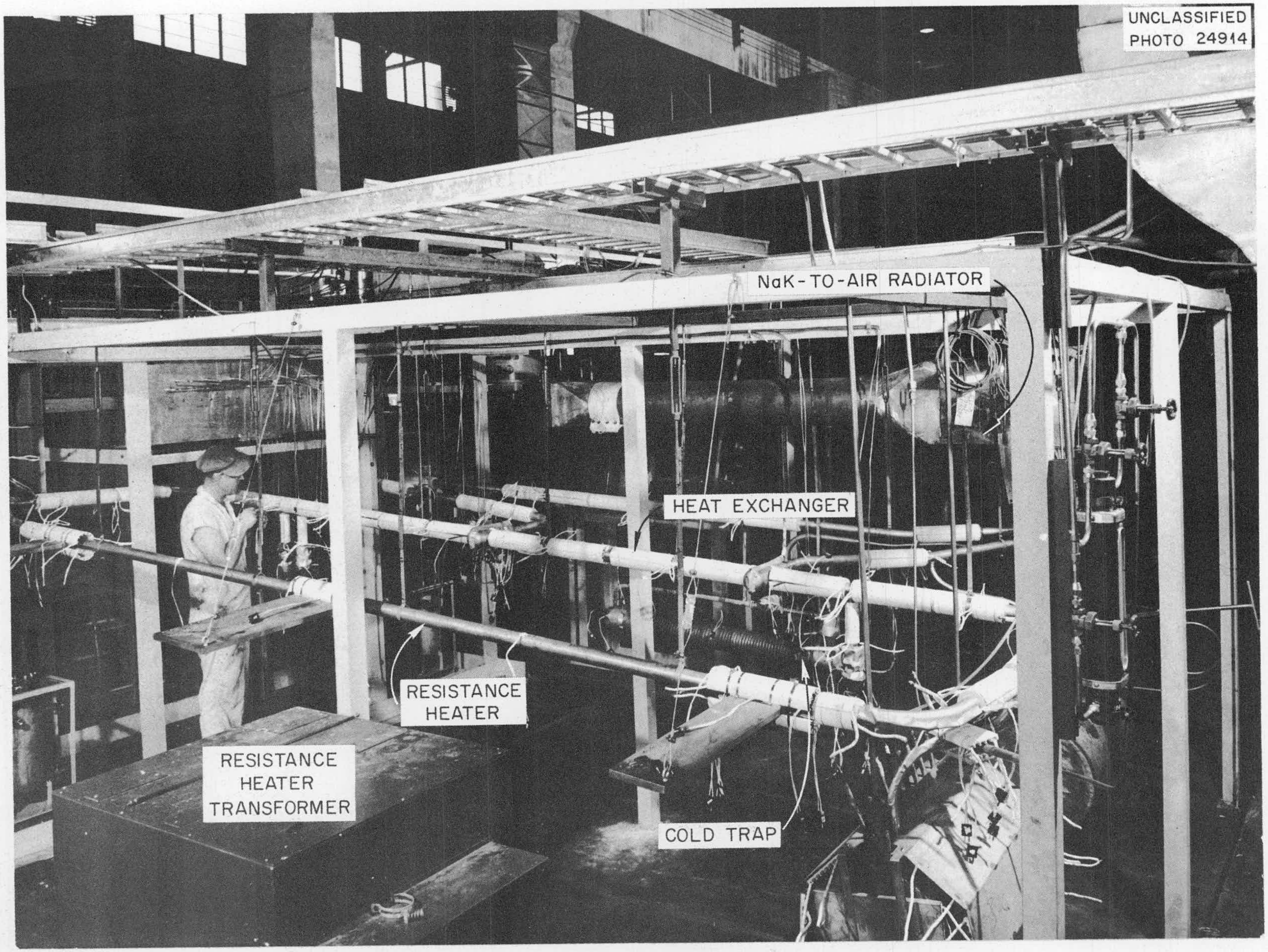

Figure 3 Photograph of Test Stand

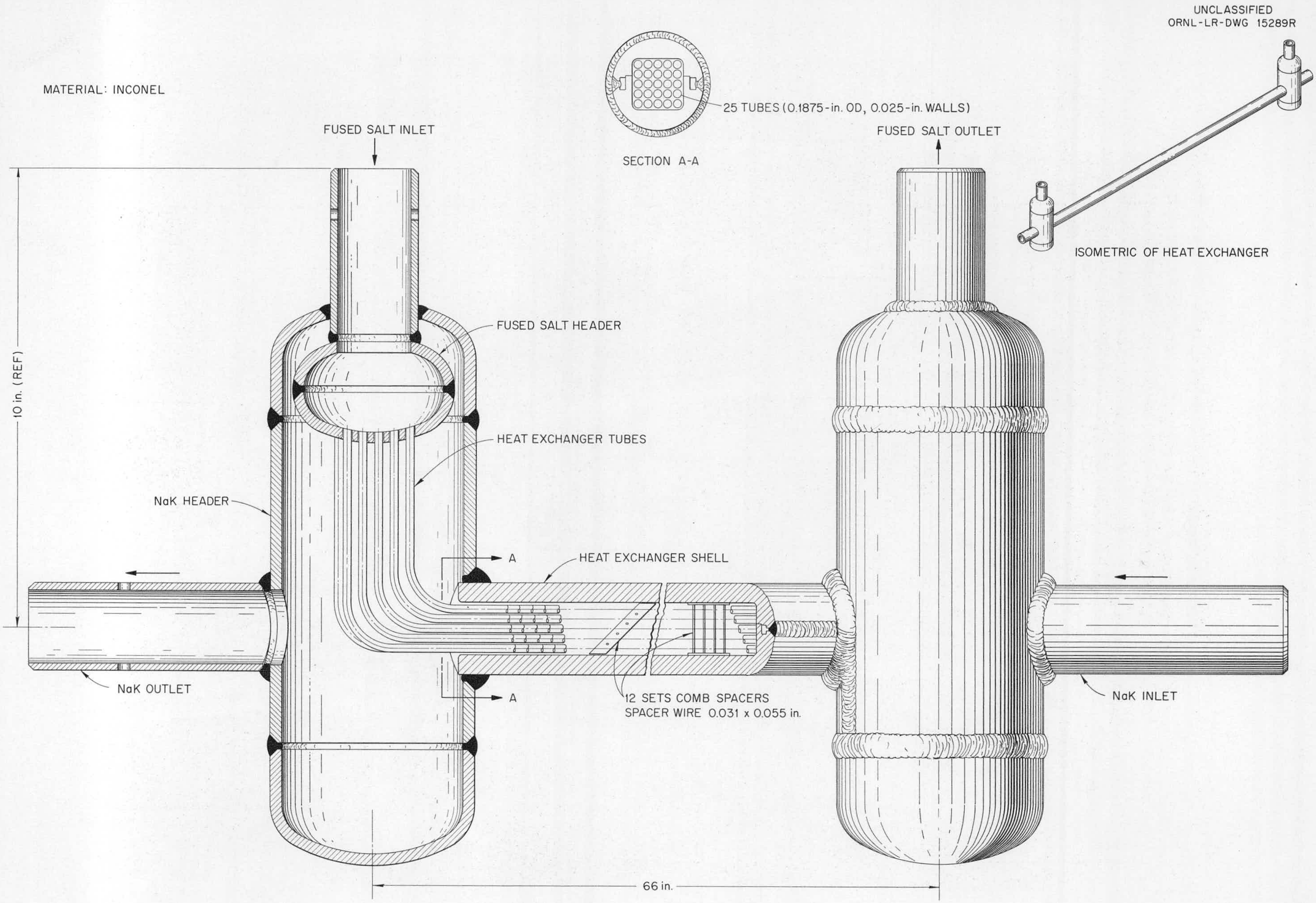

Fig. 4. Small Heat Exchanger Type SHE-7

Figure 5

Tabulation of
Type SHE-7 Heat Exchanger
Dimensional Parameters

Tube material	Inconel
Number of tubes	25
Tube O.D.	.1875 inches
Tube I.D.	.1375 inches
Tube wall thickness	.0250 inches
Number of spacers	12
Spacer Dimensions	.031" x.056"
Fused salt flow length	6.17 ft.
Fused salt free flow area	0.002595 $ft.^2$
Fused salt heat transfer area	4.93 $ft.^2$
NaK flow length	5.5 ft.
NaK free flow area	0.00428 $ft.^2$
NaK heat transfer area	6.73 $ft.^2$
NaK equivalent diameter	0.0107 ft.

and circulated for 67 hours to clean the system. The cleaning charge was then drained and replaced with a new charge of fused salt Mixture 30.

C. The NaK and fused salt pumps were stopped and the pressure measuring devices calibrated against system surge pressure over a range of 5 to 30 psi. These calibrations were repeated at intervals throughout the test.

D. With the system operating isothermally at 1200°F, fused salt and NaK pressure drop measurements were taken over maximum flow ranges.

E. A heat load was placed on the heat exchanger and thirty-five (35) data points obtained. Twenty-four of these points were taken with constant NaK flow, with the fused salt flow varied over a 425 - 6100 Reynolds Number range to establish fused salt Mixture 30 heat transfer performance. Eleven data points were taken at constant fused salt flow, with the NaK flow varied over a 60,000 to 100,000 Reynolds Number range, to provide data for determining the NaK heat transfer coefficient by means of a modified Wilson Plot.(3)

F. Fused Salt Mixture 30 was removed from the system and replaced with fused salt Mixture 130. The pressure measuring devices were recalibrated and 1200°F isothermal fused salt Mixture 130 pressure drop data obtained.

G. A heat load was placed on the system and seventy (70) heat transfer data points obtained. Forty-seven of these points were at constant NaK flow, with the fused salt varied over a 750 - 8000 Reynolds Number range to establish fused salt Mixture 130 heat transfer performance. Twenty-three data points were taken at two different fused salt flows to obtain additional data for establishing a heat exchanger shell-side NaK heat transfer coefficient.

Throughout the course of fused salt Mixture 130 test operations, air sampling devices were operated continuously to determine the level of beryllium contamination in the area. Analysis of samples indicated that beryllium contamination was well below the maximum allowable concentration throughout the test. A tabulation showing the results of this sampling is included in Appendix 8.9.

Total operating time for this test was 682 hours.

5.0 Discussion of Results

5.1 $Nu/Pr^{0.4}$ vs Reynolds Number Correlation - Fig. 6

The correlations of $Nu/Pr^{0.4}$ vs Reynolds Number for Mixture 130 and Mixture 30 are presented in Fig. 6. These correlations appear to be satisfactory for determining the heat transfer coefficients of both salt mixtures for flow in round tubes within ± 10% by back-calculation using the physical property values presented in the Appendix of this report. Accuracy of these correlations for predicting heat transfer coefficients is limited by the accuracy of the NaK side heat transfer correlation used in processing the data. As pointed out in Section 4.0, this NaK side correlation was independently determined, during the test program, using a modified Wilson Plot approach. The NaK shell-side heat transfer correlation is discussed in Section 5.3.

Fig. 6 compares the performance of the two test salts to (1) a correlation independently obtained(2) for Mixture 12 (11.5 mol % NaF - 42 mol % KF - 46.5 mol % - LiF) flowing in stainless steel and nickel tubes and (2) a correlation for Mixture 30 flowing in the shell of heat exchangers essentially identical to the present test unit.(4)

It can be seen that, with increasing Reynolds Number, all the correlations are approaching the Dittus-Boelter relationship for turbulent flow of ordinary fluids in ducts.(5) The difference in slope and location of the data curves for tube flow and shell flow in the upper laminar and lower transitional flow regions is thought to be due to the geometry of the shell side of the closely spaced tube bundle which includes flattened wire spacers at frequent intervals throughout the length of the heat transfer section. These spacers tend to promote turbulence at Reynolds Numbers normally associated with laminar flow. Boundary layer effects are thereby lessened, resulting in improved heat transfer performance. The friction factor data for these tests, as presented in Fig. 10 and discussed in Section 5.5, tend to confirm this view.

Experimental physical property values for Mixture 130 are currently being obtained by others and will be applied to the Mixture 130 correlation when available. The reasonable agreement of tube side performance for salt Mixtures 12, 30, and 130 gives reason to believe that

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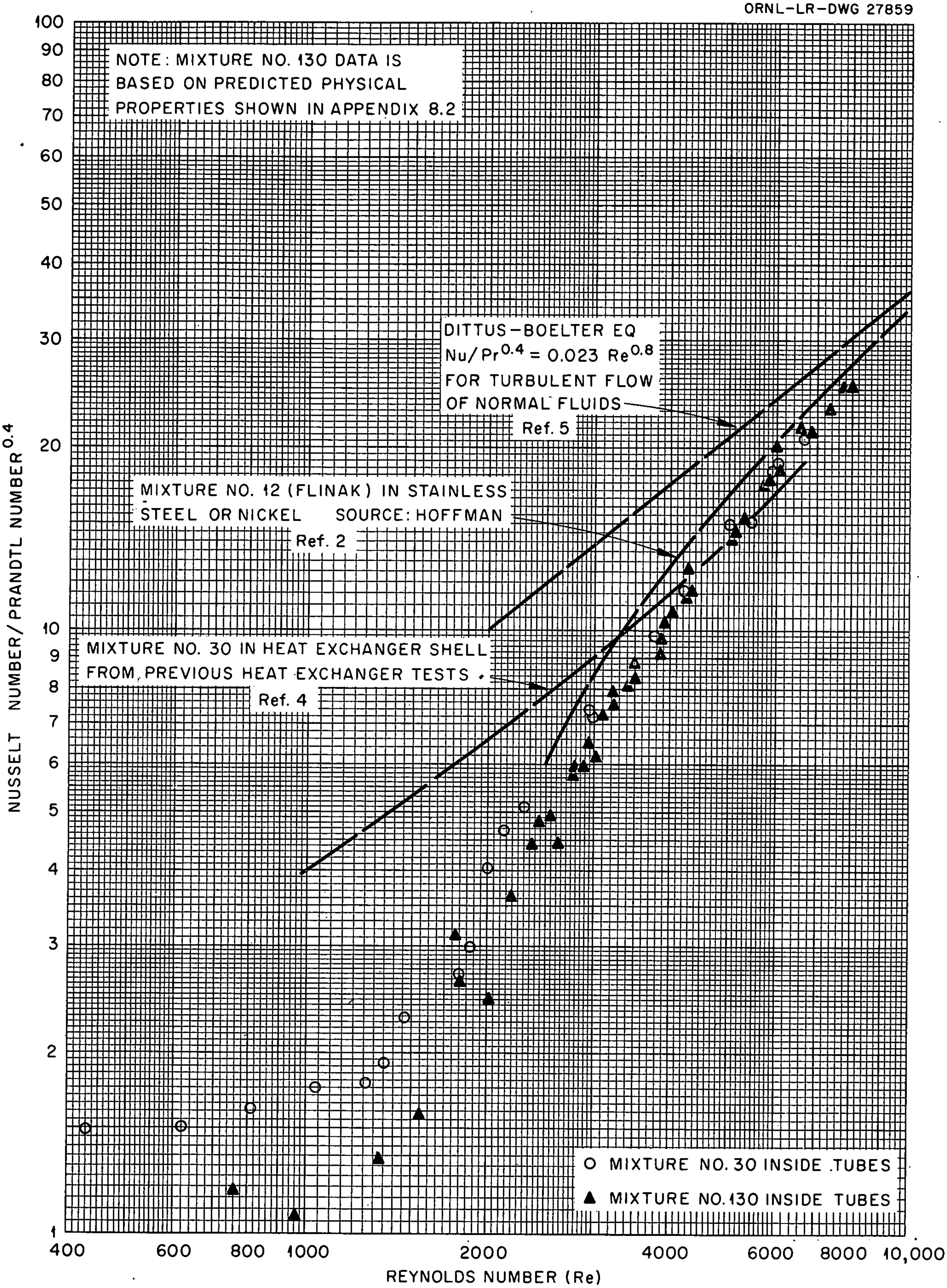

Fig. 6. $Nu/Pr^{0.4}$ vs Reynolds Number Correlation.

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the currently available physical property values are not sufficiently in error to seriously affect the present correlation.

5.2 Colburn j-Factor Correlation - Fig. 7

The fused salt data were also correlated on the basis of the Colburn j-factor,[6] which is an accepted method for representing heat transfer performance in the transition and laminar flow region. It will be noted from Fig. 7 that the general shape of the data curve is consistent with classical j-factor curves for fluids and gases.

Comparison of the fused salt Mixture 30 data with data obtained by Hoffman[7] for the same salt flowing in a single tube shows the Colburn j-factor obtained from this test to be approximately 20% higher than that obtained by Hoffman. Part of this discrepancy may be due to the method used for predicting the NaK heat transfer performance for this test, which could lead to over-estimation of the salt film heat transfer coefficient. Another factor which may influence a direct comparison is that Hoffman reports evidence of a non-wetting condition at the salt-metal interface during his test. Such a condition could seriously interfere with heat transfer performance.

5.3 NaK Shell Side Correlation - Fig. 8

The accuracy of the Wilson graphic method (see Appendix 8.44) for determining heat transfer performance is limited by the accuracy with which the test data can be extrapolated to infinite fluid flow for the system being treated. During this test, three independent groups of data were obtained. Analysis of these data indicates that all reasonable and consistent extrapolations of the independent groups agree within ± 10%. Further test work has been planned to obtain a more accurate definition of this NaK shell-side correlation.

Fig. 8 shows the NaK heat transfer correlation developed from this test compared with various other heat transfer correlations on the basis of Nusselt Number vs Reynolds Number. It is of interest to note that the correlation developed from this test is in close agreement with correlation No. 5, developed by Tidball[2] for NaK in a baffled-shell heat exchanger.

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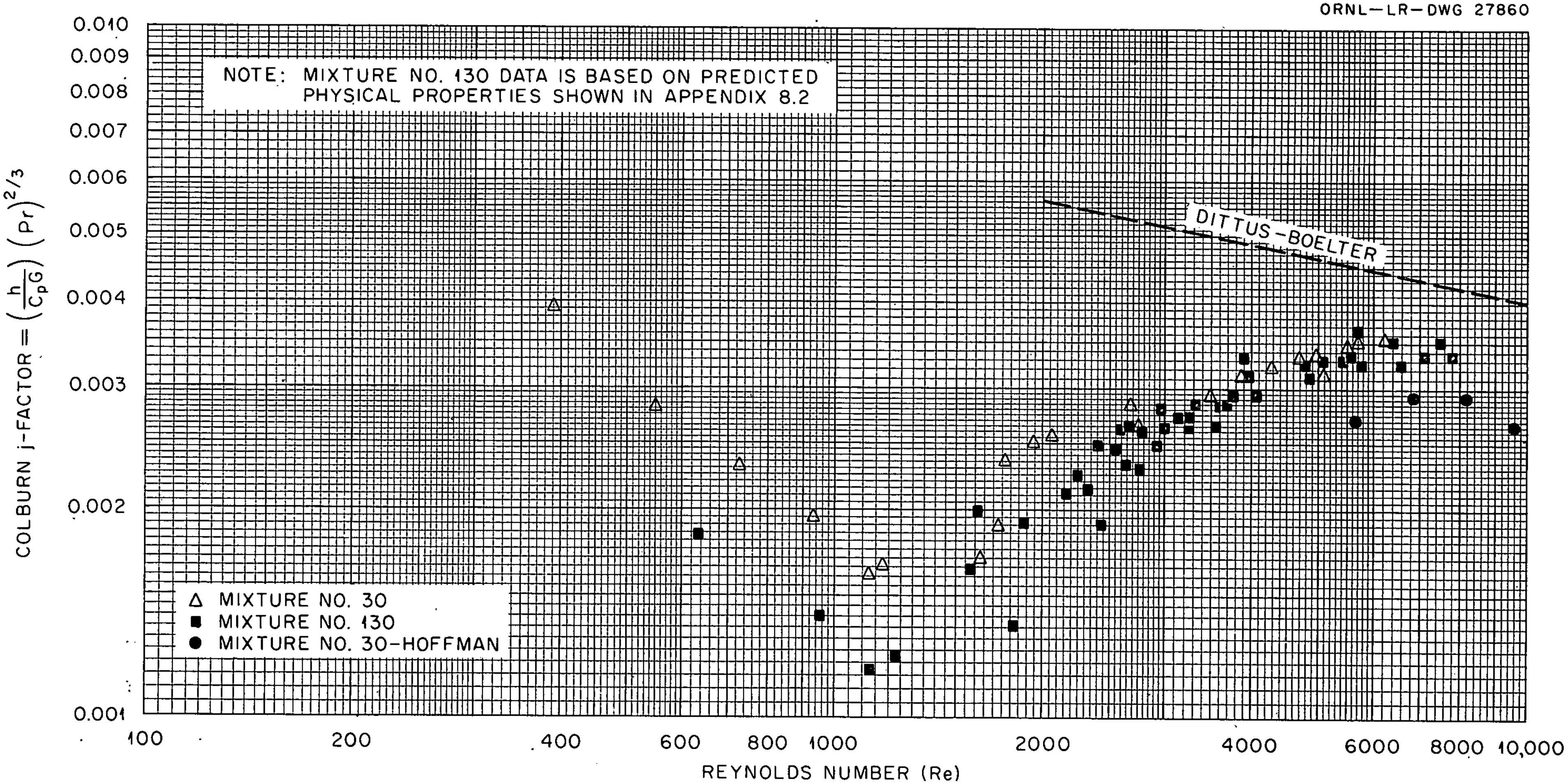

Fig. 7. Colburn j-Factor vs Reynolds Number Correlation.

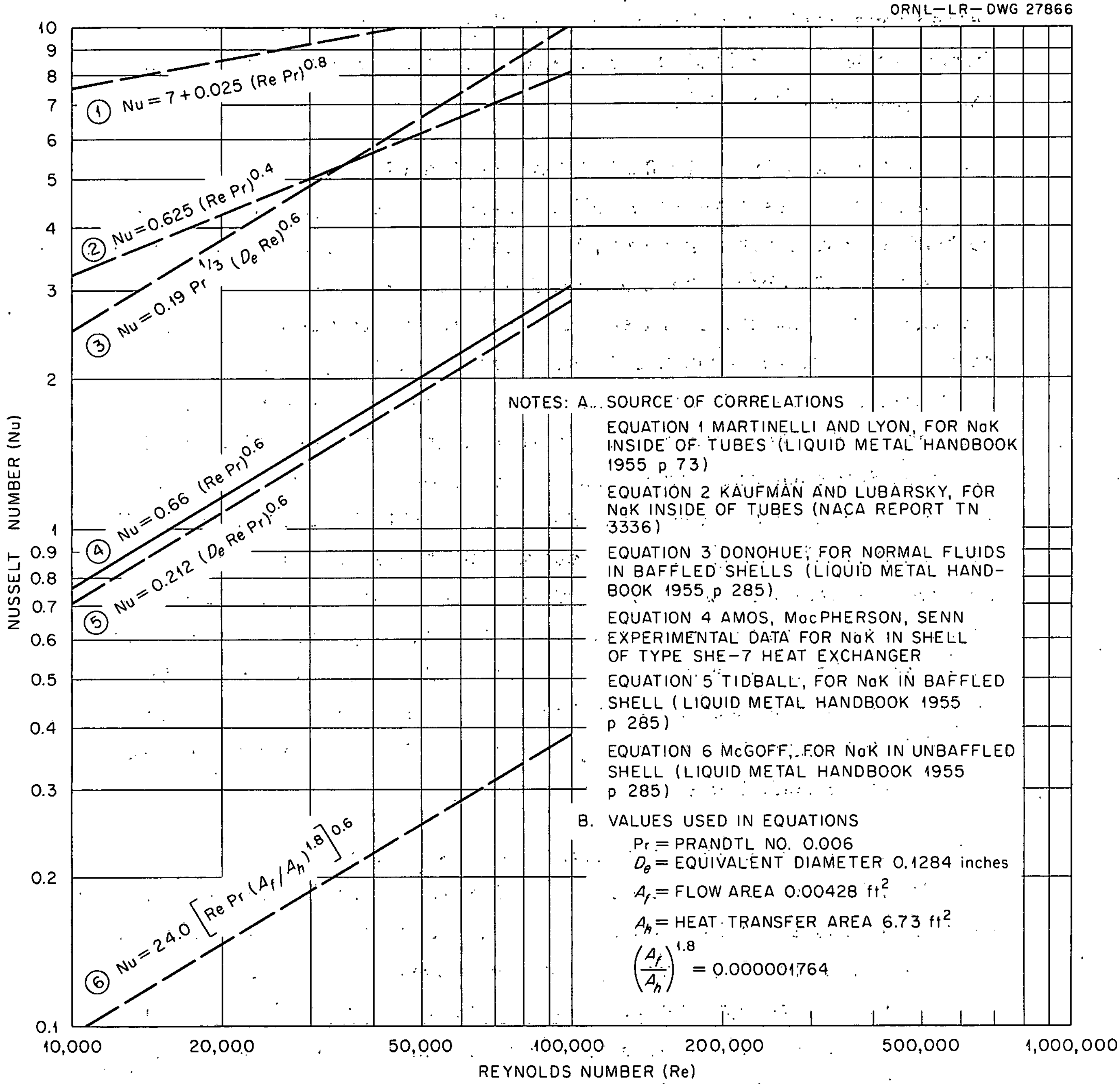

Fig. 8. Comparison of Various NaK Heat Transfer Correlations.

Correlation No. 6 for NaK in unbaffled shells[2] is included for academic interest only and is probably not valid for a heat exchanger with compact tube spacing due to the exceptionally small flow area to heated area ratio for this type of heat exchanger. The $(A_f/A_h)^{1.8}$ factor in this correlation for the heat exchanger employed in this test equals 1.764×10^{-6}.

5.4 Mixture 130 Specific Heat Determination (Fig. 9)

Heat balances were in excellent agreement throughout the Mixture 30 heat transfer run. However, Mixture 130 heat balance data were approximately 10% above the measured NaK heat load throughout the Mixture 130 run. Heat exchanger fused salt friction factor determinations for both salts were in substantial agreement, indicating reliable salt flow measurements. In addition, the relationship between the resistance heater heat inputs and the NaK heat load remained essentially the same for both salt runs. On the basis of the above observations, it was concluded that the value for the specific heat of Mixture 130 of 0.62 BTU/lb°F ± 20% used in determining the salt heat load must be in error at least to the extent of the discrepancy. Specific heat values were therefore back-calculated from the experimental NaK heat balances. The results are shown in Fig. 9 for all Mixture 130 heat transfer runs. On the basis of these data, an average specific heat value of 0.57 BTU/lb°F was assigned Mixture 130, and this value was used in the calculations.

5.5 Fused Salt Pressure Drop Correlation - Fig. 10

Fig. 10 presents the results of Mixture 30 and 130 friction factor determinations for salt flowing inside round tubes. The results for the two salt mixtures, corrected for estimated entrance and exit effects, are in good agreement. They lie above a conventional relationship[8] for smooth pipe and slightly below another reference[9] for drawn tubing of approximately the same internal diameter as that used in the test piece.

It is interesting to note that the friction factor for longitudinal flow of Mixture 30 over closely spaced, square pitch tube bundles reflects the mechanism of transition to semi-turbulent flow at low

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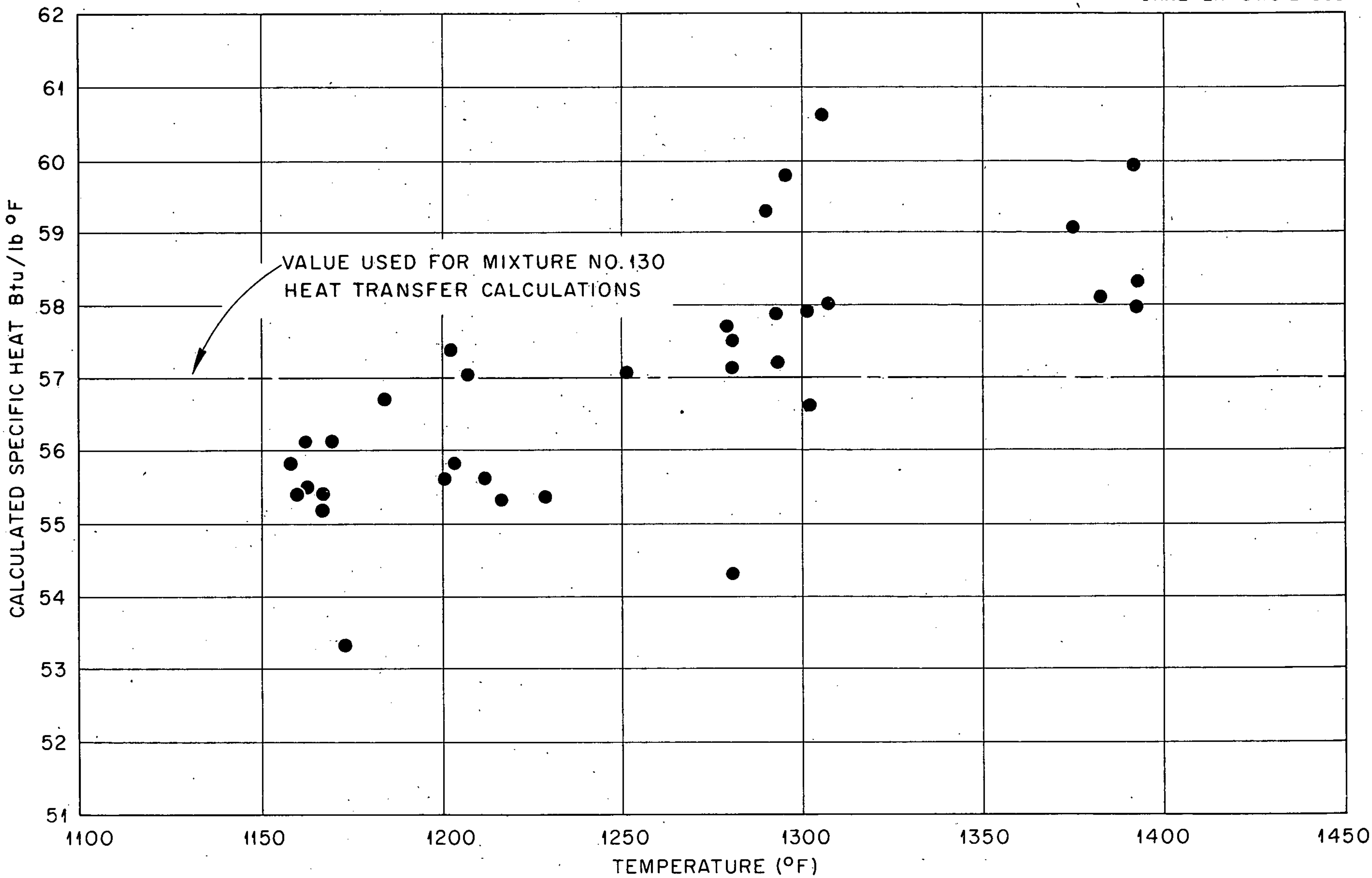

Fig. 9. Specific Heat for Mixture No. 130 Calculated from NaK Heat Balance.

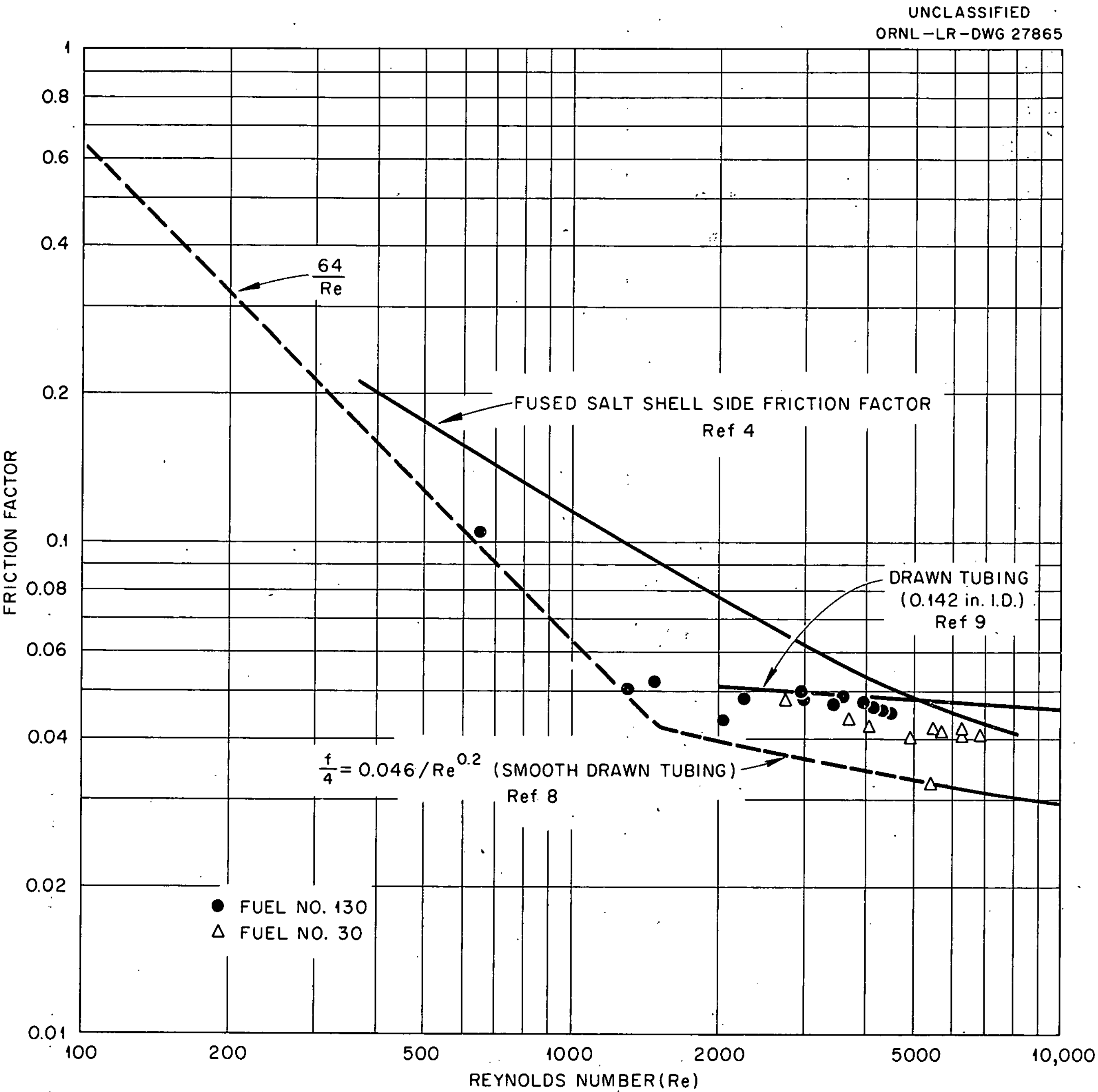

Fig. 10. Fused Salt Tube-Side Friction Factor vs Reynolds Number (Corrected for Entrance, Exit, and Bend Losses)

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Reynolds Numbers which was previously referred to in the discussion of Fig. 6. At Reynolds Numbers in the upper transition region (above 5000), shell side and tube side friction factors appear to be coming into agreement.

6.0 Future Tests

A. It is proposed to utilize this test facility in a similar manner to determine the heat transfer performance of other fused salts of interest to the Molten Salt Reactor Project as these salts become available. The next salt scheduled for testing is Mixture 84 (35 mol % LF - 27 mol % NaF - 38 mol % BeF_2).

B. It is also planned to modify the test facility so that either a Mixture 130 or 84 test can be re-run with fused salt Mixture 30 in the shell side of the test heat exchanger. Comparison of the data obtained from this test with data for the same fused salt mixture in the heat exchanger tubes with NaK in the shell will provide a verification of the NaK heat transfer correlation developed experimentally.

C. Endurance testing of small scale prototype molten salt powered reactor heat exchangers is proposed to get under way early in fiscal year 1960. These tests will provide an excellent opportunity for verifying the heat transfer performance characteristics predicted for fluids of interest in heat exchanger shells of similar geometry to heat exchanger designs proposed for molten salt reactor application.

7.0 Bibliography

(1) Hoffman, H. W., Umpublished Data.

(2) Liquid Metals Handbook, Na-NaK Supplement, TID 5277, July 1, 1955, p. 285.

(3) Wilson, E. E., Transactions A.S.M.E., 37, 34, 1915.

(4) Amos, J. C., Umpublished Data.

(5) McAdams, W. H., Heat Transmission, Third Edition, 1954, p. 219.

(6) Colburn, A. P., Trans. Am. Inst. Chem. Engrs., 29, 174-210 (1933).

(7) Hoffman, H. W., Fused Salt Heat Transfer, Oak Ridge National Laboratory Memorandum CF-56-7-85, July 20, 1956, p. 7, Secret.

(8) Op. Cit., Heat Transmission, p. 155.

(9) Flow of Fluids, Crane Co. Technical Paper No. 409, May, 1942, p. 6.

(10) Pump Engineering Data, Economy Pumps, Inc., 1954, pp. 53-54.

(11) Op. Cit., Liquid Metals Handbook, p. 80.

8.0 Appendix

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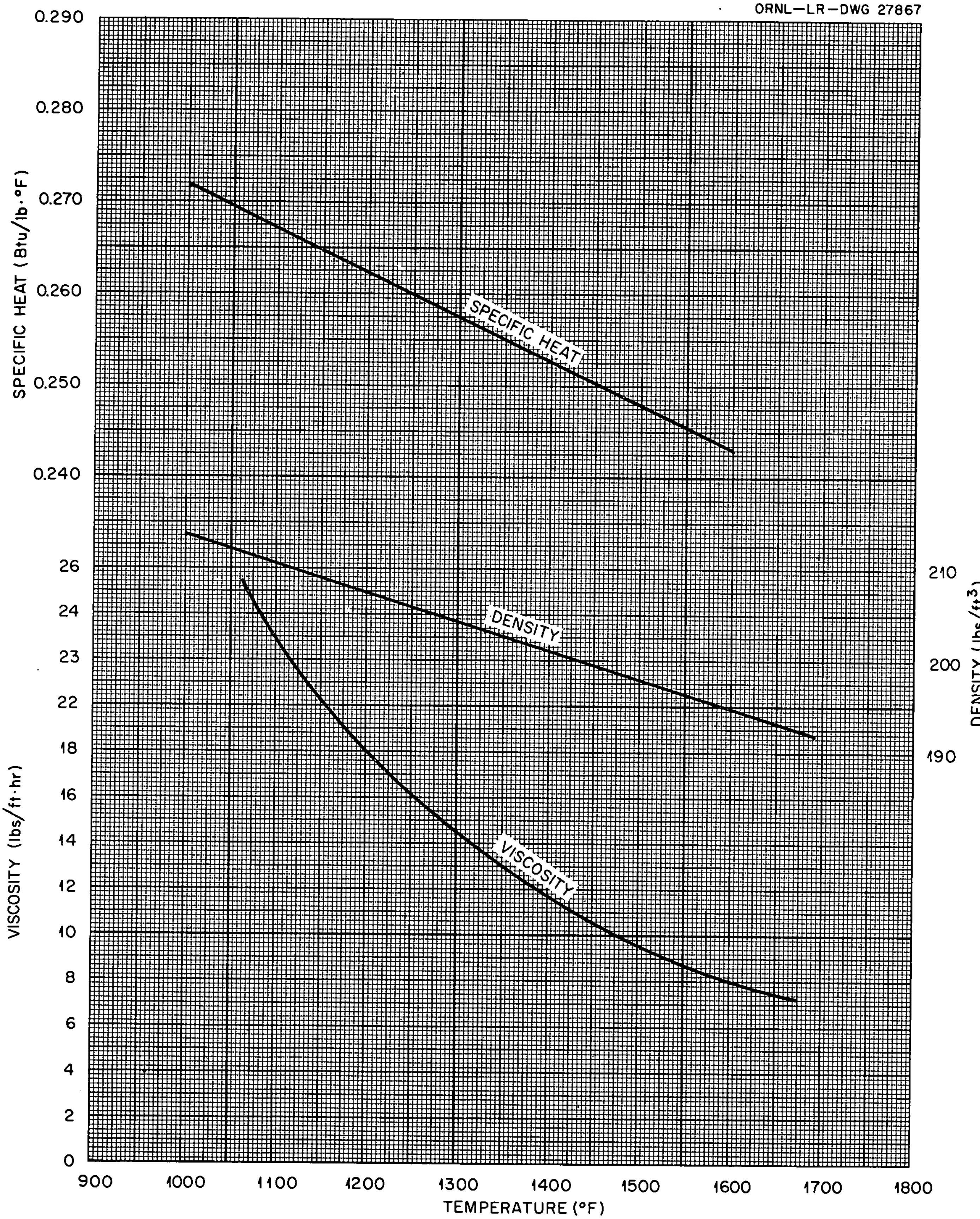

Appendix 8.1. Physical Properties of Mixture 30.
(Thermal Conductivity = 1.5 Btu | hr · ft · °F/ft 1100-1650°F)

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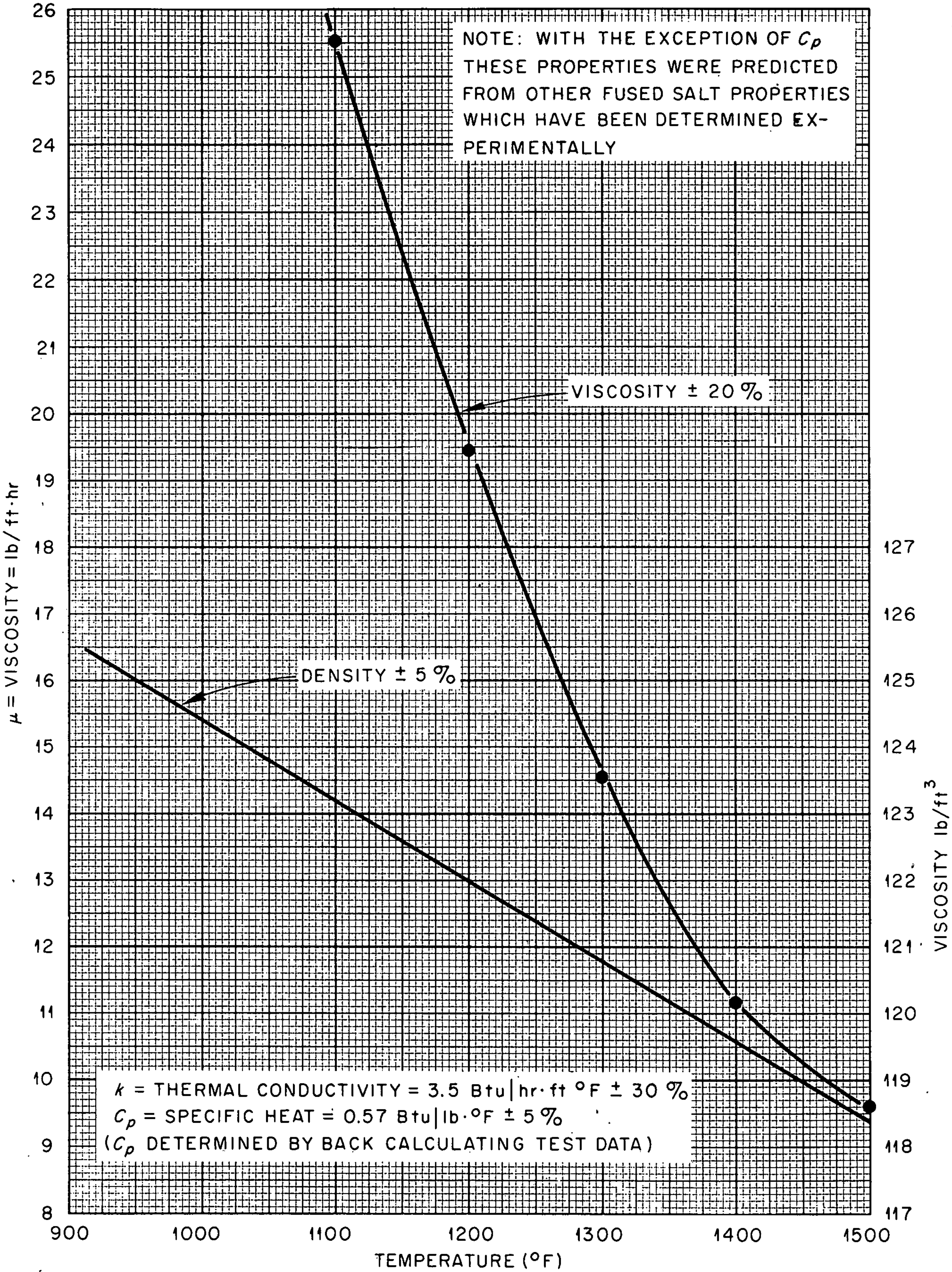

Appendix 8.2. Assumed Physical Properties Mixture Number 130 Used for MSRP Heat Transfer Coefficient Data Correlations.

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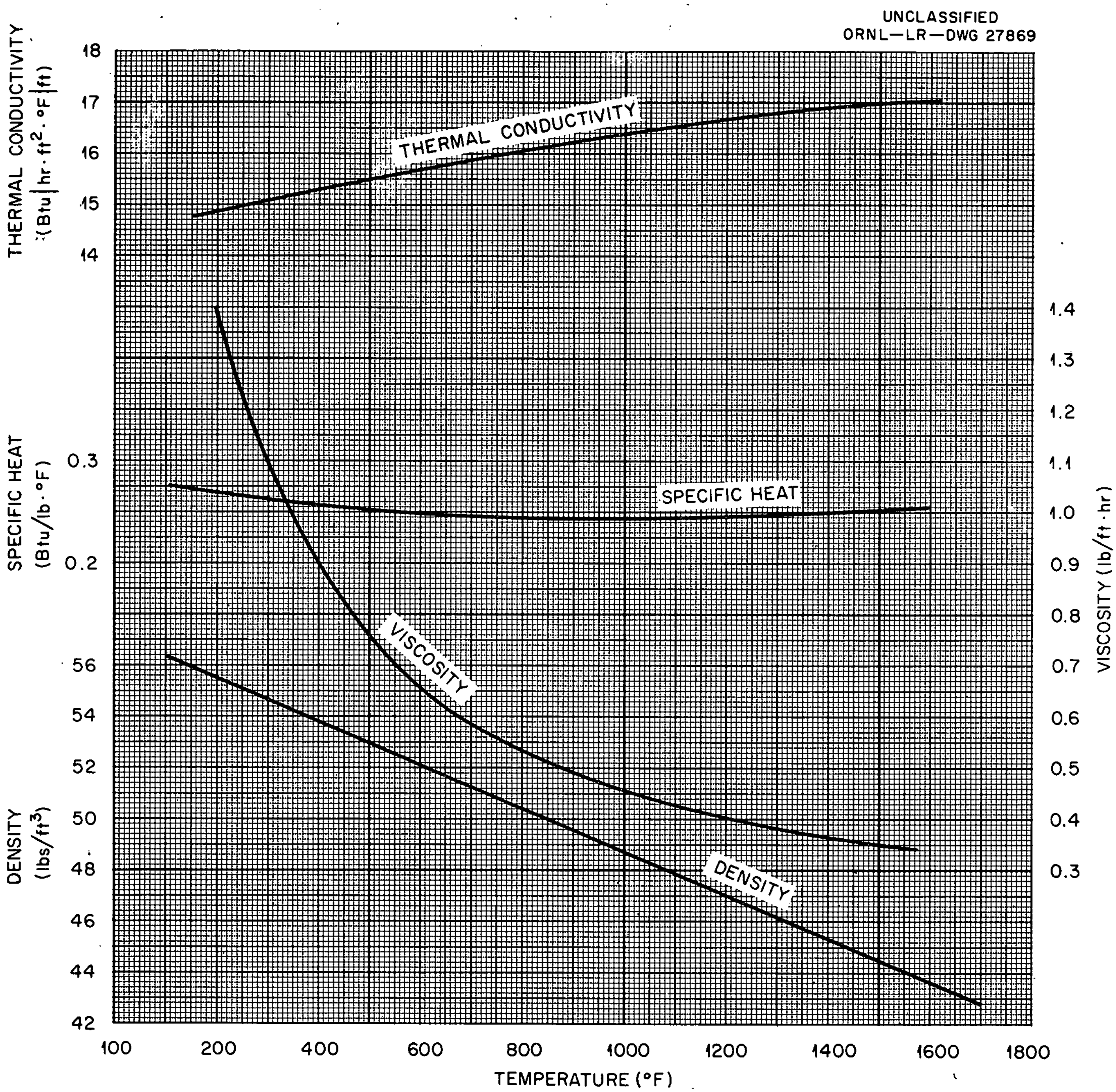

Appendix 8.3. Physical Properties of NaK, Na 56%, K 44% (by wt) Source: Liquid Metals Handbook 1955.

8.4 Data Reduction Procedure

8.41 Basic Data

The following experimental data were obtained directly from the test facility instrumentation for each data point:

Heat Exchanger Fused Salt Inlet Temperature, °F

Heat Exchanger Fused Salt Outlet Temperature, °F

Heat Exchanger NaK Inlet Temperature, °F

Heat Exchanger NaK Outlet Temperature, °F

(Each of the above temperatures was obtained by averaging two independent thermocouple readings.)

Fused Salt Venturi ΔP, psi

NaK Venturi ΔP, psi

(These readings were converted to lb/hour flow with calibration curves established from water calibration data for the venturis.)

NaK Electromagnetic Flowmeter, millivolts

(These readings were not used for data reduction since the calibration of this device tended to change throughout the test.)

Voltage and current supplied to the Fused Salt Resistance Heater Section

Heat Exchanger Fused Salt Inlet Pressure, psi

Heat Exchanger Fused Salt Outlet Pressure, psi

Heat Exchanger NaK Inlet Pressure, psi

Heat Exchanger NaK Outlet Pressure, psi

8.42 Fused Salt Heat Transfer Data Reduction

Heat balances were calculated as follows:

The heat exchanger fused salt and NaK heat loads were calculated from the standard equation:

$$Q = W \, cp \, \Delta T$$

where Q = heat load in BTU/hr

W = Fluid flow in lb/hr

cp = Fluid specific heat in BTU/lb°F

ΔT = Fluid temperature change through the heat exchanger in °F

The resistance heater heat input was calculated from the equation

$$Q = \frac{E\ I\ 3600}{1054}$$

where Q = Heat input in BTU/hr

E = Resistance heater voltage in volts

I = Resistance heater current in amperes

Overall heat exchanger heat transfer coefficients were calculated from the standard equation:

$$Q = UA\Delta T_{LM}$$

where Q = Heat load in BTU/hr

U = Overall heat transfer coefficient in BTU/hr ft^2°F

A = Fused salt heat transfer area based on the tube I.D. in ft^2

ΔT_{LM} = Log mean temperature difference between the salt and the NaK in °F

The calculated NaK heat load, based on measured NaK flow and NaK temperatures at the heat exchanger inlet and outlet, was used as Q in all heat transfer calculations for the following reasons:

First, in all Mixture 130 data, the salt heat load was based on an average specific heat determined by back calculation from NaK heat loads.

Second, during heat transfer tests on both salts, the NaK flow rate was maintained at a high level with a constant pump speed so that percentage error in venturi measurements was reduced and only temperature variations changed the flow rate. The salt flow, however, was varied widely, and in some of the low Reynolds Number data points, salt flows were not measurable with the installed venturi. This condition dictated acceptance of the NaK heat balance since none could be established independently for the salt.

For the above reasons (and since the heat balance agreement between the NaK system and the Mixture 30 system, for which an independent measurement of specific heat was available, were normally in agreement within 2%) it was felt that more consistent results would be obtained by adopting the NaK heat balance throughout.

The fused salt film heat transfer coefficient, h_f, was then determined from the equation:

$$U = \frac{1}{1/h_f + D_i/D_o h_c + D_i X/D_M k_I}$$

where U = Overall heat transfer coefficient in BTU/hr ft^2°F

h_f = Fused salt film heat transfer coefficient in BTU/hr ft^2°F

h_c = NaK film heat transfer coefficient in BTU/hr ft^2°F

X = Tube wall thickness in inches

k_I = Thermal conductivity of Inconel in BTU/hr ft^2°F/inch

For convenience in solving for h_f, this equation was rewritten in the following form

$$\frac{10{,}000}{h_f} = \frac{10{,}000}{U} - (D_i/D_o h_c + D_i X/D_M k_I) \times 10^4$$

The NaK film coefficient h_c was obtained from the equation

$$Nu = 0.066 \left[RePr\right]^{0.6}$$

which was derived from experimental data obtained during the course of this test to define the NaK heat transfer behavior in the shell side of the test heat exchanger.

$$Nu = \text{Nusselt Number} = \frac{h_c De}{k_c}$$

$$Re = \text{Reynolds Number} = \frac{DeV_c \rho_c}{\mu_c}$$

Pr = Prandtl Number = $\frac{cp_c \mu_c}{k_c}$

D_e = Heat exchanger shell side equivalent diameter in ft

= $\frac{4 \text{ x cross sectional flow area}}{\text{total wetted perimeter}}$

k_c = Thermal conductivity of NaK in BTU/hr ft^2°F/ft

ρ_c = Density of NaK in lb/ft^3

cp_c = Specific heat of NaK in BTU/lb°F

μ_c = Viscosity of NaK, lb/ft hr

V = NaK velocity, ft/hr

8.43 Fused Salt Heat Transfer Data Correlations

All fused salt heat transfer data were correlated against Reynolds Number in the dimensionless forms $Nu/Pr^{0.4}$ and the Colburn[6] j-factor $(h_f/cp_f G_f)(Pr_f)^{2/3}$

where Nu = Nusselt Number = $h_f D/k_f$

Pr = Prandtl Number = $cp_f \mu_f / k_f$

Reynolds Number = DG/μ

h_f = Fused salt film heat transfer coefficient in BTU/hr ft^2°F

D = Tube I.D. in ft

k_f = Fused salt thermal conductivity in BTU/hr ft^2°F/ft

cp_f = Fused salt specific heat BTU/lb °F

μ_f = Fused salt viscosity lb/ft hr

G = Fused salt mass flow velocity in lb/hr ft^2

For the $Nu/Pr^{0.4}$ vs Re correlation, all physical properties were evaluated at bulk mean fused salt temperature. For the Colburn j-factor correlation, the viscosity was evaluated at the salt film mean temperature. All other physical properties were evaluated at salt bulk mean temperatures.

Since the accuracy of the fused salt flow measurement was poor at very low flows, all Reynolds Numbers used in the correlations were based on fused salt flows calculated from the NaK heat balance using the equation

$$W_f = \frac{Q_{NaK}}{cp_f \, \Delta T_f}$$

where W_f = Calculated fused salt flow in lb/hr

Q_{NaK} = NaK heat balance in BTU/hr

cp_f = Fused salt specific heat in BTU/lb°F

ΔT_f = Fused salt temperature change in °F

Figure 6 presents the $Nu/Pr^{0.4}$ correlation for both salt mixtures and illustrates the comparison to the Dittus-Boelter[5] equation, $Nu/Pr^{0.4} = 0.023\,(Re)^{0.8}$, and to a previously established correlation for Mixture 30 in the <u>shell</u> side of similar heat exchangers.

Figure 7 presents the Colburn j-factor correlation for both salt mixtures as compared to data obtained by Hoffman[7] in single tube, salt heating experiments on Mixture 30. In addition, the Dittus-Boelter equation has been converted to the j-factor form and is presented for further comparison.

8.44 NaK Heat Transfer Correlation

The NaK heat transfer correlation was developed by means of a modified Wilson Plot.[3] Three sets of data were taken over a maximum range of NaK flow. For each set of data, the salt flow was held constant. The heat load (Q) and overall heat transfer coefficient (U) were determined in the same manner as for the fused salt heat transfer data.

The reciprocal of U was then plotted against the reciprocal of the NaK Reynolds Number to the 0.6 power. The 0.6 power was chosen since all experimental data available for NaK flowing in heat exchanger shells indicate that the Nusselt modulus and the Reynolds Number have this exponential relationship.[11] The method of "least squares" was

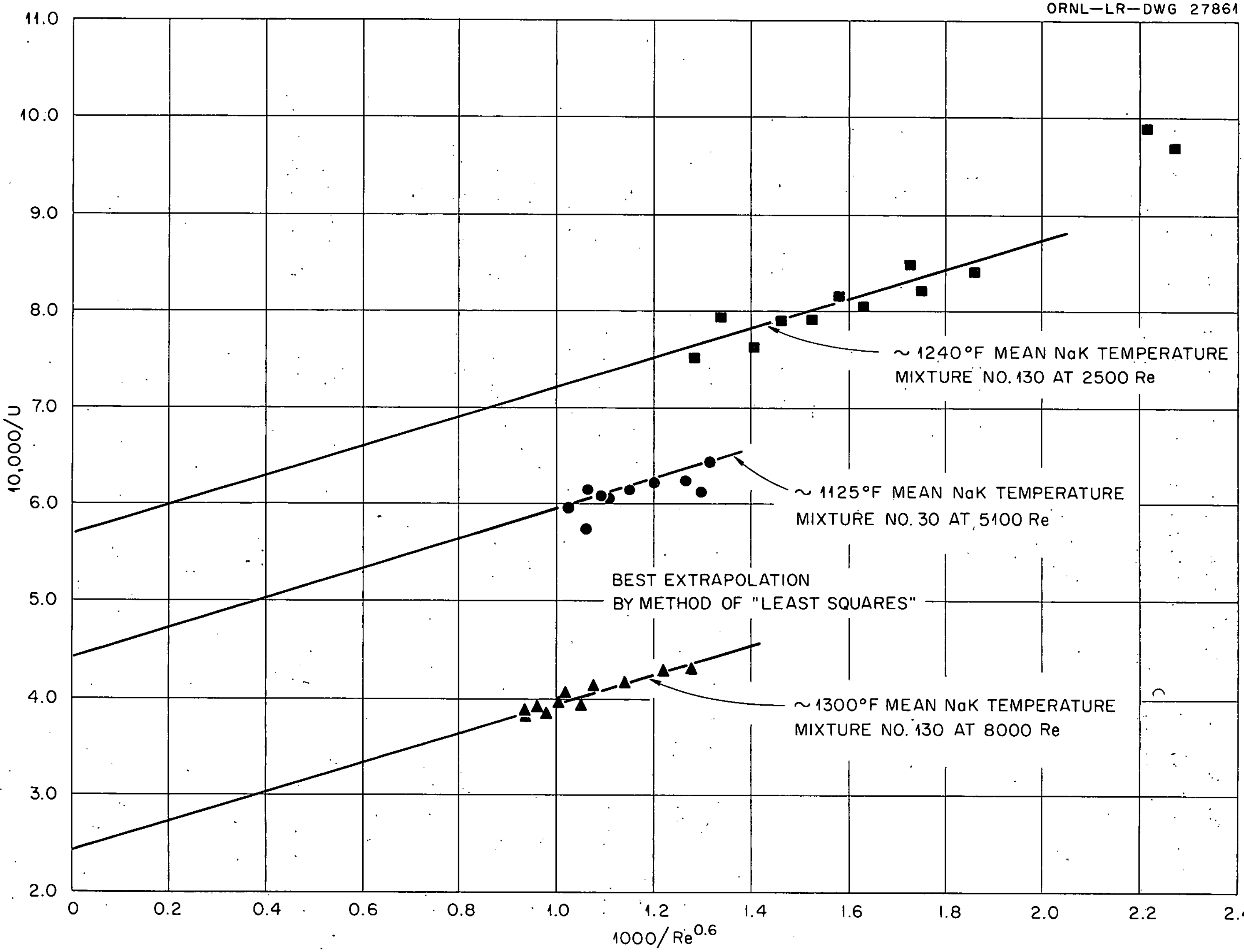

Fig. 11. Modified Wilson Plot For Determining NaK Film Coefficient.

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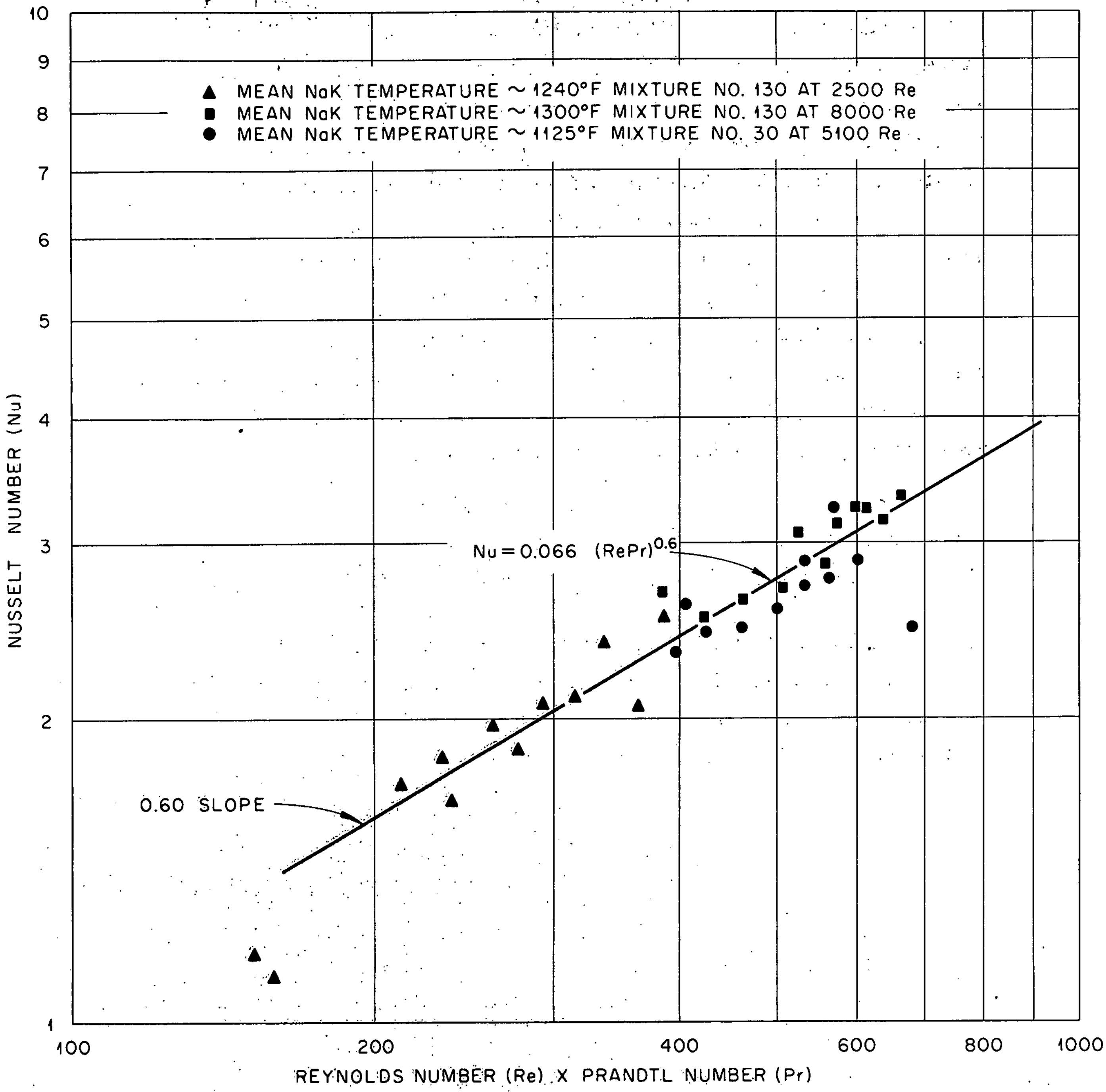

Fig. 12. Nusselt Number vs Reynolds Number x Prandtl Number. Plot for Nak from Wilson plot data.

used to establish the most representative correlation line for each data group, and this line was extrapolated to $1/Re^{0.6}$ equals zero. Since, theoretically, the NaK film resistance at infinite NaK flow would be zero, the value of 1/U read at $1/Re^{0.6} = 0$ would be made up entirely of the fused salt film resistance and the tube wall resistance. Since the fused salt flow was held constant, the difference between this combined resistance value and 1/U for each data point equals the NaK film resistance for that data point. This modified Wilson plot is presented in Fig. 11. To obtain the most representative correlation, all NaK film coefficients were then replotted in the form of Nusselt Number vs Reynolds Number times Prandtl Number, as shown in Fig. 12. A representative line drawn through this data is defined by the equation

$$Nu = 0.066\ (RePr)^{0.6}$$

This equation was used for predicting the NaK heat transfer coefficients for all fused salt heat transfer data.

8.45 Fused Salt Mixture 130 Specific Heat Determination

Mixture 130 specific heat was back-calculated from salt flow measurements and NaK heat balances obtained on Mixture 130 heat transfer data runs using the following equation:

$$cp = Q/W\Delta T$$

where cp = Specific heat in BTU/lb°F
Q = NaK heat load in BTU/hr
W = Fused salt measured flow rate in lb/hr
ΔT = Fused salt temperature drop in °F

The results of this determination are shown in Fig. 9. An average value of 0.57 BTU/lb°F was used for all Mixture 130 heat transfer correlations.

8.46 Fused Salt Pressure Drop Correlation

Salt pressure drop measurements across the heat exchanger were made between pressure taps located in the upstream and downstream piping. Included in this pressure drop measurement were (1) the head losses associated with 52 inches of 1-1/2 inch, Schedule 40 system piping, including two 90° bends on 6 inch radii, (2) expansion losses into the inlet header from the system piping and from the heat exchanger tubing into the outlet header and (3) contraction losses from the inlet header into the heat exchanger tubing and from the outlet header into the system piping.

In order to calculate tubing friction factors for the salt side of the heat exchanger, it was necessary to correct out these miscellaneous losses to determine the pressure loss associated with flow through the heat exchanger tubing only. Losses associated with flow in the system piping were determined using the conventional Fanning equation with a friction factor determined from correlations presented in Ref. 9. The 90° bends were corrected to equivalent lengths of straight pipe by methods presented in the same reference. Expansion and contraction losses were determined from Ref. 10. Fig. 13 presents the relationship of these miscellaneous losses to Reynolds Number in the heat exchanger tubing for both Mixture 30 and 130.

Fig. 10 shows the corrected friction factor for salt flowing inside the heat exchanger tubing.

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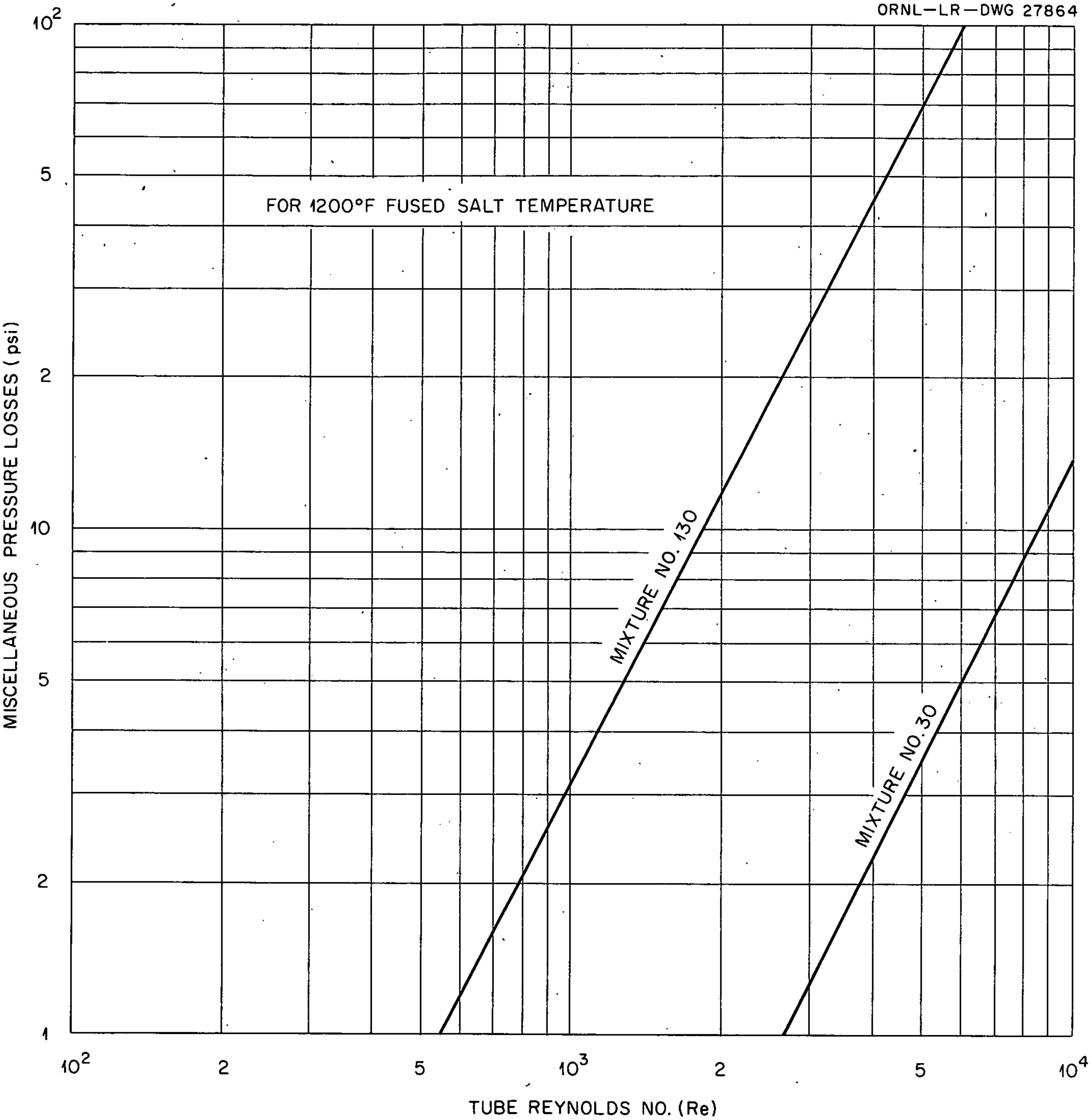

Fig. 13. Calculated Heat Exchanger Fused Salt Miscellaneous Pressure Losses. (Includes System Pipe, Entrance, Exit, and Bend Losses)

Appendix 8.5
Fused Salt Mixture 30 Heat Transfer Data

Run Number	1	2	3	4	5	6	7	8	9	10	11	12
Fused Salt Flow - lb/hr $\times 10^{-3}$	19.50	21.75	23.50	24.50	22.80	20.60	17.90	15.80	14.15	11.70	8.10	5.15
NaK Flow - lb/hr $\times 10^{-3}$	18.00	18.30	18.30	19.10	19.00	19.00	19.00	19.00	19.00	19.00	18.90	19.00
Fused Salt Temp. In - °F	1307	1281	1274	1282	1286	1285	1301	1317	1320	1306	1318	1382
Fused Salt Temp. Out - °F	1110	1116	1121	1122	1116	1107	1103	1102	1105	1097	1110	1116
Mean Salt Temp. - °F	1209	1199	1198	1202	1201	1196	1202	1210	1213	1202	1214	1249
NaK Temp. Out - °F	1194	1185	1193	1199	1194	1181	1176	1175	1168	1142	1130	1087
NaK Temp. In - °F	961	974	979	960	963	966	968	974	991	1002	1031	1008
Mean NaK Temp. - °F	1078	1080	1086	1080	1079	1074	1072	1075	1080	1072	1081	1048
ΔT_{LM} - °F	130.4	117.3	108.5	118.2	119.8	121.5	129.8	135.4	131.9	126.5	124.6	186.2
Resistance Heat Load - BTU/hr $\times 10^{-5}$	11.14	9.91	9.97	10.67	10.60	10.02	9.67	9.47	8.34	6.69	4.87	3.85
Fused Salt Heat Load - BTU/hr $\times 10^{-5}$	10.07	9.42	9.44	10.28	10.17	9.62	9.31	8.90	7.95	6.42	4.42	3.56
NaK Heat Load - BTU/hr. $\times 10^{-5}$	10.28	9.46	9.60	11.18	10.76	10.00	9.68	9.365	8.24	6.52	4.59	3.68
Fused Salt Heat Transfer Coefficient h_f (1)	3012	3125	3774	4310	3846	3226	2688	2358	2000	1497	952	453
Measured Salt Reynolds No.	4950	5400	5840	6050	5625	5100	4450	4050	3650	2900	2040	1440
Calculated Salt Reynolds No. (2)	5000	5400	5900	6600	6000	5300	4620	4200	3750	2950	2140	1460
$Nu/Pr^{0.4}$	14.8	15.1	18.4	20.9	18.75	15.70	13.10	11.6	9.8	7.29	4.67	2.30
Calculated Mean Salt Film Temp. - °F	1174	1168	1172	1175	1175	1164	1165	1170	1171	1158	1165	1217
Colburn j-Factor $(h/C_pG)(Pr)^{2/3} \times 10^4$	33.45	31.65	34.95	35.50	35.05	33.65	32.25	31.40	29.80	28.50	25.10	17.50
Corrected Salt Reynolds No. (3)	4655	5030	5530	6220	5650	4910	4260	3875	3460	2680	1940	1350

(1) Heat Transfer Coefficient Calculated Using NaK Heat Balance

(2) Calculated Fused Salt Reynolds Number Using NaK Heat Balance

(3) Calculated Fused Salt Reynolds Number Corrected for Salt Viscosity at the Mean Salt Film Temperature

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Appendix 8.5

Fused Salt Mixture 30 Heat Transfer Data - Page 2

Run Number	24	25	26	27	28	29	30	31	32	33	34
Fused Salt Flow - lb/hr $\times 10^{-3}$	2.79	4.10	6.25	7.85	8.85	11.80	3.75	-	4.40	5.60	6.00
NaK Flow - lb/hr $\times 10^{-3}$	15.80	15.70	15.70	15.70	15.70	15.70	15.70	15.70	15.80	15.80	15.80
Fused Salt Temp. In - °F	1301	1297	1284	1281	1284	1294	1316	1358	1305	1286	1282
Fused Salt Temp. Out - °F	1090	1120	1114	1107	1107	1115	1112	1060	1136	1132	1126
Mean Salt Temp. - °F	1196	1209	1199	1194	1196	1204	1214	1209	1221	1209	1204
NaK Temp. Out - °F	1090	1100	1115	1126	1139	1168	1104	1076	1106	1101	1119
NaK Temp. In - °F	1054	1049	1037	1031	1025	1024	1060	1042	1050	1043	1051
Mean NaK Temp. - °F	1072	1075	1076	1079	1084	1096	1082	1059	1078	1072	1085
ΔT_{LM} - °F	99.1	123.5	117.	111	108.7	107.5	113.8	96	134.6	131.1	113.4
Resistance Heat Load - BTU/hr $\times 10^{-5}$	1.676	2.072	3.26	3.94	4.54	5.30	1.89	1.51	2.34	2.41	2.80
Fused Salt Heat Load - BTU/hr $\times 10^{-5}$	1.545	1.902	2.79	3.587	4.11	5.54	2.00	.40	1.94	2.26	2.46
NaK Heat Load - BTU/hr $\times 10^{-5}$	1.394	1.960	3.00	3.65	4.27	5.53	1.69	1.31	2.17	2.25	2.63
Fused Salt Heat Transfer Coefficient h_f (1)	313	356	617	840	1053	1531	331	303	362	389	549
Measured Salt Reynolds No.	695	1020	1550	1960	2200	2940	940	-	1160	1430	1490
Calculated Salt Reynolds No. (2)	620	1045	1860	2000	2290	2925	810	430	1270	1350	1800
$Nu/Pr^{0.4}$	1.52	1.75	3.0	4.05	5.10	7.40	1.62	1.48	1.78	1.92	2.67
Calculated Mean Salt Film Temp. - °F	1151	1153	1150	1150	1155	1167	1162	1165	1160	1150	1155
Colburn j-Factor $(h/C_pG)(Pr)^{2/3} \times 10^4$	28.20	19.53	19.00	23.75	25.80	26.30	23.20	39.50	16.35	16.80	17.20
Corrected Salt Reynolds No. (3)	549	925	1724	1760	2060	2714	723	390	1128	1176	1620

(1) Heat Transfer Coefficient Calculated Using NaK Heat Balance

(2) Calculated Fused Salt Reynolds Number Using NaK Heat Balance

(3) Calculated Fused Salt Reynolds Number Corrected for Salt Viscosity at the Mean Salt Film Temperature

Appendix 8.6
Fused Salt Mixture 130 Heat Transfer Data

Run Number	1	2	3	4	5	6	7	8	9	10	11	12
Fused Salt Flow - lb/hr $\times 10^{-3}$	17.20	15.90	14.60	13.50	12.10	10.4	9.10	7.95	-	-	11.60	13.55
NaK Flow - lb/hr $\times 10^{-3}$	19.00	19.00	19.00	19.00	19.00	18.60	18.60	18.60	18.80	19.00	18.75	18.90
Fused Salt Temp. In - °F	1210	1216	1220	1227	1234	1296	1292	1298	1323	1338	1280	1262
Fused Salt Temp. Out - °F	1109	1106	1107	1109	1113	1208	1184	1167	1162	1133	1156	1147
Mean Salt Temp. - °F	1159	1161	1163	1168	1174	1252	1238	1233	1243	1236	1218	1205
NaK Temp. Out - °F	1153	1151	1147	1147	1145	1238	1210	1171	1118	1076	1198	1192
NaK Temp. In - °F	945	943	953	958	975	1124	1088	1054	1000	984	1024	1004
Mean Nak Temp. - °F	1049	1047	1050	1053	1060	1181	1149	1118	1059	1030	1111	1098
ΔT_{LM} - °F	101.4	106.5	108.5	111.8	111.9	70.3	88.8	119.8	183.1	200.5	105	102.2
Resistance Heat Load - BTU/hr $\times 10^{-5}$	9.66	9.74	9.49	8.91	8.07	5.53	5.78	6.02	5.86	4.77	8.52	8.79
Fused Salt Heat Load - BTU/hr $\times 10^{-5}$	9.90	9.97	9.40	9.08	8.34	5.21	5.61	5.94	-	-	8.20	8.87
NaK Heat Load - BTU/hr $\times 10^{-5}$	9.68	9.68	9.04	8.80	7.81	5.22	5.58	5.33	5.44	4.28	8.00	8.70
Fused Salt Heat Transfer Coefficient h_f (1)	4430	3970	3340	2970	2400	2650	2000	1220	730	495	2800	3450
Measured Salt Reynolds No.	3480	3240	2950	2825	2575	2750	2300	2025	-	-	2800	3100
Calculated Salt Reynolds No. (2)	3390	3140	2825	2710	2380	2750	2320	1770	1525	950	2620	3025
$Nu/Pr^{0.4}$	8.74	7.93	6.68	5.97	4.84	5.86	4.41	2.64	1.595	1.075	5.94	7.15
Calculated Salt Cp - BTU/lb-°F	.558	.554	.548	.553	.533	.571	-	-	-	-	.556	.558
Calculated Mean Salt Film Temp.-°F	1138	1136	1136	1138	1141	1232	1210	1189	1167	1148	1184	1180
Colburn j-Factor $(h/C_pG)(Pr)^{2/3} \times 10^4$	29.2	28.30	26.70	24.70	22.80	23.40	21.20	16.50	12.40	14.10	25.00	25.00
Corrected Salt Reynolds No. (3)	3160	2920	2610	2510	2210	2570	2130	1550	1210	930	2360	2870

(1) Heat Transfer Coefficient Calculated Using NaK Heat Balance

(2) Calculated Fused Salt Reynolds Number Using NaK Heat Balance

(3) Calculated Fused Salt Reynolds Number Corrected for Salt Viscosity at the Mean Salt Film Temperature

Appendix 8.6
Fused Salt Mixture 130 Heat Transfer Data - Page 2

Run Number	13	14	15	16	17	18	19	43	44	45	46	47
Fused Salt Flow - lb/hr $\times 10^{-3}$	14.70	16.20	17.50	17.10	16.50	15.30	14.10	6.55	5.15	-	3.15	5.90
NaK Flow - lb/hr $\times 10^{-3}$	18.90	18.80	18.80	18.80	19.00	19.00	19.00	18.50	18.60	18.75	18.80	18.50
Fused Salt Temp. In - °F	1256	1272	1284	1250	1213	1221	1224	1395	1410	1436	1383	1382
Fused Salt Temp. Out - °F	1150	1164	1176	1153	1113	1118	1111	1294	1285	1200	1235	1250
Mean Salt Temp - °F	1203	1218	1230	1202	1163	1170	1168	1345	1348	1318	1309	1316
NaK Temp. Out - °F	1196	1215	1234	1200	1154	1158	1151	1319	1285	1186	1191	1265
NaK Temp. In - °F	1003	1005	1007	1000	955	968	962	1229	1199	1118	1115	1161
Mean NaK Temp. - °F	1100	1110	1121	1100	1055	1063	1057	1274	1242	1152	1153	1213
ΔT_{LM} - °F	97.1	99.6	97.8	92.1	100.6	100.3	106.5	70.5	104.2	156.	153.3	102.4
Resistance Heat Load - BTU/hr $\times 10^{-5}$	9.18	10.0	10.61	9.33	9.33	9.05	8.66	4.40	4.30	3.11	4.165	5.43
Fused Salt Heat Load - BTU/hr $\times 10^{-5}$	8.87	9.97	10.77	9.46	9.40	8.98	9.08	3.77	3.67	-	2.63	4.44
NaK Heat Load - BTU/hr $\times 10^{-5}$	8.94	9.67	10.46	9.22	9.26	8.85	8.80	4.16	3.97	3.12	3.50	4.75
Fused Salt Heat Transfer Coefficient h_f (1)	4050	4570	5810	4850	4080	3730	3270	1820	990	459	532	129
Measured Salt Reynolds Number	3350	3900	4350	3900	3375	3185	2950	2260	1825	-	980	1925
Calculated Salt Reynolds No. (2)	3360	3760	4150	3820	3320	3140	2850	2550	1985	745	1310	1730
$Nu/Pr^{0.4}$	8.45	9.72	12.52	10.3	8.14	7.54	6.57	4.48	2.45	1.18	1.335	3.13
Calculated Salt Cp - BTU/lb - °F	.574	.553	.554	.556	.561	.561	.552	-	-	-	-	-
Calculated Mean Salt Film Temp. - °F	1181	1197	1207	1183	1140	1146	1141	1322	1308	1249	1243	1279
Colburn J-Factor $(h/CpG)(Pr)^{2/3} \times 10^4$	27.70	28.50	33.50	28.80	27.50	26.70	26.50	19.05	13.66	18.50	11.80	20.00
Corrected Salt Reynolds No. (3)	3190	3540	3820	3590	3080	2950	2600	2380	1780	622	1110	1580

(1) Heat Transfer Coefficient Calculated Using NaK Heat Balance

(2) Calculated Fused Salt Reynolds Number Using NaK Heat Balance

(3) Calculated Fused Salt Reynolds Number Corrected for Salt Viscosity at the Mean Salt Film Temperature

Appendix 8.6

Fused Salt Mixture 130 Heat Transfer Data - Page 3

Run Number	48	49	50	51	52	53	54	55	56	57	58	59
Fused Salt Flow - lb/hr $\times 10^{-3}$	7.75	9.65	11.30	12.60	14.60	16.10	17.70	16.90	15.40	14.40	18.00	18.40
NaK Flow - lb/hr $\times 10^{-3}$	18.55	18.55	18.70	18.70	18.70	18.70	18.80	18.70	18.80	18.70	18.70	18.80
Fused Salt Temp. In - °F	1371	1348	1349	1335	1335	1354	1360	1349	1352	1342	1355	1354
Fused Salt Temp. Out - °F	1237	1234	1239	1220	1228	1250	1256	1243	1240	1222	1256	1251
Mean Salt Temp. - °F	1304	1291	1294	1278	1282	1302	1308	1296	1296	1282	1306	1303
NaK Temp. Out - °F	1275	1274	1287	1273	1282	1308	1318	1303	1302	1282	1318	1312
NaK Temp. In - °F	1139	1132	1131	1089	1088	1098	1088	1081	1080	1078	1084	1080
Mean NaK Temp. - °F	1207	1203	1209	1181	1186	1203	1203	1192	1191	1180	1201	1196
ΔT_{LM} - °F	97	87.3	82.9	92.3	88.2	88.7	90.9	91.5	94.6	96.	87.9	91.9
Resistance Heat Load - BTU/hr $\times 10^{-5}$	6.40	6.86	7.40	8.65	9.26	9.88	10.54	10.16	10.16	9.46	10.80	10.63
Fused Salt Heat Load - BTU/hr $\times 10^{-5}$	5.91	6.26	7.06	8.27	8.90	9.53	10.48	10.58	9.83	9.85	10.15	10.80
NaK Heat Load - BTU/hr $\times 10^{-5}$	6.23	6.51	7.20	8.50	8.98	9.70	10.68	10.25	10.31	9.38	10.76	10.74
Fused Salt Heat Transfer Coefficient h_f (1)	2110	2670	2550	4020	5050	6100	7520	6580	6060	4650	8480	7410
Measured Salt Reynolds No.	2375	2825	3400	3600	4200	4900	5500	5040	4625	4200	5550	5710
Calculated Salt Reynolds No. (2)	2490	2950	3380	3730	4220	4980	5670	5180	4910	3930	5800	5580
$Nu/Pr^{0.4}$	4.92	6.17	8.35	9.13	11.68	14.40	17.84	15.44	14.35	10.75	20.03	17.42
Calculated Salt Cp - BTU/lb - °F	-	.593	.579	.587	.575	.579	.580	.572	.598	.543	.606	.566
Calculated Mean Salt Film Temp. - °F	1274	1266	1274	1256	1264	1286	1293	1280	1279	1262	1293	1288
Colburn J-Factor $(h/CpG)(Pr)^{2/3} \times 10^4$	21.80	23.05	26.80	26.75	29.81	31.10	33.65	33.25	32.50	29.75	36.75	33.40
Corrected Salt Reynolds No. (3)	2270	2710	3180	3490	4020	4730	5420	4940	4690	3690	5580	5340

(1) Heat Transfer Coefficient Calculated Using NaK Heat Balance

(2) Calculated Fused Salt Reynolds Number Using NaK Heat Balance

(3) Calculated Fused Salt Reynolds Number Corrected for Salt Viscosity at the Mean Salt Film Temperature

Appendix 8.6
Fused Salt Mixture 130 Heat Transfer Data - Page 4

Run Number	60	61	62	63	64	65	66	67	68	69	70
Fused Salt Flow - lb/hr x 10^{-3}	14.30	10.50	6.95	-	-	18.70	18.40	17.60	17.20	16.40	14.40
NaK Flow - lb/hr x 10^{-3}	18.80	18.80	18.80	18.90	19.00	18.60	18.60	18.70	18.70	18.70	18.90
Fused Salt Temp. In - °F	1337	1352	1385	1370	1373	1440	1445	1448	1440	1437	1446
Fused Salt Temp. Out - °F	1222	1211	1215	1076	1017	1346	1344	1340	1327	1316	1313
Mean Salt Temp. - °F	1280	1282	1300	1223	1195	1393	1395	1394	1384	1377	1380
NaK Temp. Out - °F	1281	1265	1244	1091	1036	1407	1410	1409	1398	1393	1393
NaK Temp. In - °F	1076	1082	1098	1054	1007	1180	1176	1172	1155	1140	1138
Mean NaK Temp. - °F	1179	1174	1171	1073	1022	1294	1293	1291	1277	1267	1266
ΔT_{LM} - °F	93.8	106.5	128.7	101.2	92.9	82.4	84.8	88.4	92.3	95.3	102.2
Resistance Heat Load - BTU/hr x 10^{-5}	9.74	8.65	7.02	1.822	1.534	10.72	10.97	10.97	11.70	11.64	11.86
Fused Salt Heat Load - BTU/hr x 10^{-5}	9.37	8.44	6.74	-	-	10.05	10.60	10.84	11.08	11.30	10.91
NaK Heat Load - BTU/hr x 10^{-5}	9.49	8.47	6.75	1.714	1.35	10.51	10.84	11.04	11.30	11.74	11.94
Fused Salt Heat Transfer Coefficient h_f (1)	4980	3000	1530	-	-	9710	9710	8930	8330	8480	7190
Measured Salt Reynolds No.	4150	3050	2140	-	-	7450	7320	7000	6650	6200	5500
Calculated Salt Reynolds No. (2)	4150	3000	2140	240	150	7840	7520	7140	6680	6460	5910
$Nu/Pr^{0.4}$	11.48	6.88	3.63	-	-	25.45	25.45	23.2	21.1	21.7	18.36
Calculated Salt Cp - BTU/lb - °F	.577	.572	-	-	-	.599	.583	.580	.581	.591	.622
Calculated Mean Salt Film Temp. - °F	1261	1253	1255	-	-	1382	1383	1381	1370	1363	1363
Colburn J-Factor $(h/C_pG)(Pr)^{2/3} \times 10^4$	30.15	26.15	19.35	-	-	33.75	35.25	33.85	32.95	35.25	32.85
Corrected Salt Reynolds No. (3)	3900	2750	1860	-	-	7640	7300	6950	6400	6230	5650

(1) Heat Transfer Coefficient Calculated Using NaK Heat Balance

(2) Calculated Fused Salt Reynolds Number Using NaK Heat Balance

(3) Calculated Fused Salt Reynolds Number Corrected for Salt Viscosity at the Mean Salt Film Temperature

Appendix 8.7
Wilson Plot Data Sheet

Run Number	13 (1)	14	15	16	17	18	19	20	21	22	23
Fused Salt Flow - lb/hr $\times 10^{-3}$	19.40	19.80	19.50	19.50	19.60	19.60	19.60	19.60	19.60	19.60	19.60
NaK Flow - lb/hr $\times 10^{-3}$	18.80	11.20	15.20	16.00	11.20	11.70	12.70	13.80	14.70	16.50	15.70
Fused Salt Temp. In - °F	1280	1308	1298	1308	1289	1293	1295	1300	1306	1306	1309
Fused Salt Temp. Out - °F	1114	1165	1148	1154	1160	1156	1155	1155	1154	1145	1153
Mean Salt Temp. - °F	1197	1247	1223	1231	1229	1224	1225	1227	1230	1225	1231
NaK Temp. Out - °F	1178	1261	1228	1231	1250	1247	1242	1239	1238	1226	1234
NaK Temp. In - °F	987	997	1020	1028	1002	1001	1009	1015	1018	1020	1020
Mean NaK Temp. - °F	1083	1129	1124	1130	1126	1124	1125	1127	1128	1123	1127
ΔT_{LM} - °F	114	95	96	99.6	85	90	92	95	98	101	95
Resistance Heat Load - BTU/hr $\times 10^{-5}$	8.80	7.71	7.89	8.08	6.98	7.40	7.58	7.89	8.20	8.68	8.43
Fused Salt Heat Load - BTU/hr $\times 10^{-5}$	8.45	7.43	7.68	7.88	6.64	7.05	7.20	7.46	7.82	8.28	8.03
NaK Heat Load - BTU/hr $\times 10^{-5}$	8.80	7.25	7.75	7.96	6.80	7.06	7.25	7.57	7.93	8.33	8.10
NaK Reynolds Number $\times 10^{-4}$	10.60	6.35	8.60	9.05	6.50	6.85	7.35	8.00	8.50	9.65	9.10
1,000/NaK $Re^{0.6}$	.964	1.310	1.092	1.058	1.295	1.258	1.198	1.150	1.100	1.020	1.058
10,000/U	6.39	6.46	6.11	6.17	6.16	6.28	6.26	6.18	6.09	5.98	5.78

Notes: (1) Run Numbers 13 through 23 were taken with fused salt Mixture 30 in the salt loop with the salt Reynolds Number at approximately 5100.

(2) Run Numbers 20 through 30 were taken with fused salt Mixture 130 in the salt loop with the salt Reynolds Number at approximately 8000.

(3) Run Numbers 31 through 42 were taken with fused salt Mixture 130 in the salt loop with the salt Reynolds Number at approximately 2500.

Run Number	20[2]	21	22	23	24	25	26	27	28	29	30
Fused Salt Flow - lb/hr $\times 10^{-3}$	18.45	18.40	18.35	18.35	18.40	18.40	18.40	18.40	18.45	18.45	18.55
NaK Flow - lb/hr $\times 10^{-3}$	13.90	15.60	15.60	16.95	18.70	17.80	16.40	14.70	12.80	11.20	10.70
Fused Salt Temp. In - °F	1475	1474	1479	1474	1477	1477	1474	1475	1475	1466	1485
Fused Salt Temp. Out - °F	1375	1370	1373	1360	1358	1363	1366	1370	1375	1366	1387
Mean Salt Temp. - °F	1425	1422	1425	1417	1418	1420	1420	1423	1425	1416	1436
NaK Temp. Out - °F	1454	1448	1453	1442	1440	1443	1447	1454	1457	1452	1474
NaK Temp. In - °F	1147	1160	1161	1156	1163	1166	1163	1144	1127	1083	1086
Mean NaK Temp. - °F	1301	1304	1307	1299	1302	1305	1305	1298	1292	1268	1280
ΔT_{LM} - °F	86.8	88	88.7	92.9	95.1	92.8	87.2	86.3	87.9	89.4	87.7
Resistance Heat Load - BTU/hr $\times 10^{-5}$	10.74	11.65	11.65	12.12	12.85	12.49	11.96	11.71	10.75	10.63	10.63
Fused Salt Heat Load - BTU/hr $\times 10^{-5}$	10.32	10.71	11.10	11.71	12.27	11.75	11.20	10.82	10.34	10.34	10.07
NaK Heat Load - BTU/hr $\times 10^{-5}$	10.66	11.22	11.38	12.08	12.95	12.33	11.65	11.40	10.56	10.33	10.37
Calculated Salt Mix.130 cp-BTU/lb-°F	.578	.588	.575	.578	.591	.588	.586	.590	.573	.560	.572
NaK Reynolds Number $\times 10^{-4}$	9.05	10.03	10.03	11.00	12.20	11.60	10.70	9.60	8.35	7.20	6.80
1,000/NaK $Re^{0.6}$	1.073	1.012	1.000	.955	.936	.934	.971	1.048	1.135	1.218	1.272
10,000/U	4.14	4.05	3.94	3.91	3.82	3.89	3.84	3.93	4.19	4.26	4.29

Note: (1) Run Numbers 13 through 23 were taken with fused salt Mixture 30 in the salt loop with the salt Reynolds Number at approximately 5100.

(2) Run Numbers 20 through 30 were taken with fused salt Mixture 130 in the salt loop with the salt Reynolds Number at approximately 8000.

(3) Run Numbers 31 through 42 were taken with fused salt Mixture 130 in the salt loop with the salt Reynolds Number at approximately 2500.

Appendix 8.7
Wilson Plot Data Sheet - Page 3

Run Number	31(3)	32	33	34	35	36	37	38	39	40	41	42
Fused Salt Flow-lb/hr x 10^{-3}	7.20	7.00	6.75	6.90	6.78	6.90	6.65	6.90	6.95	6.60	6.90	6.90
NaK Flow - lb/hr x 10^{-3}	10.40	8.98	7.58	5.98	9.90	9.10	7.05	5.38	3.26	3.85	6.30	7.70
Fused Salt Temp. In - °F	1481	1480	1473	1454	1474	1474	1473	1452	1421	1426	1444	1464
Fused Salt Temp. Out - °F	1270	1279	1287	1296	1276	1274	1287	1305	1324	1325	1298	1278
Mean Salt Temp. - °F	1376	1380	1380	1375	1375	1374	1380	1379	1373	1376	1371	1371
NaK Temp. Out - °F	1398	1417	1428	1428	1400	1414	1433	1432	1414	1417	1416	1416
NaK Temp. In - °F	1077	1068	1045	1041	1090	1050	1040	1030	1040	1062	1062	1048
Mean NaK Temp. - °F	1238	1243	1237	1235	1245	1232	1237	1231	1227	1240	1239	1232
ΔT_{LM} - °F	130.5	122.5	117.1	102.5	121.8	124.6	113.7	97.3	74.9	75.3	97.6	116.2
Resistance Heat Load - BTU/hr x 10^{-5}	8.66	8.14	7.46	6.58	8.34	7.74	7.74	6.15	4.17	4.73	6.06	7.28
Fused Salt Heat Load - BTU/hr x 10^{-5}	8.51	7.88	7.03	6.11	7.52	7.73	6.93	5.68	3.78	3.74	5.64	7.19
NaK Heat Load - BTU/hr x 10^{-5}	8.24	7.73	7.16	5.71	7.58	8.18	6.85	5.34	3.01	3.38	5.51	7.00
Calculated Salt Mix.130 cp-BTU/lb-°F	.543	.549	.571	.524	.564	.592	.555	.527	.447	.507	.548	.545
NaK Reynolds Number x 10^{-4}	6.30	5.67	4.76	3.75	6.24	5.70	4.40	3.37	2.02	2.42	3.94	4.80
1,000/NaK $Re^{0.6}$	1.277	1.400	1.582	1.745	1.335	1.455	1.626	1.855	2.27	2.21	1.726	1.522
10,000/U	7.55	7.66	8.21	8.26	7.98	7.94	8.09	8.44	9.75	9.94	8.54	7.96

Note: (1) Run Numbers 13 through 23 were taken with fused salt Mixture 30 in the salt loop with the Reynolds Number at approximately 5100.

(2) Run Numbers 20 through 30 were taken with fused salt Mixture 130 in the salt loop with the salt Reynolds Number at approximately 8000.

(3) Run Numbers 31 through 42 were taken with fused salt Mixture 130 in the salt loop with the salt Reynolds Number at approximately 2500.

Appendix 8.8

Fused Salt Mixture 30 Pressure Drop Data

Run Number	11	12	13	14	15	16	17	18	19	20
Mean Fused Salt Temp. - °F	1210	1212	1213	1217	1223	1235	1232	1235	1235	1234
Fused Salt Flow - lb/hr	10800	16000	19400	21800	24000	25600	23400	20700	20200	13700
Fused Salt Reynolds No.	2750	4070	4930	5640	6320	6910	6320	5580	5450	3700
Heat Exchanger Total ΔP - psi	18.8	36.85	51.55	67.55	82.20	91.30	75.90	61.10	46.00	28.30
Miscellaneous ΔP(1) - psi	1.05	2.30	3.40	4.50	5.55	6.30	5.55	4.38	4.15	1.95
Heat Exchanger Net ΔP - psi	17.75	34.55	48.15	63.05	76.65	85.00	70.35	56.72	41.85	26.35
Salt Friction Factor "f"	0.0477	0.0423	0.0397	0.0416	0.0418	0.0407	0.0403	0.0415	0.0322	0.0440

$$"f" = \frac{\Delta P}{\rho/144 \times V^2/2g}$$

Fused Salt Mixture 130 Pressure Drop Data

Run Number	1	2	3	4	5	6	7	8	9	10	11	12
Mean Fused Salt Temp. - °F	1188	1188	1194	1200	1207	1209	1211	1213	1213	1213	1211	1212
Fused Salt Flow - lb/hr	6800	10400	13200	15900	17800	19200	10400	16900	14800	12200	8750	5600
Fused Salt Reynolds No.	1480	2260	2940	3580	4110	4435	4300	3960	3460	2860	2050	1310
Heat Exchanger Total ΔP - psi	14.00	30.20	49.95	69.60	84.70	97.45	90.00	77.95	60.40	42.20	19.50	9.35
Miscellaneous ΔP(1) - psi	0.65	1.50	2.55	3.60	4.70	5.45	5.20	4.35	3.40	2.30	1.20	.55
Heat Exchanger Net ΔP - psi	13.35	28.70	47.40	66.00	80.00	92.00	84.80	73.60	57.00	39.90	18.30	8.80
Salt Friction Factor "f"	0.0529	0.0487	0.0500	0.0480	0.0464	0.0458	0.0460	0.0474	0.0478	0.0493	0.0438	0.0515

$$"f" = \frac{\Delta P}{\rho/144 \times V^2/2g}$$

(1) Piping, and expansion and contraction losses included in heat exchanger total ΔP

8.9 Beryllium Control Samples

The following tabulation lists the results of air samples taken from SHE Stand C during operation with beryllium base fuel Mixture 130. The No. 1 sampler was located at the front of the stand, on the fuel loop side, while No. 2 sampler was located at the rear of the stand, again on the fuel side. Both of the air samplers were located at breathing level height.

The maximum allowable concentration (MAC) for beryllium is 2.0 $\mu g/m^3$ during an eight hour period with 25 $\mu g/m^3$ as the maximum instantaneous dose.

Date	Sampler	Micrograms per cubic meter
1-21-58	Portable sampler during filling operation	<.001
1-21-58	" " " " "	<.001
1-22-58	" " " " "	.021
1-22-58	No. 1	<.001
1-23-58	Portable sampler at oil scrubbed exhaust vent while purging	<.097
1-23-58	No. 1	<.001
1-23-58	No. 2	<.001
1-24-58	No. 1	<.001
1-24-58	No. 2	<.001
1-25-58	No. 1	<.001
1-25-58	No. 2	<.001
1-26-58	No. 1	<.001
1-26-58	No. 2	<.001
1-27-58	No. 1	<.001
1-27-58	No. 2	<.001
1-28-58	No. 1	<.001
1-28-58	No. 2	<.001
1-29-58	No. 1	<.001
1-29-58	No. 2	<.001
1-30-58	No. 1	<.0001
1-30-58	No. 2	<.0001
1-31 thru 2-2	No. 1	<.0001
1-31 thru 2-2	No. 2	<.0001
2-3-58	No. 1	<.0001
2-3-58	No. 2	<.0001
2-4-58	Portable Sampler at top of pump while replacing helium supply line	.2
2-4-58	Portable Sampler at fuel sump during dumping operation	<.0001
2-4-58	No. 1	<.001
2-4-58	No. 2	<.001
2-5-58	No. 1	<.001
2-5-58	No. 2	<.001

A smear survey was made 2-6-58 at the completion of the test run to determine the level of beryllium contamination in the vicinity of SHE Stand C. The MAC is 25 micrograms per twelve square inches.

Location	Micrograms per 12 sq. in.
On top of steel beam beside SHE-C fuel pump	.03
On side of steel beam beside SHE-C fuel pump	.024
On top of fuel pump bowl	.078
On shield at scrubber outlet	.001
On floor below scrubber outlet	.009
On top of SHE Stand B transformer, west of loop	.002
On outside of shield, west of loop	.001

:r

Approved by: W. B. McDonald
W. B. McDonald

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