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EXPERIMENTAL STUDY OF THE EFFECTIVE THERMAL CONDUCTIVITY OF LIQUID SATURATED SINTERED FIBER METAL WICKS

B. S. SINGH, A. DYBBS and F. A. LYMAN*

Division of Fluid, Thermal and Aerospace Sciences, Case Western Reserve University, Cleveland, Ohio, U.S.A.

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Abstract—This paper presents an experimental investigation of the effective thermal conductivity of liquid saturated sintered fiber metal wicks. An experimental apparatus, based on the principle of steady state method of comparison, was designed and used for determining the effective thermal conductivity of water saturated copper, nickel 200, and 430 stainless steel wicks over a wide range of porosities. Bureau of Standards melting point lead was used as the reference material of known thermal conductivity. Based on these experimental results a new correlation for predicting the effective thermal conductivity of liquid saturated sintered fiber metal wicks is also presented.

NOMENCLATURE

m, least square slope of the temperature distribution curve;
k, thermal conductivity;
ψ, porosity of the wick;
ρ, density of the wick, $1 - \psi$;
ν, ratio of the thermal conductivities of the liquid and the solid phase, respectively, k_2/k_1;
β, $(1 + \nu)/(1 - \nu)$.

Subscripts
1, properties of the solid phase of the wick;
2, properties of the liquid phase of the wick;
L, properties of lead;
p, parallel arrangement of the constituent phases of the wick;
s, series arrangements of the constituent phases of the wick;
w, properties of the wicks.

INTRODUCTION

METAL wicks have many engineering applications. Heat pipes [1], wicking evaporative heat exchangers, transpiration cooling, and filters provide a few examples. Many of these applications involve heat transfer through liquid saturated wicks. Heat transfer through such porous materials may be considered as an overall effect of three mechanisms, namely, conduction, convection, and radiation. If the temperature levels are below 400°C the contribution of radiation to the total heat transfer is small [2]. Furthermore, if a suitably defined Raleigh number is small then natural convection is also insignificant [3]. Under these circumstances conduction is the only significant mode of heat transfer. Thus for the design and performance evaluation of devices using wicking materials a knowledge of the conductive heat transfer through liquid saturated wick is required.

Since conduction in porous materials is important in many applications the "effective thermal conductivity" of porous media has been of interest to many research workers. This conductivity is usually defined as the ratio of the total heat flux to the average temperature gradient [4]. It is an appropriate volume averaged quantity and its value depends upon the geometrical arrangement of the constituent

* Presently. Associate Professor, Department of Mechanical Engineering, Syracuse University.

phases of the porous media. If this geometrical arrangement and the thermal conductivities of the two phases are known, the effective thermal conductivity of the porous media can, in principle, be evaluated. In practice, however, the geometrical arrangement is seldom known and is so irregular that evaluation of the effective thermal conductivity becomes extermely difficult except in the simplest of the cases. These cases are those in which the two phases are arranged in parallel or in series, the thermal conductivities of the respective arrangements are:

$$\frac{k_p}{k_1} = 1 + \psi(k_2/k_1 - 1) \tag{1}$$

$$\frac{k_s}{k_1} = \frac{1}{1 + \psi(k_1/k_2 - 1)}. \tag{2}$$

Equations (1) and (2) also give the maximum and minimum values, respectively, for a given ψ, k_1 and k_2. If the thermal conductivities of the two phases differ by an order of magnitude or more, the bounds determined by equations (1) and (2) become too wide and are not useful in determining the effective thermal conductivity.

Due to the analytical difficulties of determining the effective thermal conductivity most of the studies have been concerned with postulating simple geometrical models which can approximate the structure of the porous media [4–11]. The effective thermal conductivity of this model is evaluated by an appropriate integration over the phases or by a suitable electrical analog of thermal resistances. Each model is thus expected to be good only for the porous materials whose geometrical arrangement of the phases is similar to the model. Since the geometrical arrangement of the phases of most porous media is not precisely known an experimental verification is needed prior to using any proposed model.

Very little experimental work seems to have been done on the effective thermal conductivity of liquid saturated sintered fiber metal wicks. The work that has been done [10, 11] is inconclusive and suggests the need for a more accurate and comprehensive experimental program.

Thus the purpose of this study is to carry out a very precise experimental determination of the effective thermal conductivity of liquid saturated sintered fiber metal wicks of a wide range of materials and porosities. In addition the experimental results will be used to evaluate the existing models that may be useful in predicting the effective thermal conductivity of such liquid saturated metal wicks.

EXPERIMENTAL APPARATUS AND PROCEDURE

Any method used for determining the effective thermal conductivity of liquid saturated wicks should meet the following requirements.

(i) The wick should be fully saturated with the liquid at all times.
(ii) There should be no flow in the wick.
(iii) There should be no natural convection in the wick.
(iv) Contact resistance should be minimized.
(v) Soldering and welding of the wick should be avoided to prevent changes in wick properties.

In addition the method should also have good accuracy and reproducibility.

A method which meets all of the above requirements is the steady state method of comparison [12]. This method is based on the principle that when two cylinders of the same diameter are placed end to end and heat is supplied at the one end of the assembly, the heat flux through both of the cylinders is the same provided that their lateral surfaces are insulated against any type of heat loss. If the thermal conductivity of one of the cylinders is known (reference cylinder), the thermal conductivity of the other (specimen) can be determined if the axial temperature gradient in both of the cylinders is measured.

Figure 1 shows a schematic diagram of the test section designed to study the effective thermal conductivity of liquid saturated wicks. The test specimen is a sintered fiber metal wick cylinder $\frac{3}{4}$ in. nominal dia. and 3 in. long. The

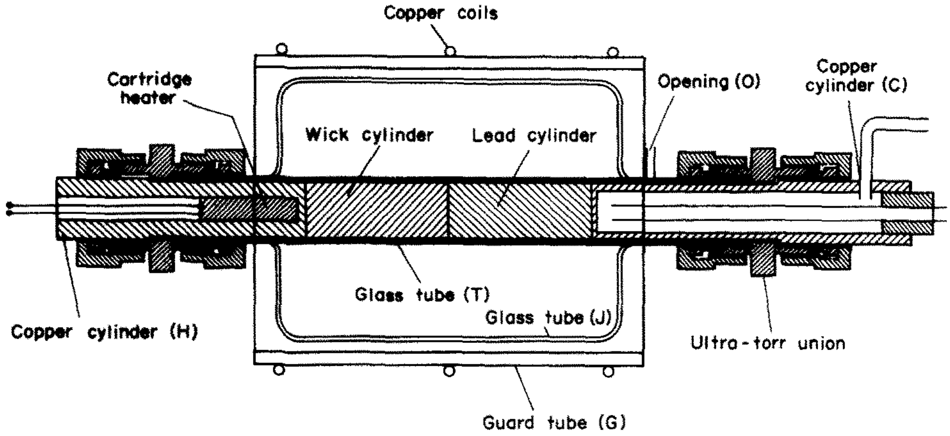

FIG. 1. Schematic diagram of the test section.

reference material of known thermal conductivity is the Bureau of Standards' melting point standard lead. This lead standard is also a cylinder $\frac{3}{4}$ in. nominal dia. and 3 in. long. On the surface of each of the cylinders a groove $\frac{1}{8}$ in. wide and $\frac{1}{16}$ in. deep is cut. Along the centerline of the groove radial holes 0·02 in. nominal dia. are drilled $\frac{1}{2}$ in. apart. Holes were drilled very slowly and with extreme care so as to minimize any effect on the structure and porosity of the wick. Since the volume of all holes was less than 0·1 per cent of the volume of the sample, measurements of the porosity of the sample before and after the holes were drilled showed no change within the experimental accuracy of $\pm$ 1 per cent. Each cylinder has five holes and thermocouples are introduced in each of the holes. Measurement of radial temperature was not thought to be necessary as the experimental procedure requires elimination of radial heat losses. However, to make sure that radial losses were negligible the thermal conductivity of the standard material was measured. This is discussed in the following section titled Precision of the Method.

The wick and the lead cylinders are contained in a $\frac{3}{4}$ in. i.d. precision bore glass tube (T), as shown in Fig. 1. There is a copper cylinder (H) containing a cartridge heater in contact with the wick cylinder and another copper cylinder (C) containing a cooling chamber in contact with the lead cylinder. These cylinders are connected to the glass tube (T) by two Ultra-Torr-Unions. These unions hold the cylinders in place and also provide a contact pressure on the wick and the lead cylinders. The central portion of the glass tube covering the wick and the lead cylinders is surrounded by a glass jacket (J). The annular space between tubes (T) and (J) is evacuated to a pressure of 10^{-7} micron, baked, and then sealed. The jacket (J) in turn is surrounded by a copper guard tube (G) which has three copper coils soldered to it. Each of these coils is supplied with water at a controlled temperature and flow rate. By adjusting the flow rate and temperature of the water flowing through each of the coils any required temperature distribution can be maintained in the guard tube. Thermocouples are attached to the guard tube to measure its temperature distribution. Evacuating the annular space eliminates natural convection and reduces conduction losses from the test section. The guard tube temperature is matched to that of the wick specimen and the lead reference cylinder. This reduces conduction losses and eliminates radiation losses from the test section.

After proper positioning of the thermocouples the opening (O) is sealed using high vacuum epoxy. The thermocouples are made from copper–constantan (AWG 30) wires supplied by Leeds & Northrup. The output of the thermocouples is read by a type K-3 Leeds & Northrup potentiometer which uses an electronic d.c. null detector. The accuracy of the potentiometer is better than a microvolt. The thermocouples are calibrated against a standard mercury-in-glass thermometer having an accuracy of 0·1°F. The thermocouples were found to be accurate to within ± 0·2°F in the temperature range used in the tests (40–120°F). The power to heater was supplied by a d.c. power supply unit having a built in voltage regulator.

During the test the wick is evacuated to a pressure of about 2 μ and filled with deaerated distilled water. The degree of saturation obtainable from this procedure was found to be better than 98 per cent.

To start the test the heater and cooling water supplies are turned on. Temperature readings are taken at intervals of 30 min and the guard tube temperature distribution is matched to that in the test section. When the guard tube temperature distribution is matched to within ± 1·5°F and the difference between two consecutive sets of readings is less than ± 0·2°F steady state is assumed to have been reached. A series of data are then taken at 30 min intervals. Throughout the duration of the experiments no vapor bubbles were observed nor temperature "hot spots" measured in the samples. This would indicate an absence of vapor in the samples during the tests. Further experimental details can be found in [13].

Precision of the method

Since this apparatus has probably never been used before, tests were performed to determine the precision obtainable by this method. The thermal conductivity of the Bureau of Standards' melting point lead was measured against itself. Two samples were interchanged and a series of data were taken. The results indicated that the matching of guard tube and test section temperatures was very critical. If these temperatures were

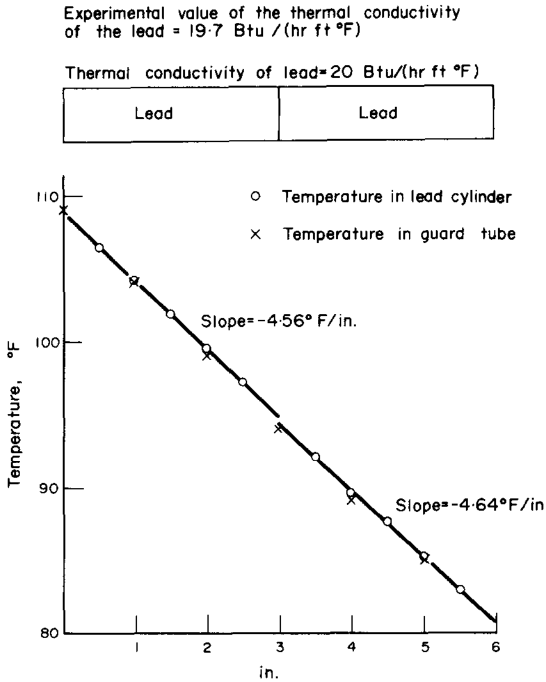

FIG. 2. Experimental temperature distribution in the guard tube, and the Bureau of Standards' melting point lead when it was used both as reference and specimen.

maintained to within ± 2°F an accuracy of ± 2 per cent was obtained. Results of a typical set of data are plotted in Fig. 2. The temperature distribution is a pair of straight lines. The jump discontinuity in temperature distribution represents the contact resistance at the interface. The effect of this was negligible when the guard tube temperature distribution is matched to that in the test section. It also indicates that with properly matched guard tube temperature the radial heat losses are negligible.

EXPERIMENTAL RESULTS

Tests were performed on seven different sintered fiber metal wicks made of copper, nickel, and stainless steel, covering a wide range of porosities. The thermal conductivity determined was that parallel to the felting plane. The properties of these wicks are listed in Table 1.

*Table 1. Wick samples and their properties**

Wick	Porosity (%)	Median pore size (μ)	Mean fiber diameter (μ)	Length to dia. ratio of the fibers	Supplier
Ni200	81·5	74	16	80	Huyck Metals Co. Milford, Conn.
Ni200	43·9	12·5	16	80	
Ni200	33·4	8	16	80	
Ni200	28·8	6·4	16	80	
430SS	75·9	142	16	80	
430SS	82·6	190	40	80	
Copper	80·0	140	35	40	

* Data supplied by the manufacturer.

Typical experimental temperature distributions for each wick specimen and lead reference cylinder combination is shown in Figs. 3–6. In each case the temperature distributions are a pair of straight lines. The straight lines shown in the figure are least square fits of the experimental data. Their slopes, also obtained by the method of least squares, are indicated in each figure. The confidence interval for least square slopes [18] for each pair of straight lines in

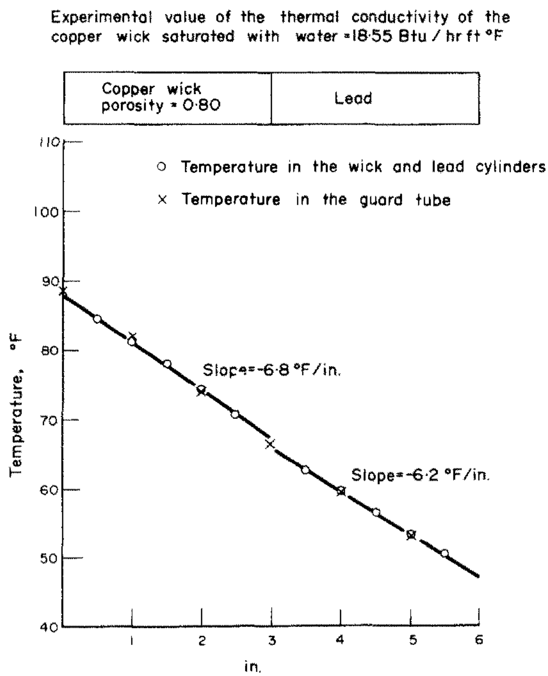

FIG. 3. Experimental temperature distributions in the guard tube, the water saturated copper wick specimen, and the lead reference. (Thermal conductivity of lead reference = 20 Btu/(hft°F).)

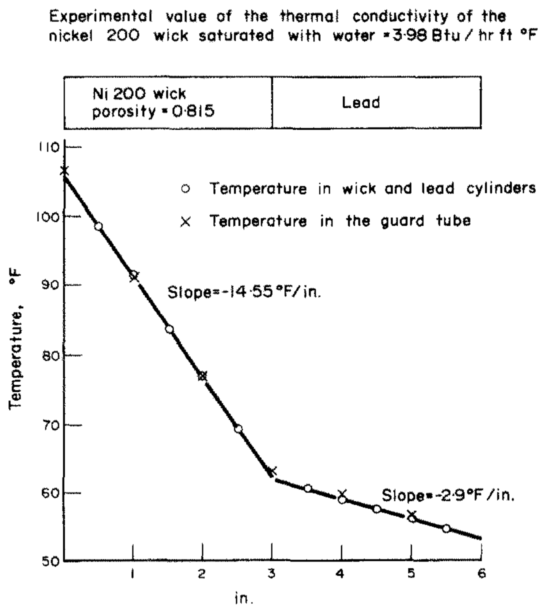

FIG. 4. Experimental temperature distributions in the guard tube, the water saturated nickel 200 wick specimen, and the lead reference. (Thermal conductivity of lead reference = 20 Btu/(hft°F).)

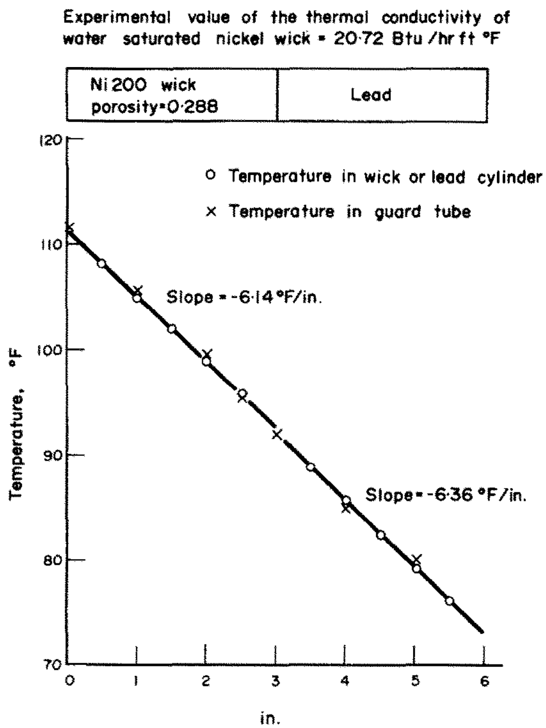

FIG. 5. Experimental temperature distributions in the guard tube, the water saturated nickel wick specimen, and the lead reference. (Thermal conductivity of the lead reference = 20 Btu/(hft°F).)

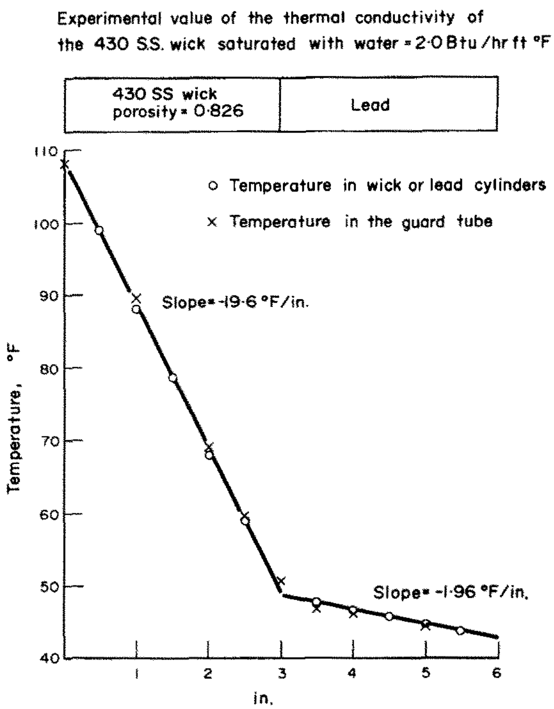

FIG. 6. Experimental temperature distributions in the guard tube, the water saturated 430 stainless steel wick specimen, and the lead reference. (Thermal conductivity of the lead reference = 20 Btu/(hft°F).)

Figs. 3–6, are $-6{\cdot}8 \pm 0{\cdot}22$, $-6{\cdot}2 \pm 0{\cdot}14$; $-14{\cdot}56 \pm 0{\cdot}56$, $-2{\cdot}9 \pm 0{\cdot}047$; $-6{\cdot}14 \pm 0{\cdot}118$, $-6{\cdot}36 \pm 0{\cdot}13$; and $-19{\cdot}6 \pm 0{\cdot}78$, $-1{\cdot}96 \pm 0{\cdot}054$, respectively. In each case this corresponds to a probability of 0·95 that these limits enclose the true value of the slope. The jump discontinuity in the temperature distribution represents the contact resistance at the wick lead interface. This contact resistance was, however, small due to the Ultra-Torr unions and the surface tension forces between the specimen and the reference cylinder which promoted good thermal contact.

The experimental data shown in Figs. 3–6 were used to calculate the effective thermal conductivity of the wicks as follows:

The value of the thermal conductivity of lead was taken to be 20 Btu/(hft°F) at 60°F according to [14]. Since the temperature range of the experiments was narrow (40–120°F) and the temperature coefficient of the thermal conductivity of lead is small (0·004 Btu/(fth°F^2)) the same value of the thermal conductivity of lead was used in all the cases. With this and the knowledge of the slopes of the temperature distributions of the wick and lead, the thermal conductivity of liquid saturated wick can be calculated as:

$$k_w = \frac{m_L}{m_w} k_L. \tag{3}$$

From each set of experimental data the value of the effective thermal conductivity of the water saturated wick is computed. The values listed in Table 2 are obtained by taking an average of approximately ten sets of data, whose deviation

Table 2. Experimental value of the Effective thermal conductivity of water saturated wicks in Btu/(hft°F)

Alloy	Porosity (%)	k_w Experiment	Temperature range (°F)	Experimental errors (%)	k_l Thermal conductivity of wick alloy	$\frac{k_w}{k_l}$
Ni200	81·5	4·0	62–105	± 6	36·0	0·11
Ni200	43·9	16·2	90–112	± 5	36·0	0·45
Ni200	33·4	18·2	88–112	± 5	36·0	0·506
Ni200	28·8	20·8	92–112	± 5	36·0	0·577
430SS	75·9	2·6	48–105	± 8	12·6	0·20
430SS	82·6	2·0	48–110	± 8	12·6	0·16
Copper	80·0	18·6	65–90	± 5	223·0	0·083

is found to be ± 2·5 per cent. Experimental errors are also listed in the Table.

EXPERIMENTAL ERRORS

To eastablish the validity and usefulness of the experimental results, it is important to examine the sources of error and evaluate their contribution to the total error.

Errors in the experimental results could be introduced due to the following effects:

(i) Conductivity mismatch between the specimen and the standard. Differences in conductivities may divert some of the heat flux from the specimen to the glass tube and air gap which may again return to the standard. If this happens then the heat flux through the standard and the specimen will no longer be the same. A discussion and method of estimation of this error may be found in [15]. In these experiments, the conductivity mismatch was at most a factor of 10 and the thermal conductivity of insulation (glass tube and evacuated annular space) was small. Thus the error due to this effect is less than 1 per cent.

(ii) Contact resistance at the interface can distort the isotherms. This may introduce an error in the readings of the thermocouples close to the interface and may also lead to some heat losses. Estimation and discussion of this error is also given in [15]. The contact resistance was so small in the present case that the error estimate is less than 1 per cent.

(iii) Heat loss due to improperly matched guard tube temperature distribution. If the guard tube temperature is not properly matched to that in the test section, there will be radiation and conduction losses from the test section. These losses can be estimated by calculating the conduction and radiation between two concentric cylinders. With ± 1·5°F mismatch between the test section and the guard tube temperatures, the error was found to be negligible.

(iv) Uncertainty in thermocouple locations.

(v) Uncertainty in thermocouple readings.

The thermocouples used in these experiments were calibrated and showed an error of ± 0·2°F and the heat losses through the thermocouples were found to be very small.

Of all the errors discussed above, those due to thermocouple positioning are the most important. These errors coupled with those of thermocouple accuracy affect the temperature distributions and hence the value of the effective thermal conductivity of the wick. A discussion of these follows:

The maximum error due to these sources can be estimated by considering the thermocouples at the ends of the specimen and reference cylinders and determining the change in slopes

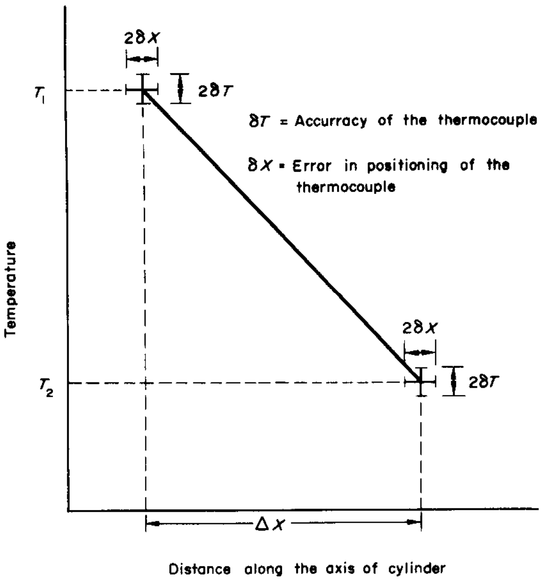

FIG. 7. The estimate of the error in the slope of the temperature distribution due to the effect of uncertainties in thermocouple location and reading.

due to thermocouple positioning and accuracy errors as indicated in Fig. 7. The maximum error due to these effects was different for each wick and was found to be $\pm$ 3 per cent for copper and nickel, and $\pm$ 5 per cent for stainless steel.

Estimates of the errors from all these sources are indicated in Table 2 along with the experimental results. The maximum error was $\pm$ 8 per cent for stainless steel.

COMPARISON WITH PREVIOUS WORKS

The results of the present experimental study are compared with previously suggested analytical models which have some geometrical similarlity with the structure of the sintered fiber metal wicks.

Sintered fiber metal wicks are made by felting the fibers in a plane, stacking the felted fibers together and then sintering them at an appropriate temperature [16]. The planes in which the fibers are felted are known as felting planes. There is a preferred orientation of fibers along the felting plane. The wick cylinders used in this study are machined from the plates of sintered fiber metal. There is a preferred orientation of fibers along the axis of the cylinders [17]. Due to the nature of the sintered fiber metal wicks, discussed above, those models having cylindrical geometry of the solid phase appear to be of some utility. Maxwell [5] gave an expression for the conductivity of a random arrangement of randomly sized cylinders, which is

$$\frac{k}{k_1} = \frac{\beta - \psi}{\beta + \psi}. \tag{4}$$

Raleigh [6] obtained a series solution for the conductivity of a square array of uniformly sized cylinders using potential theory. His solution is

$$\frac{k}{k_1} = 1 - \frac{2\psi}{\beta + \psi - \dfrac{0{\cdot}036\psi^4}{\beta} - \dfrac{0{\cdot}0134\psi^8}{\beta} \cdots} \tag{5}$$

If the terms of order ψ^2 and higher are dropped from equation (5) then one obtains equation (4) which is Maxwell's expression. For all the nickel wicks Raleigh's model is quite good (see Table 3). But for the copper and stainless steel wicks the agreement is poor.

Dul'nev [7] developed a model for determining the thermal conductivity of porous media having interconnected pores. He postulated a unit cell in which the solid phase is in the form of a cubical skeleton. He assumes that the isotherms are parallel planes i.e. pure unidirectional conduction. His result is:

$$\frac{k}{k_1} = c^2 + v(1 - c)^2 + \frac{2vc(1 - c)}{vc + 1 - c} \tag{6}$$

where $c = 0{\cdot}5 + A\cos\frac{\theta}{3}$

and

$0 \leqslant \psi \leqslant 0{\cdot}5, A = -1, \theta = \arccos(1 - 2\psi)$

$0{\cdot}5 \leqslant \psi \leqslant 1, A = 1, \theta = \arccos(2\psi - 1).$

Table 3. Comparison with previous works

Wick	Porosity	k_w Present experiment	k_w Correlation of Soliman *et al.* [10]	k_w Raleigh [6]	k_w Dul'nev [7]	k_w Present correlation equation (7)
Ni200	0·815	4·0	3·4	4·2	3·1	3·78
Ni200	0·439	16·2	14·5	14·3	11·0	14·4
Ni200	0·334	18·2	18·7	18·2	14·1	18·5
Ni200	0·288	20·8	20·7	20·2	16·3	20·5
430SS	0·759	2·6	2·4	2·0	1·6	2·33
430SS	0·826	2·0	1·7	1·4	1·2	1·74
Copper	0·80	18·6	13·8	33·0	18·4	20·9

Values of the thermal conductivity are in Btu/(hft°F).

A comparison of Dul'nev's results with the present experimental results (Table 3) shows that the former predicts too low a value for all the wicks except the copper one for which the result is very close.

Soliman *et al.* [10] performed some experiments and gave an empirical correlation for the thermal conductivity of high porosity sintered fiber metal wicks saturated with water.

As is shown in Table 3 their correlation is within $\pm$ 10 per cent for Nickel 200, 15 per cent lower for 430 stainless steel, and 30 per cent lower for copper than those values reported in this study. This discrepancy may be due to the fact that in their experiments Soliman *et al.* [10] do not consider radiation losses which were found to be crucial in the present work. Furthermore, because the temperature is measured at the brazed interface non-uniformities in the brazing and contact resistance may affect the measurements. The correlation based on their experiments also predicts a lower value for high porosity liquid saturated sintered fiber metal wicks as is shown in Table 3. However, for nickel wicks of low porosity correlation of Soliman *et al.* [10] is in good agreement with the experimental results. Since none of the existing models is satisfactory a new correlation based on the present work is now presented.

CORRELATION BASED ON THE PRESENT WORK

The experimental results for the thermal conductivity of the water saturated metal wicks were used to determine the correlation shown in Fig. 8. In the figure a normalized thermal conductivity $k_w/k_1 - \psi\, k_2/k_1$ was plotted against the porosity. The following equation correlated that data for copper, 430 stainless steel, and nickel 200 wicks.

$$\frac{k_w}{k_1} = \left[1 - \psi + \frac{k_2}{k_1}\psi\, e^{(1-\sqrt{k_2/k_1})^b}\right] e^{-\psi(1-\sqrt{k_2/k_1})^b} \qquad (7)$$

where $b = 20\sqrt{(k_2/k_1)}$.

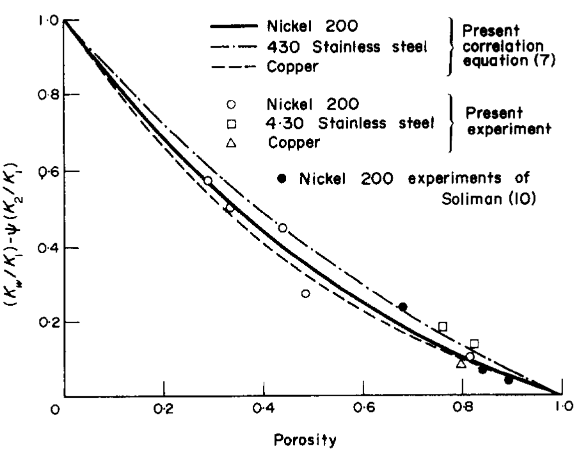

FIG. 8. Comparison of the correlation, equation (7), with the experimental data.

Equation (7) agrees with the nickel 200 data to within $\pm$ 5 per cent with the exception of the point at $\psi = 0{\cdot}484$. This data point is in question because it was found that the specimen used in this experiment was non uniform in porosity. The nickel 200 data was for porosities from 28·8 to 81·5 per cent. Both the copper and the 430 stainless steel are within $\pm$ 10 per cent of the correlation. However, it should be noted that the porosity range for these was more limited i.e. from 75 to 83 per cent. Nevertheless, equation (7) appears to give good agreement for both copper and 430 stainless steel wicks. Thus the correlation may be used to predict the effective thermal conductivity parallel to the felting plane of liquid saturated copper, 430 stainless steel, and nickel 200 sintered fiber metal wicks.

Also shown in Fig. 8 is the data of Soliman *et al.* [10] for nickel 200 wicks. This data is within $\pm$ 20 per cent of equation (7). Also, it should be noted that equation (7) in the limit $k_2 \to 0$ (evacuated wick) gives

$$\frac{k_w}{k_1} = (1 - \psi)\,e^{-\psi}. \tag{8}$$

A comparison of equation (8) with appropriate data of [10] shows agreement to within 40 per cent in the worst case. These differences may be attributed to the sources of error in their experiments as previously discussed.

Another correlation based on the contact resistance may be found in [13].

CONCLUSIONS AND DISCUSSIONS

This paper has used the steady state method of comparison to accurately determine the effective thermal conductivity of liquid saturated sintered fiber metal wicks. Copper, 430 stainless steel, and nickel 200 wicks over a wide range of porosity were tested with water as the saturating fluid. The experimental results had a maximum error of $\pm$ 5 per cent for the copper, $\pm$ 6 per cent for the nickel 200, and $\pm$ 8 per cent for 430 stainless steel wicks. A correlation, equation (7), based on the experimental results was found.

The existing models and correlations that may be applicable for predicting the effective thermal conductivity of liquid saturated sintered fiber metal wicks do not seem to give uniform agreement to the experimental results for copper, nickel, and stainless steel wicks throughout the range of porosities. However, the correlation proposed in this study does give good agreement for all these metal wicks tested within a wide porosity range to within $\pm$ 10 per cent.

ACKNOWLEDGEMENTS

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REFERENCES

1. G. M. Grover, T. P. Cotter and G. F. Erickson. Structures of very high conductance, *J. Appl. Phys.* **35**, 1990–1991 (1964).
2. F. B. Hill and R. H. Wilhelm, Radiative and conductive heat transfer in quiescent gas solid beds: theory and experiment, *A.I.Ch.E. Jl* **5**, 486 (1959).
3. A. L. Waddams, Flow of heat through granular materials, *J. Soc. Chem. Ind., Lond.* **63**, 486 (1944).
4. R. L. Gorring and S. W. Churchill, Thermal conductivity of heterogeneous materials. *Chem. Engng Prog.* **57**, 58 (1961).
5. J. Maxwell, *Treatise on Electricity and Magnetism*, Vol. 1, 3rd ed. Oxford Univ. Press (1891). Reprinted Dover, N. Y. (1954).
6. Lord Raleigh. On the influence of obstacles arranged in rectangular order upon the properties of a medium, *Phil. Mag.* **34**, 481 (1892).
7. G. N. Dul'nev, Heat transfer through solid disperse systems, *Inz. Fiz. Zh.* **9**, 399 (1965). English translation, *J. Engng Phys.* **9**, 275 (1965).
8. G. T. Tsao, Thermal conductivity of two phase materials. *Engng Approaches* **35**, 395 (1961).
9. A. V. Luikov, A. G. Shaskov, L. L. Vasilier and Yu E. Frainan, Thermal conductivity of porous systems, *Int. J. Heat Mass Transfer* **11**, 117 (1968).
10. M. M. Soliman, D. W. Graumann and P. J. Berenson, Effective thermal conductivity of dry and liquid-saturated sintered fiber metal wicks, ASME paper 70-HT/SpT-40 (1970).
11. R. P. Tye, An experimental investigation of the thermal conductivity and electrical resistivity of three porous 304L stainless steel "Pigmesh" materials to 1300K. NASA CR-72710 (1970).
12. M. S. Van Dusen and S. M. Shelton, Apparatus for measuring thermal conductivity of metals up to 600°C. *Nat. Bur. Stand. J. Res.* **12**, 429 (1934).

13. B. S. SINGH, Experimental Study of the thermal conductivity of liquid saturated metal wicks, M.S. Thesis, Case Western Reserve University, Cleveland, September 1971.
14. T. M. DAUPHINEE, L. D. ARMSTRONG and S. B. WOODS, The thermal conductivity of pure lead. *Can. J. Phys.* **44**, p. 2035 (1966).
15. R. P. TYE, (editor), *Thermal Conductivity*, Vol. 1, p. 174, Academic Press, New York (1969).
16. Feltmetal Technical Bulletin, Huyck Metals Co., Milford, Conn.
17. Private Communications with Huyck Metals Co.
18. A. H. BOWKER and G. J. LIEBERMAN, *Engineering Statistics*, p. 246. Prentice-Hall, Englewood Cliffs, N.J. (1959).

ETUDE EXPERIMENTALE DE LA CONDUCTIVITE THERMIQUE EFFECTIVE DE MECHES A FIBRES METALLIQUES SATUREES DE LIQUIDE

Résumé Cet article présente une recherche expérimentale sur la conductivité thermique effective de mèches à fibres métalliques saturées de liquide. Un montage expérimental basé sur le principe de la méthode de comparaison en régime stationnaire a été réalisé et utilisé pour la détermination de la conductivité thermique effective de mèches de cuivre, de nickel 200, d'acier inoxydable 430 saturés d'eau, pour un large domaine de porosités. La donnée du Bureau of Standards pour le plomb au point de fusion est prise comme référence de conductivité thermique connue. On a présenté une nouvelle relation basée sur ces résultats expérimentaux pour l'estimation de la conductivité thermique effective de mèches à fibres métalliques saturées de liquide.

EINE EXPERIMENTELLE UNTERSUCHUNG DER EFFEKTIVEN WÄRMELEITFÄHIGKEIT VON FLÜSSIGKEITS-GETRÄNKTEN, GESINTERTEN METALLFASER-DOCHTEN

Zusammenfassung—Diese Arbeit beschreibt eine experimentelle Untersuchung der effektiven Wärmeleitfähigkeit mit Flüssigkeit getränkter, gesinterter Metallfaser-Dochte.

Eine Versuchsapparatur, beruhend auf dem Prinzip der Vergleichsmethode stationärer Zustände, wurde entworfen und für die Bestimmung der effektiven Wärmeleitfähigkeit wassergetränkter Dochte aus Kupfer, Nickel 200 und nichtrostendem Stahl 430 für einen grossen Bereich von Porositäten benutzt. Als Referenzmaterial bekannter Wärmeleitfähigkeit wurde NBS–Schmelzblei herangezogen. Beruhend auf diesen experimentellen Ergebnissen wurde auch eine neue Beziehung zur Bestimmung der effektiven Wärmeleitfähigkeit mit Flüssigkeit getränkter, gesinterter Metallfaser-Dochte angegeben.

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ЭФФЕКТИВНОЙ ТЕПЛОПРОВОДНОСТИ МЕТАЛЛОКЕРАМИЧЕСКИХ ВОЛОКНИСТЫХ ФИТИЛЕЙ С ЖИДКИМ НАПОЛНЕНИЕМ

Аннотация—В статье описывается экспериментальное исследование эффективной теплопроводности металлокерамических волокнистых фитилей с жидким наполнением. Разработана экспериментальная аппаратура, работающая по принципу стационарного метода сравнения, которая использовалась для определения эффективной теплопроводности фитилей из меди, никеля-200 и нержавеющей стали-430 с жидким наполнением в широком диапазоне пористости. В качестве материала для сравнения использовался свинец со стандартной точкой плавления, теплопроводность которого была известна. На основе экспериментальных результатов получено новое соотношение для расчета эффективной теплопроводности металлокерамических волокнистых фитилей с жидким наполнением.