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THERMAL TRANSFER FROM A SMALL WIRE IN THE BOUNDARY FLOW ABOUT A CYLINDER

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Abstract—Measurements of the heat transfer coefficient from a platinum wire 0.001 in. in diameter were made throughout the boundary flows about a 1 in. diameter cylinder at gross air velocities of 4, 8, and 16 ft/s. The results are presented in terms of the Nusselt number for the wire and are depicted in graphical and tabular form. Comparison is made with values predicted from estimated velocities in the boundary flows, and available heat transfer data for small wires in free streams.

NOMENCLATURE

C_p, isobaric heat capacity, Btu/lb °F;
D, substantial differential operator;
d, diameter, ft or in;
d, differential operator;
E, internal energy, Btu/lb;
F, force per unit volume, lb/ft^3;
h, heat transfer coefficient, Btu/s ft^2 °F;
I_n, modified Bessel function of first kind;
K_n, modified Bessel function of second kind;
k, thermal conductivity, Btu/s ft °F;
l, length, ft or in;
N, number of experimental points;
Nu, Nusselt number, corrected for deviation from "ideal" conditions;
P, pressure, lb/ft^2;
Pr, Prandtl number;
$\dot{q}$, thermal flux, Btu/s ft^2;
$\mathring{q}$, total thermal flux, Btu/s;
Re, Reynolds number;
r_0, radius of cylinder, ft or in;
r, radial position, ft or in;
t, temperature, °F;
T, absolute temperature, °R;
U, gross air velocity, ft/s;
u, point velocity, ft/s;
V, specific volume, ft^3/lb;
x, distance from centerline of cylinder parallel to axis of flow, ft or in;
y, distance from centerline of cylinder normal to axis of flow, ft or in.

Greek

δ_{ij}, Kronecker delta;
ζ, correction factor;
η, absolute viscosity, lb s/ft^2;
θ, time, s;
ν, kinematic viscosity, ft^2/s;
ξ, distance parameter, $[(r/r_0)-1]Re^{1/2}$;
ρ, density, lb s^2/ft^4;
σ, specific weight, lb/ft^3;
Σ, summation operator;
Φ, viscous dissipation, Btu/s ft^3;
$\phi_1, \phi_2 \ldots$, stream functions;
ψ, angle from stagnation, deg;
∂, partial differential operator;
∇, del operator.

Subscripts

c, cylinder;
e, experimental;
i, j, dummy variables;
n, index;
r, radial;
w, wire;
∞, airstream;
ψ, tangential.

Superscripts

—, vector.

INTRODUCTION

THE convective thermal transfer from small wires has been a subject of numerous experimental studies. The early work of King [1] followed by measurements of Cole and Roshko [2] and the more recent data of Collis and Williams [3] established with reasonable accuracy the effect of the dimensions of the wire and the gross velocity of the approaching stream upon the thermal transfer. As the temperature difference between the surface of the wire and the stream in which it is immersed increases, linear correlations become less useful. The variations in the molecular properties of the fluid with distance from the surface of the wire materially influences the nature of the transport phenomena, and linear averages no longer satisfy the requirements for effective predictions of thermal transport.

Few investigations appear to have been carried out upon the thermal transfer from small wires where velocity gradients exist normal to the wire. Such gradients are encountered in the boundary flows about cylinders. Difficulties were experienced [4] in predicting the thermal transfer to small thermocouple wires in the boundary flows about cylinders and spheres from the local speed of flow and available experimental information concerning thermal transfer from small wires in free air streams [2, 5]. As a result of these difficulties, direct measurements of the thermal transfer as a function of the temperature of a 1-mil platinum wire in the boundary flow about a cylinder 1 in. in diameter were made for velocities of the approaching air stream of 4, 8, and 16 ft/s. The results are in fair agreement with predictions based on the speed in the boundary flows and recently reported [3] thermal transfer coefficients to small wires in free air streams.

EXPERIMENTAL APPROACH

Theory

In predicting the flow field about a cylinder at Reynolds numbers large compared to unity, it has become customary to treat the field in two parts. In close proximity to the surface of the cylinder, the flow is considered to follow that of conventional boundary layer equations [6, 7]. The flow in this region may be described by the equations based on the conservation of momentum, energy, and material. For Newtonian fluids these equations are

$$\rho \frac{\mathrm{D}u_i}{\mathrm{D}\theta} = F_i - \frac{\partial P}{\partial x_i} + \sum_{j=1}^{3} \frac{\partial}{\partial x_j}\left[\eta\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\,\delta_{ij}\,\nabla \cdot u\right)\right] \qquad (1)$$

$$\sigma\left[\frac{\mathrm{D}E}{\mathrm{D}\theta} + P\,\frac{\mathrm{D}V}{\mathrm{D}\theta}\right] = -\nabla \cdot \mathring{q} + \Phi \qquad (2)$$

$$\frac{\mathrm{D}\sigma}{\mathrm{D}\theta} = -\sigma \nabla \cdot \bar{u}. \qquad (3)$$

A reasonable approximation has been established by Prandtl [6] and solved by Hiemenz [8] and Howarth [9] to yield

$$u_\psi = 2\,U_\infty\left(\psi \frac{\mathrm{d}\phi_1}{\mathrm{d}\xi} - \frac{4}{3!}\,\psi^3 \frac{\mathrm{d}\phi_3}{\mathrm{d}\xi} + \frac{6}{5!}\,\psi^5 \frac{\mathrm{d}\phi_5}{\mathrm{d}\xi} \ldots\right) \qquad (4)$$

$$u_r = \frac{2U_\infty}{Re^{1/2}}\,(\phi_1 - 2\psi^2\,\phi_3 + \tfrac{1}{4}\,\psi^4\,\phi_5 \ldots). \qquad (5)$$

The above equations lend themselves to tabular solutions [7] which are readily available and permit an approximation of the boundary flow in the immediate vicinity of the periphery of the cylinder to be established with some certainty.

At a distance from the cylinder it is convenient to utilize the concepts of potential flow which will permit the evaluation of the tangential and radial velocities in terms of the following expressions:

$$u_\psi = U_\infty\left(1 + \frac{r_0^2}{r^2}\right)\sin\psi \qquad (6)$$

$$u_r = U_\infty\left(1 - \frac{r_0^2}{r^2}\right)\cos\psi. \qquad (7)$$

The speed normal to a wire parallel to the axis of the cylinder is found from the normal and tangential velocities by the following expression:

$$|u| = (u_\psi^2 + u_r^2)^{1/2}. \tag{8}$$

The foregoing expressions permit the speed normal to a small wire in the boundary and potential flows about a cylinder to be predicted as a function of position. It is an obvious step to predict the thermal transfer in boundary flows from measurements of the thermal transfer from a wire in a free stream normal to its axis. When the dissipation function is neglected and the molecular properties of the fluid are considered constant, the thermal transfer from a wire can be expressed as

$$\bar{u} \cdot \nabla T = \frac{k}{C_p \sigma} \nabla^2 T. \tag{9}$$

The approximation of equation (9) with a uniform velocity field corresponds to the Oseen [10] approximation for momentum transport. It was solved by Cole and Roshko [2] to yield the following equation for the Nusselt number of a wire normal to the stream:

$$Nu = z \sum_{n=0}^{\infty} (-1)^n \frac{I_n\,[(Re\,Pr)/4]}{K_n\,[(Re\,Pr)/4]}. \tag{10}$$

Piercy, Richardson and Winny [11] have obtained a solution to equation (9) assuming the flow field is potential in a region bounded by an infinite isothermal flat plate and a cylinder. The solution is shown in Fig. 1. It should be recognized that the data of Fig. 1 involve a number of approximations as have been indicated earlier, and therefore are only an approximation of the physical situation.

Definition of terms

Before proceeding with the evaluation of experimental data it is desired to define a number of terms. The Reynolds number of the cylinder was established from

$$Re_\infty = \frac{d_c\, U_\infty}{\nu_\infty} \tag{11}$$

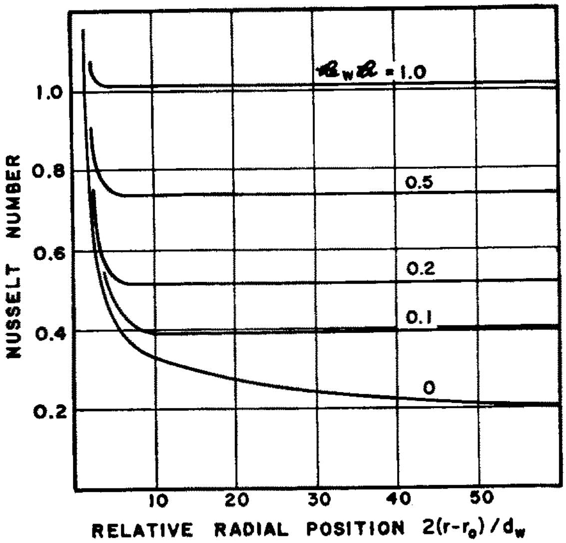

FIG. 1. Effect of relative radial position on Nusselt number.

while that of a wire is given by

$$Re_w = \frac{d_w\, u}{\nu_\infty}. \tag{12}$$

The heat transfer coefficient from a small wire is for present purposes defined as

$$h = \frac{\mathring{q}}{\pi\, d_w\, l\,(t_w - t_\infty)}. \tag{13}$$

In equation (13) the temperature of the wire t_w is taken as that determined from its electrical resistance.

For the present situation the Nusselt number of the wire was established in terms of the free stream properties. The latter approach introduced a significant variation in the Nusselt number with change in wire temperature. Such changes can be markedly reduced by assuming some other temperature at which to evaluate the average molecular properties of the boundary flow. However, for clarity of presentation and ease of interpretation, the following simple definition of the Nusselt number was employed:

$$Nu_e = \frac{h\, d_w}{k_\infty}. \tag{14}$$

In order to reduce to a minimum the effects of wire temperature upon the Nusselt number, all values have been reduced to a Nusselt number corresponding to a wire temperature of 150·0°F and a free stream temperature of 100·0°F. The methods employed in accomplishing these small adjustments in the experimental data are available [12].

The use of the resistance temperature of the wire as equal to the wire surface temperature is subject to some error as a result of finite wire length [13] and small radial temperature variations which were neglected. The magnitude of the first correction depends on the ratio of the length to the diameter of the wire. Errors will also arise from a "temperature jump" at the air–wire interface as a result of molecular-free paths of the order of magnitude of the wire diameter [3]. These effects were all combined into a single factor ζ.

$$Nu = \zeta\, Nu_e. \qquad (15)$$

A description of the quantitative determination of this correction factor ζ is available [12]. These three corrections were never larger than 2 per cent of the total thermal transfer.

In the analysis of the experimental results, the radiant transfer between the wire and the surroundings was neglected. A review of the magnitude of the radiant transport indicates that, under the most unfavorable conditions, the maximum error introduced by such neglect was less than 0·1 per cent. The influence of the electric current employed in connection with the use of a Mueller bridge for the measurement of the resistance of the wire at small energy dissipations was neglected. It amounted to less than 0·05°F. under the most adverse conditions and was in the opposite direction of the radiation correction. The combined effects of radiation loss and bridge current wire temperature rise involved an uncertainty in the evaluation of the air temperature of less than 0·02°F. As would be expected, some perturbations in air temperature with time were encountered and in some cases were as large as 0·1°F. Throughout the analysis a time average of the values was taken in evaluating the variables.

EQUIPMENT

The experimental work associated with this program was carried out in a free jet emerging from a rectangular duct 3 in. by 12 in. The duct terminated at the end of a one-dimensional converging section from a uniform duct 12 in. by 12 in. [14]. The cylinder was constructed of copper 1 in. in diameter. The wire, which was approximately 1·25 in. in length and 0·001 in. in diameter, was mounted with its axis parallel to that of the cylinder.

The air supply used for these investigations has been described in some detail [15]. It consists of two blowers connected to a single direct current motor, so arranged that they could be connected in series or parallel. The speed of the motor was controlled by a suitable modulating circuit [16] and a quartz oscillator. The speed was held at a fixed value within 0·01 per cent or 5 angular degrees, whichever was the smaller measure of uncertainty. After leaving the blower, the air stream passed over refrigeration equipment and a small electric heater, which permitted the temperature to be controlled at the desired value within approximately 0·1°F. The temperature was measured with a strain-free platinum resistance thermometer [17] which was located immediately upstream of the converging section.

The flow of air past the cylinder was adjusted to a predetermined nominal value which was controlled from the indications of a venturi meter [23] inserted in the duct work leading to the jet. The venturi meter permitted the weight rate of flow to be determined within 0·5 per cent The arrangement of the duct and converging section is shown in Fig. 2. The velocity distribution was relatively uniform across the exit of the jet. The temperature of the air jet emerging from the duct was also established by two 0·003 in. copper–constantan thermocouples located across the exit of the duct.

The copper cylinder, which was 0·9987 in. in diameter $\pm$ 0·0001, was mounted on suitable supports approximately 2 in. above the exit of the duct. The 0·001 in. platinum wire was mounted on a conventional bird [18] shown at A in Fig. 2, and was provided with four leads, permitting the electromotive force across the wire to be determined directly with a potentio-

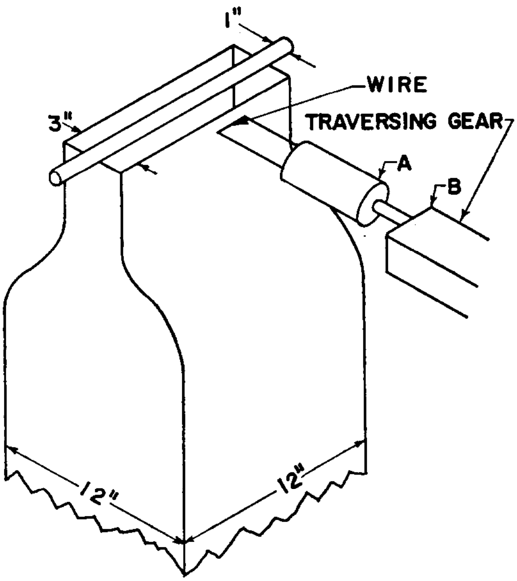

FIG. 2. Arrangement of air jet.

meter. The current flowing through the wire was measured by determination of the electromotive force across a known resistance in series with the small wire.

In order to furnish one additional means of measuring the temperature of the air stream, the 0·001 in. platinum wire was used as a resistance thermometer. The resistance was determined by means of a conventional four-lead Mueller bridge circuit with a current of 0·001 A. The bird A of Fig. 2 was mounted upon a traversing gear [18] shown schematically at B. The position of the wire relative to the cylinder was determined by optico-mechanical means with an uncertainty of not more than 0·002 in. As a result of the small vortices shed by the wire [19, 20], some oscillation of the center of the wire normal to the air stream was encountered. These oscillations amounted to as much as 0·001 in. The traversing gear B of Fig. 2 permitted the wire to be moved vertically and horizontally, thus permitting traverses to be made throughout the boundary flows forward of the axis of the cylinder.

The temperatures were measured with an uncertainty of 0·05°F in a total temperature difference of approximately 50°F. Position was established within 0·002 in. in both the vertical and horizontal co-ordinates, and the energy dissipation from the wire was known within 0·1 per cent. The dimensions of the small wire employed are perhaps the largest uncertainty encountered. Measurements were made from photomicrographs of the wire, and these yielded a diameter of 0·0010 in. In addition, by using a value of 9·83 $\mu\Omega$ cm [21, 22] for the specific resistance of pure platinum at 100°F, a diameter of 0·00100 was obtained, assuming zero ovality for the wire. The latter dimension was employed throughout the calculations in determining the Nusselt number and the heat transfer coefficient. However, even with the satisfactory agreement between the optical measurements of the diameter of the wire and those obtained from its electrical resistance, it is still believed that an uncertainty of as much as 1 per cent exists in the diameter of the wire, which is one of the largest uncertainties in the evaluation of the actual values of the heat transfer coefficients for the wire. The relative values of these coefficients are not influenced directly by the absolute value of the size of the wire, and the reported Nusselt numbers are not influenced directly by the wire diameter.

PROCEDURE

At each of a number of positions along traverses made in a horizontal direction from several different elevations relative to the axis of the cylinder, the temperature of the wire was determined for several different known thermal fluxes. Similar traverses were made in the vertical direction. From such data, it was possible to obtain the Nusselt number as a function of the temperature of the wire. There is shown in Fig. 3 the heat transfer coefficient as a function of the temperature difference between the wire and the air stream for five different positions which are indicated on the figure. The trends shown in Fig. 3 were found throughout the boundary flow of the cylinder at gross air velocities of 4, 8, and 16 ft/s for an air temperature of 100°F.

Following the procedures which have been mentioned earlier in this discussion and described elsewhere in detail [12], the Nusselt

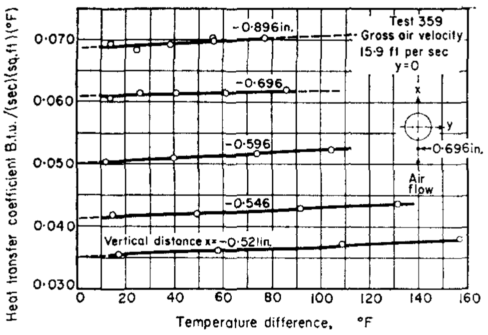

FIG. 3. Effect of wire temperature upon heat transfer coefficient for wire.

numbers utilizing the molecular properties of air at free stream conditions were calculated. These values were corrected for the errors introduced by the finite length of the wire, the small "temperature jump" at the air–wire interface, and the fact that all measurements were not obtained at a wire temperature of precisely 150°F.

RESULTS

The Nusselt number corrected as described is shown parametrically for velocities of 4, 8, and 16 ft/s in Figs. 4, 5, and 6. The information presented in these figures does not permit the behavior in the immediate vicinity of the surface of the cylinder to be visualized.

For a gross velocity of 16 ft/s Fig. 7 portrays variation in radial position with angle from stagnation with the Nusselt number as a parameter. The rapid increase in Nusselt number with increase in the angle from stagnation at a fixed radial position is evident. With further increase in the angle from stagnation there is a corresponding decrease as separation is approached. The small change in Nusselt number with radial position at the smaller angles from stagnation for radial distances between 0·005 in. and 0·05 in. is evident. To emphasize the effect of the logarithmic scale, the diameter of the wire has been indicated in each decade. Detailed experimental results are available in tabular form [12].

From speeds calculated from equation (8) for both boundary and potential flow and utilizing the experimental values of heat transfer from small wires in uniform stream obtained by Collis and Williams [3], there is shown in Fig. 8 a comparison of the Nusselt numbers at an air velocity of 4 ft/s for stagnation and for an angle of 30° from stagnation. The agreement between the Nusselt number obtained in this way and the experimental values is fair.

In Fig. 9 the variation of the Nusselt number with radial position for four different angles measured from stagnation is shown for the three stream velocities which were investigated. These data delineate the rapid change in the Nusselt number with radial position and the relatively complicated influence of position upon the local Nusselt number in parts of the boundary flow.

Table 1 records the thermal transfer coefficients and Nusselt numbers, Nu, for a 0·001 in. platinum wire at 150°F as a function of radial and angular position in the boundary flows forward of the axis of a 1 in. cylinder. These data were obtained by appropriate large-scale graphical operations, and it is believed that they represent the measured behavior for the conditions described relative to a standard error of estimate of about 0·01.

Table 2 presents experimental values of the Nusselt numbers Nu_e and Nu defined by equations (14) and (15), respectively, for three pairs of duplicate traverses. The data compared were obtained at the same position and conditions of flow but at different times. The reproducibility shown confirms an estimate of probable error of less than 1·5 per cent in the reported values of the heat transfer coefficient and Nusselt number. The estimate was based on the accuracy of measurement of the primary variables.

ACKNOWLEDGEMENT

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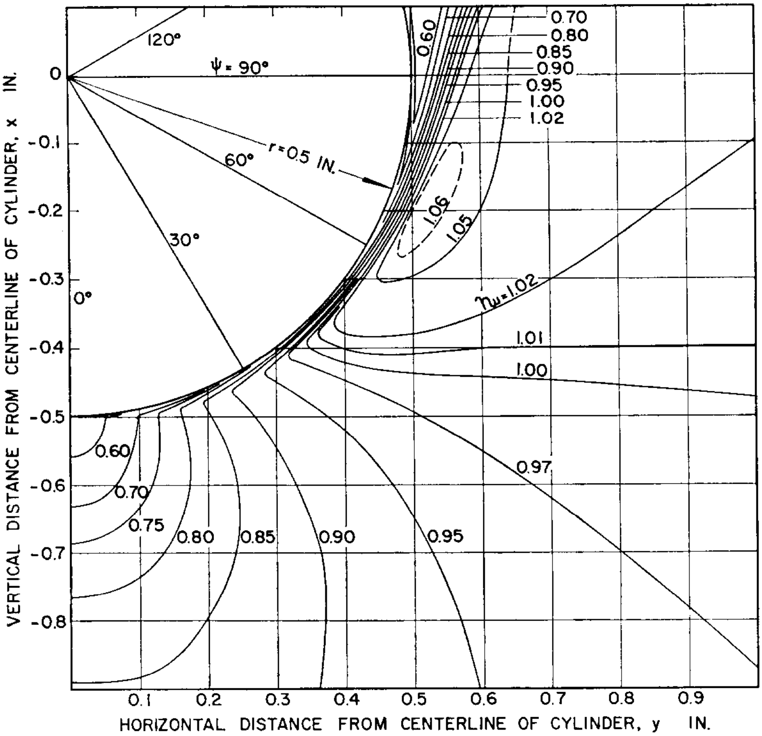

FIG. 4. Distribution of Nusselt number for an air velocity of 4 ft/s.

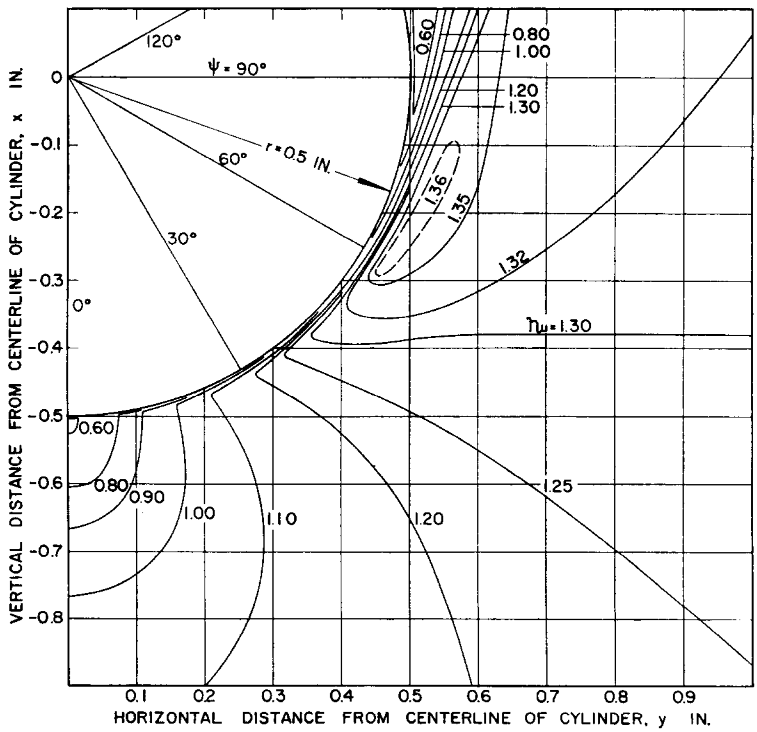

FIG. 5. Distribution of Nusselt number for an air velocity of 8 ft/s.

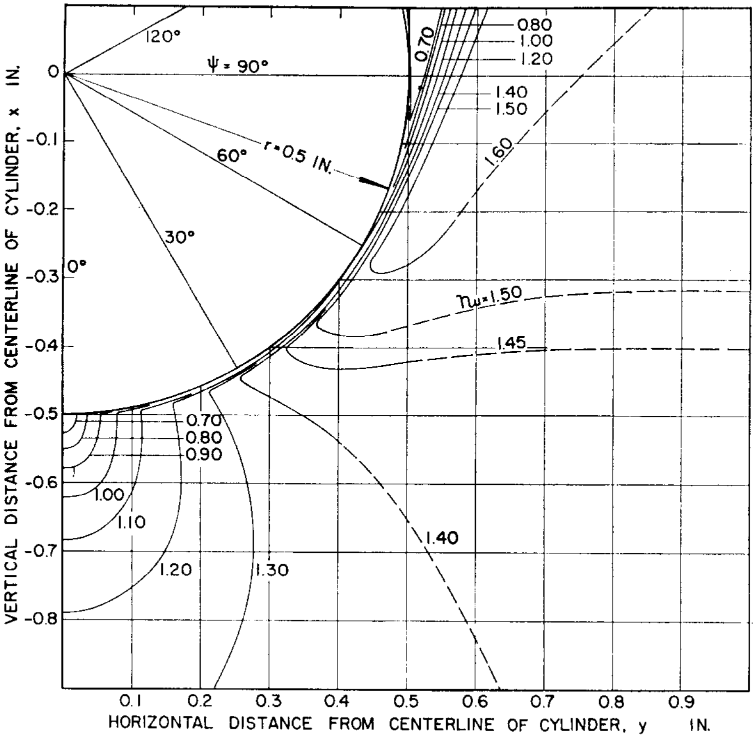

FIG. 6. Distribution of Nusselt number for an air velocity of 16 ft/s.

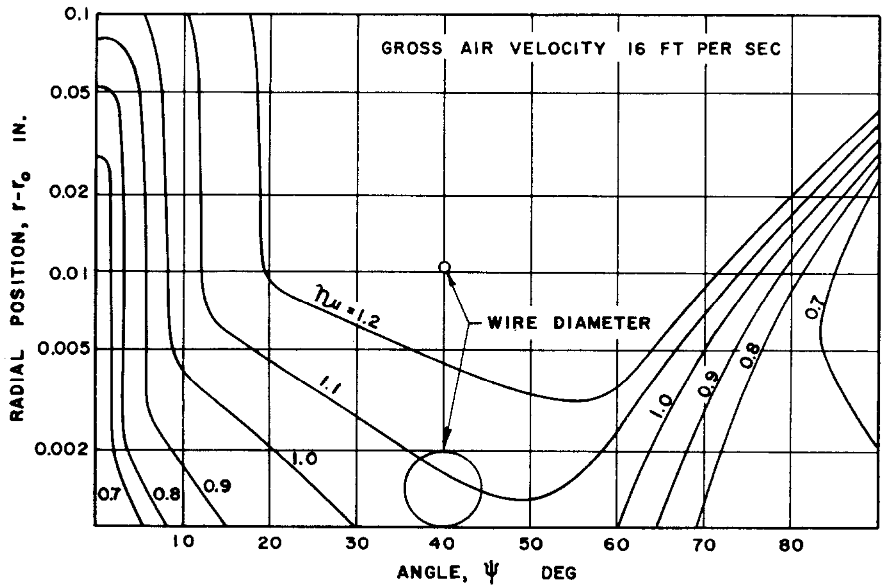

FIG. 7. Distribution of Nusselt numbers near the cylinder wall.

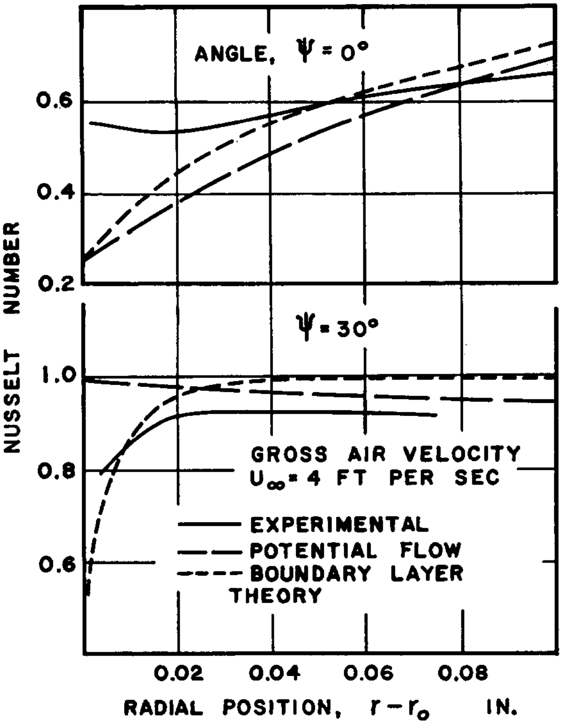

FIG. 8. Comparison of experimental results with theory.

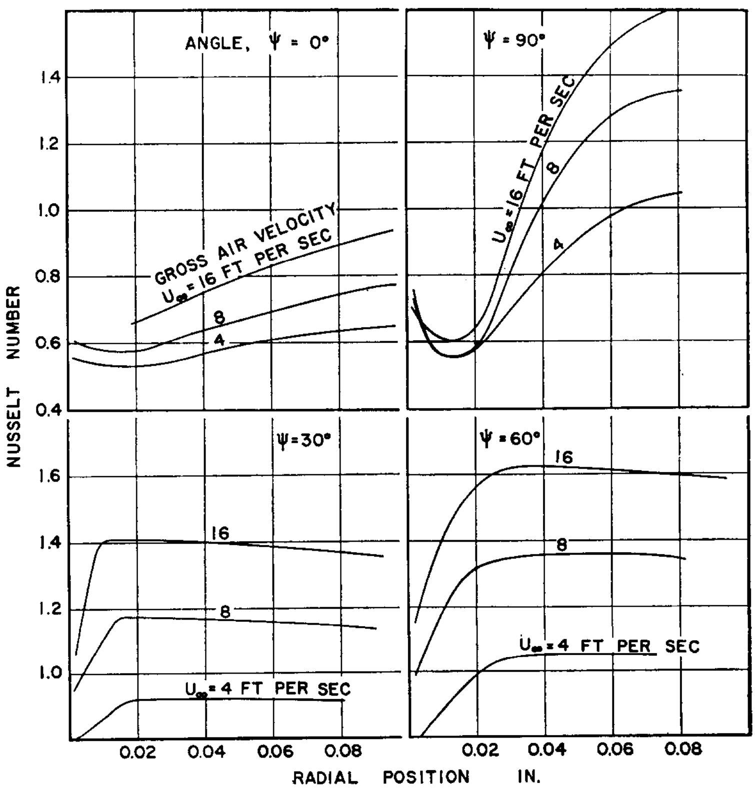

FIG. 9. Radial distribution of Nusselt numbers.

Table 1. Thermal transfer from a small wire

Radial distance from surface (in.)	Heat transfer coefficient	Nusselt number	Heat transfer coefficient	Nusselt number	Heat transfer coefficient	Nusselt number	Heat transfer coefficient	Nusselt number
Angle*	0°		30°		60°		90°	
			Gross air velocity 4 ft/s					
0·002	0·0292†	0·560‡	0·0418	0·801	0·0410	0·786	0·0356	0·683
0·004	0·0287	0·550	0·0426	0·816	0·0424	0·813	0·0333	0·638
0·006	0·0283	0·542	0·0434	0·823	0·0438	0·840	0·0315	0·603
0·008	0·0280	0·536	0·0443	0·848	0·0450	0·862	0·0312	0·578
0·010	0·0278	0·532	0·0450	0·862	0·0463	0·887	0·0294	0·563
0·012	0·0276	0·528	0·0458	0·878	0·0474	0·909	0·0291	0·557
0·014	0·0274	0·526	0·0468	0·896	0·0486	0·932	0·0289	0·554
0·016	0·0273	0·524	0·0475	0·910	0·0497	0·953	0·0291	0·558
0·018	0·0273	0·524	0·0478	0·916	0·0507	0·972	0·0295	0·565
0·020	0·0274	0·526	0·0480	0·920	0·0517	0·990	0·0302	0·578
0·025	0·0279	0·534	0·0481	0·921	0·0534	1·024	0·0304	0·582
0·030	0·0284	0·544	0·0481	0·922	0·0543	1·041	0·0363	0·696
0·035	0·0289	0·554	0·0481	0·922	0·0547	1·049	0·0393	0·753
0·040	0·0294	0·564	0·0481	0·921	0·0548	1·050	0·0421	0·807
0·045	0·0300	0·574	0·0480	0·920	0·0549	1·052	0·0448	0·858
0·050	0·0304	0·583	0·0480	0·919	0·0550	1·054	0·0472	0·904
0·055	0·0309	0·593	0·0480	0·919	0·0550	1·054	0·0493	0·945
0·060	0·0314	0·602	0·0479	0·918	0·0550	1·054	0·0511	0·979
0·065	0·0318	0·610	0·0479	0·918	0·0549	1·052	0·0525	1·005
0·070	0·0323	0·618	0·0480	0·917	0·0549	1·052	0·0533	1·021
0·075	0·0327	0·626	0·0478	0·916	0·0549	1·052	0·0540	1·034
0·080	0·0331	0·634	0·0478	0·915	0·0548	1·051	0·0545	1·045
0·085	0·0335	0·641	0·0478	0·915	0·0548	1·050	0·0548	1·050
0·090	0·0338	0·648	0·0477	0·914	0·0547	1·049	0·0549	1·052
0·095	0·0341	0·654	0·0476	0·913	0·0546	1·047	0·0549	1·052
0·100	0·0345	0·661	0·0476	0·913	0·0546	1·046	0·0549	1·052
0·200	0·0397	0·760	0·0474	0·909	0·0535	1·026	0·0546	1·046
0·300	0·0428	0·820	0·0477	0·914	0·0528	1·011	0·0543	1·040
0·400	0·0445	0·853	0·0482	0·924	0·0523	1·002	0·0539	1·033
0·500	0·0455	0·871	0·0490	0·938	0·0519	0·995	0·0536	1·027
			Gross air velocity 8 ft/s					
0·002	0·0318†	0·609‡	0·0503	0·963	0·0519	0·994	0·0393	0·753
0·004	0·0309	0·593	0·0521	0·999	0·0547	1·048	0·0346	0·662
0·006	0·0307	0·588	0·0539	1·033	0·0574	1·099	0·0315	0·603
0·008	0·0305	0·584	0·0578	1·069	0·0598	1·140	0·0302	0·578
0·010	0·0303	0·580	0·0580	1·102	0·0620	1·188	0·0294	0·563
0·012	0·0302	0·577	0·0594	1·138	0·0640	1·227	0·0291	0·557
0·014	0·0301	0·576	0·0609	1·167	0·0657	1·259	0·0291	0·557
0·016	0·0301	0·576	0·0613	1·175	0·0671	1·286	0·0292	0·560
0·018	0·0302	0·578	0·0614	1·176	0·0682	1·307	0·0298	0·571
0·020	0·0303	0·581	0·0613	1·175	0·0690	1·322	0·0306	0·587
0·025	0·0312	0·598	0·0612	1·173	0·0699	1·340	0·0351	0·672
0·030	0·0319	0·612	0·0611	1·171	0·0705	1·350	0·0417	0·799
0·035	0·0328	0·628	0·0610	1·169	0·0707	1·356	0·0478	0·915
0·040	0·0336	0·643	0·0609	1·167	0·0709	1·359	0·0530	1·016
0·045	0·0343	0·658	0·0608	1·165	0·0710	1·361	0·0576	1·103
0·050	0·0350	0·670	0·0607	1·163	0·0712	1·362	0·0613	1·175
0·055	0·0358	0·685	0·0606	1·161	0·0711	1·363	0·0644	1·234

For footnotes, see opposite.

Table 1—*contd.*

Radial distance from surface (in.)	Heat transfer coefficient	Nusselt number	Heat transfer coefficient	Nusselt number	Heat transfer coefficient	Nusselt number	Heat transfer coefficient	Nusselt number
Angle*	0°		30°		60°		90°	
				Gross Air Velocity 8 ft/s				
0·060	0·0364	0·697	0·0605	1·159	0·0711	1·362	0·0667	1·278
0·065	0·0371	0·711	0·0604	1·157	0·0710	1·361	0·0685	1·312
0·070	0·0377	0·723	0·0603	1·155	0·0708	1·357	0·0696	1·334
0·075	0·0384	0·736	0·0602	1·153	0·0706	1·353	0·0703	1·347
0·080	0·0390	0·748	0·0601	1·151	0·0704	1·350	0·0705	1·351
0·085	0·0396	0·759	0·0600	1·149	0·0703	1·347	0·0707	1·354
0·090	0·0402	0·770	0·0599	1·147	0·0701	1·344	0·0707	1·354
0·095	0·0408	0·781	0·0598	1·146	0·0700	1·342	0·0707	1·354
0·100	0·0413	0·792	0·0597	1·144	0·0699	1·340	0·0707	1·354
0·200	0·0492	0·943	0·0599	1·141	0·0684	1·311	0·0700	1·342
0·300	0·0530	1·016	0·0603	1·156	0·0675	1·293	0·0695	1·332
0·400	0·0545	1·044	0·0611	1·171	0·0666	1·277	0·0691	1·324
0·500	0·0553	1·060	0·0615	1·179	0·0660	1·264	0·0687	1·316
				Gross air velocity 16 ft/s				
0·002	—	—	—	—	0·0605	1·160	0·0362	0·693
0·004	0·0355†	0·682‡	0·0554	1·062	0·0641	1·228	0·0345	0·661
0·006	0·0352	0·676	0·0625	1·198	0·0678	1·299	0·0335	0·641
0·008	0·0348	0·669	0·0668	1·280	0·0707	1·354	0·0326	0·624
0·010	0·0346	0·664	0·0711	1·363	0·0736	1·410	0·0320	0·614
0·012	0·0343	0·658	0·0732	1·403	0·0757	1·450	0·0317	0·607
0·014	0·0342	0·656	0·0735	1·409	0·0775	1·485	0·0318	0·609
0·016	0·0343	0·658	0·0736	1·410	0·0791	1·516	0·0321	0·615
0·018	0·0344§	0·661§	0·0736	1·410	0·0805	1·543	0·0328	0·628
0·020	0·0348	0·667	0·0736	1·410	0·0816	1·564	0·0338	0·647
0·025	0·0357	0·684	0·0736	1·410	0·0836	1·601	0·0391	0·750
0·030	0·0370	0·708	0·0735	1·409	0·0846	1·621	0·0470	0·901
0·035	0·0381	0·730	0·0734	1·406	0·0848	1·625	0·0544	1·043
0·040	0·0392	0·752	0·0732	1·402	0·0848	1·624	0·0610	1·169
0·045	0·0404	0·774	0·0728	1·396	0·0847	1·622	0·0641	1·279
0·050	0·0415	0·796	0·0726	1·391	0·0845	1·619	0·0716	1·371
0·055	0·0425	0·815	0·0724	1·387	0·0843	1·616	0·0752	1·440
0·060	0·0435	0·833	0·0721	1·382	0·0842	1·614	0·0778	1·491
0·065	0·0444	0·850	0·0719	1·377	0·0841	1·611	0·0800	1·532
0·070	0·0451	0·864	0·0716	1·372	0·0839	1·607	0·0817	1·566
0·075	0·0459	0·880	0·0713	1·367	0·0836	1·602	0·0831	1·594
0·080	0·0467	0·894	0·0710	1·361	0·0835	1·599	0·0841	1·611
0·085	0·0474	0·909	0·0708	1·357	0·0832	1·594	0·0844	1·618
0·090	0·0482	0·923	0·0706	1·353	0·0829	1·589	0·0846	1·621
0·095	0·0490	0·938	0·0704	1·349	0·0827	1·584	0·0842	1·614
0·100	0·0497	0·952	0·0702	1·346	0·0824	1·579	0·0848	1·625
0·200	0·0586	1·123	0·0706	1·352	0·0779	1·492	0·0841	1·611
0·300	0·0628	1·204	0·0713	1·366	0·0758	1·453	0·0830	1·590
0·400	0·0646	1·237	0·0721	1·381	0·0744	1·426	0·0826	1·582
0·500	0·0656	1·256	0·0729	1·397	0·0733	1·404	0·0813	1·558

* Angle from stagnation, degrees.
† Heat transfer coefficient expressed in Btu/s ft^2 °F.
‡ Dimensionless.
§ Values of this and smaller radial positions are extrapolated from data at larger radial positions.

Table 2. Reproducibility of thermal transfer from a small wire

Vertical distance from centerline (in.)	Nusselt number* Measured	Corrected	Nusselt number Measured	Corrected
	Measurement A		Measurement B	
	Gross air velocity 4 ft/s Horizontal distance from centerline 0·0 in.			
−0·886	0·8892	0·8547	0·8808	0·8453
−0·786	0·8546	0·8207		
−0·686	0·7848	0·7518	0·7784	0·7446
−0·586	0·6776	0·6463		
−0·536	0·5855	0·5561	0·5773	0·5473
	Gross air velocity 8 ft/s Horizontal distance from centerline 0·2 in.			
−0·906	1·1411	1·1054	1·1380	1·1015
−0·806	1·1167	1·0811	1·1113	1·0765
−0·706	1·0842	1·0489	1·0819	1·0470
−0·606	1·0663	1·0311	1·0621	1·0277
−0·556	1·0727	1·0375	1·0720	1·0358
−0·506	1·1009	1·0655	1·0995	1·0616
−0·486	1·1137	1·0781	1·1203	1·0832
−0·466	1·0540	1·0190	1·0677	1·0300
−0·556	1·0725	1·0372	1·0722	1·0348
	Gross air velocity 16 ft/s Horizontal distance from centerline 0·174 in.			
−0·860	1·3284	1·2840	1·3382	1·2895
−0·760	1·2943	1·2504	1·3034	1·2555
−0·660	1·2595	1·2160	1·2662	1·2190
−0·560	1·2583	1·2149	1·2675	1·2204
−0·510	1·2911	1·2473	1·3016	1·2541
−0·485	1·3012	1·2574	1·3017	1·2660

* Nusselt numbers are reported as measured and with corrections for finite length of wire, "temperature jump" at interface, and to a uniform wire temperature of 150·0°F.

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Résumé—Les auteurs ont mesuré le coefficient d'échange thermique d'un fil de platine de 0,025 mm de diamètre placé dans l'écoulement au voisinage d'un cylindre de 25 mm de diamètre, pour des vitesses de 1,2, 2,4, 4,8 m/s.

Les résultats sont présentés, en fonction du nombre de Nusselt du fil, sous forme de tableaux et de diagrammes. Ils sont comparés aux valeurs calculées à partir des vitesses dans les couches limites et des données valables de transmission de chaleur pour des petits fils dans des écoulement libres.

Zusammenfassung—An einem Platindraht von 0,025m m Durchmesser wurde der Wärmeübergangskoeffizient in der Grenzschicht eines Zylinders von 25 mm Durchmesser bei Freistromgeschwindigkeit der Luft von 1,2, 2,4 und 4,8 m/s gemessen. Die Ergebnisse werden als Nusseltzahl für den Draht angegeben und graphisch und tabellarisch mitgeteilt. Vergleiche werden mit berechneten Werten für Grenzschichtströmung und mit verfügbaren Wärmeübergangsdaten für dünne Drähte im Freistrom angestellt.

Аннотация—Проведены измерения коэффициента теплообмена от платиновой проволоки диаметром в 0,001 дюйма в пограничном слое цилиндра диаметром в один дюйм при скоростях набегающего потока воздуха, равных 4, 8 и 16 футам в сек. Результаты представлены в виде графиков величины критерия Нуссельта для проволоки, а также в виде таблиц. Сделано сравнение с величинами, полученными из расчётных скоростей в пограничном слое, и с имеющимися данными по теплообмену в свободном потоке для малых проволок.