EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER BY NATURAL CONVECTION IN AN ENCLOSURE

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An experimental study has been made of heat transfer by natural convection from a thin wire in a cylindrical enclosure filled with liquid. The dependence of the convection coefficient on the parameter $Gr_\delta Pr$ has been found with different lengths of measuring interval and for various inclinations of the measuring tube to the horizontal.

Small diameter coaxial cylinders have been used as heat exchangers in recent heat technology equipment. However, almost no attention has been given in the literature to heat transfer by natural convection across small cylindrical gaps (of dimension 1 to 7 mm). Results were presented in [1] of investigations of natural convection in heat transfer from a fine wire in a cylindrical enclosure filled with liquid. The paper examined the dependence of the convection coefficient ε on the parameter $Gr_\delta Pr$ for various gap sizes, but for only one length. The investigation was carried out with a vertical and horizontal arrangement of the measuring tubes. It was found that for small gaps, commensurate with the boundary layer thickness, the generalized relation between ε and $Gr_\delta Pr$, obtained by Kraussol'd and Mikheev for large gaps, did not hold. The experiments showed that ε was independent of the measuring gap for vertical and horizontal measuring tubes and can be described by two distinct curves. The convection in horizontal tubes was considerably greater than in vertical tubes.

TABLE 1. Dimensions of Measuring Tubes, mm

Outside diameter of glass tube	Inside diameter of glass tube	Gap size	Length of measuring section
15,60	13,3	6,6	133
14,70	12,67	6,28	500
15,10	12,8	6,35	900
4,89	3,14	1,52	129
11,25	8,86	4,38	143

The present paper concerns the dependence of the convection coefficient on the length l of the measuring section and the angle of its slope to the horizontal φ. The measurements were carried out using a heated wire (d = 0.1 mm) in water and in 96% ethyl alcohol, in 3 tubes. The tube sizes (the first 3) are shown in Table 1. The measurement technique was described in [1].

The convection coefficient was measured at various temperatures. The temperature head Δt varied from 2 to 14°. In the experimental conditions the similarity parameter $Gr_\delta Pr$ varied from 20,000 to 800,000. The data for computing $Gr_\delta Pr$ were taken from [2].

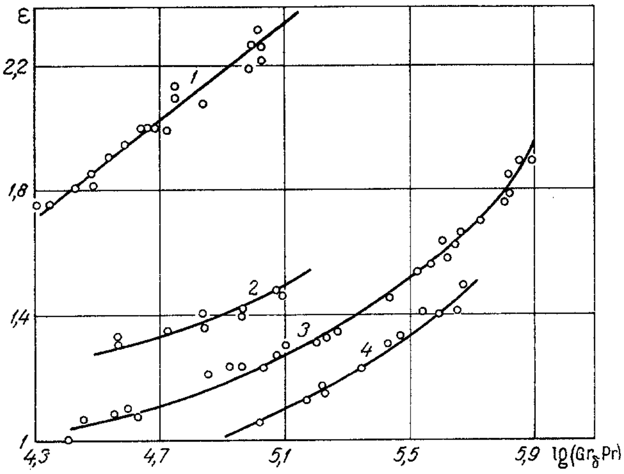

Fig. 1. The quantity ε as a function of the parameter $Gr_\delta Pr$: 1) horizontal tube arrangement; 2, 3, and 4) vertical arrangement of tubes of length 133, 500, and 900 mm, respectively.

Figure 1 shows the measured values of ε for all three measuring tubes. It can be seen from Fig. 1 (1) that the convection with a horizontal tube is considerably greater than with a vertical tube, and does not depend on the length of the measuring section.

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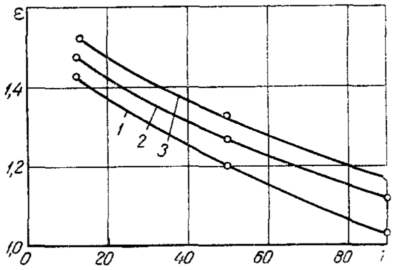

Fig. 2

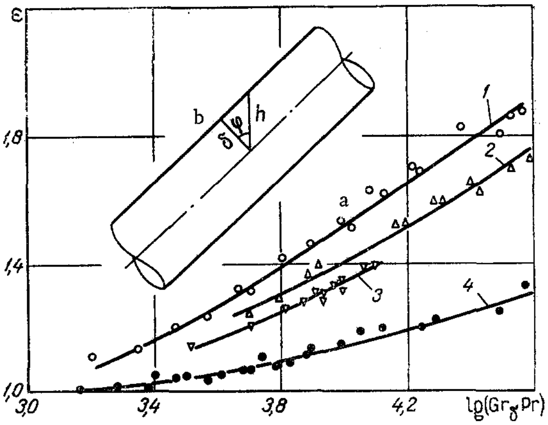

Fig. 3

Fig. 2. Dependence of ε on tube length l. Curves 1, 2, and 3 correspond to $Gr_\delta Pr$ of 87,000, 126,000, 159,000, respectively.

Fig. 3. a) ε as a function of $Gr_\delta Pr$ for various angles of inclination to the horizontal [1) 0 and 30°; 2) 45; 3) 60; 4) 90, vertical tubes]; b) tube location, where δ is the gap width, and h is the height of the circulation contour.

This is apparently due to the fact that the magnitudes of the convective circulatory contours formed in this case do not depend on the length of the tube.

For the vertical tube ε was larger, the shorter was the tube. Curves 2, 3, and 4 show the convection in vertical tubes of length 133, 500, and 900 mm, respectively.

In a longer tube the boundary layer around the wire can develop to a greater thickness, and, therefore, the longer the tube is, the greater is the thermal resistance. In addition, the longer the tube is, the longer are the circulation contours in the core of the heat transmitting layer, and the worse is the heat transfer. With increase in tube length the start of convection corresponds to higher values of the parameter $Gr_\delta Pr$. The values of ε obtained for alcohol and water lie on a single curve for a tube of the same length.

Figure 2 shows ε as a function of tube length. It is plotted versus the parameter $Gr_\delta Pr$. Figure 2 shows that ε decreases with increase of tube length for constant $Gr_\delta Pr$.

Later in the work an investigation was made of the convection coefficient as a function of the inclination of the tube to the horizontal. Measurements were made with two tubes. Their dimensions (the last two tubes) are given in Table 1.

The measured results are shown in Fig. 3a. The convection coefficients for tubes inclined at angle 30° to the horizontal are practically the same as for convection with horizontal cylinders. At an angle of 45° to the horizontal the convection is somewhat less than for horizontal tubes. At 60° the convection has already decreased considerably, and has its least value for the vertical position. Between the greatest and least values the dependence of the convection coefficient (for a single value of $Gr_\delta Pr$) on the tube slope angle corresponds approximately to cos φ.

The decrease of ε with increase of the angle φ of the tube is due to the increase in length of the circulation contour. While the height h of the circulation contour is determined by the gap width δ with a horizontal tube location, with an inclined tube (Fig. 3b) it increases and is given by the equation

$$h = \frac{\delta}{\cos\varphi}.$$

The convective heat-transfer deteriorates with increase in the length of the circulation contour.

NOTATION

ε is the convection coefficient;
Gr_δ is the Grashof number;
Pr is the Prandtl number;

δ is the gap width;
Δt is the temperature head;
φ is the angle of tube inclination to horizontal;
l is the tube length.

LITERATURE CITED

1. A. A. Berkengeim, Inzhen.-Fiz. Zh., 10, No. 4 (1966).
2. N. B. Vargaftik, Handbook of Thermophysical Properties of Gases and Liquids [in Russian], Fizmatgiz (1963).