# HEAT TRANSFER OF CYLINDRICAL BODIES WHEN A SYSTEM OF ROUND JETS FLOWS OVER THEM

N. I. Syromyatnikov, L. K. Vasanova, V. I. Bader, and A. M. Koryakin

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An experimental installation for the study of the heat transfer of cylindrical bodies in interaction with multijet streams is described. The test data are generalized in criterial dependences with allowance for the range of variation of the heights of rise of the cylinders above the jet grids.

In connection with the growing demands imposed on processes of heat and mass transfer in industrial installations, investigators have before them the task of finding new ways to increase the efficiency of operation of heat exchangers. Jet blowing on bodies is one of the methods of intensification of heat-transfer processes in technological apparatus and installations.

The purpose of the present work was to study heat transfer from cylinders of different diameters when they are washed transversely by a system of axisymmetric jets.

The investigations were made on an experimental installation for which a diagram is shown in Fig. 1. Air was supplied from a gas blower to the static pressure chamber 1 through a receiver. To form the jet stream the chamber was tightly covered at the top by interchangeable perforated grids 6 having the shape of a half-cylinder with a radius R = 18 mm. Openings with diameters d = 1.0, 1.7, and 5.5 mm were drilled in the grids, arranged in staggered order with spacings $S_1 \times S_2$ = 17.6 × 8.8, 20 × 10, and 33 × 16.5 mm, respectively. As the detectors we used cylindrical electrocalorimeters 7 of two types: to investigate the average and local heat transfer [1, 2].

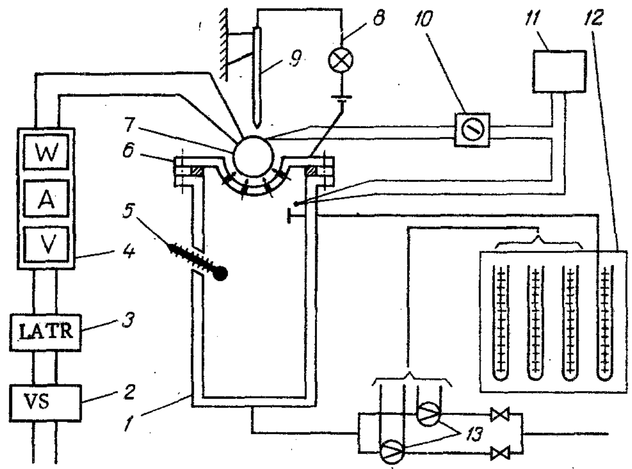


Fig. 1. Diagram of experimental installation: 1) chamber; 2) voltage stabilizer; 3) laboratory autotransformer; 4) K-50 electrical-measurement complex; 5) thermometer; 6) jet grid; 7) electrocalorimeter; 8) low-voltage electrical circuit; 9) micrometer; 10) switch; 11) potentiometer; 12) liquid manometers; 13) diaphragm.

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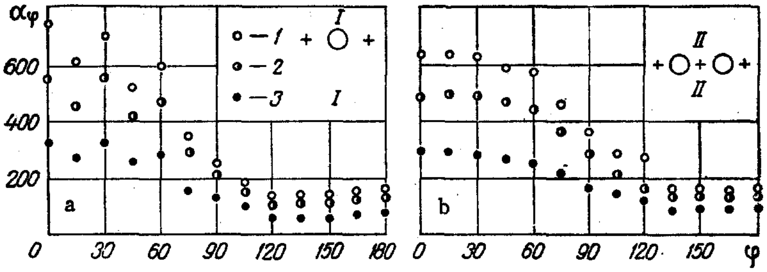


Fig. 2. Distribution of local heat-transfer coefficient over perimeter of cylinder (D = 32 mm; d = 1.3 mm; $S_1 \times S_2$ = 10 × 10 mm; h = 0.65 mm): a) along axis I—I; b) along axis II—II; 1) w = 30.3 m/sec; 2) 99 m/sec; 3) 131 m/sec.

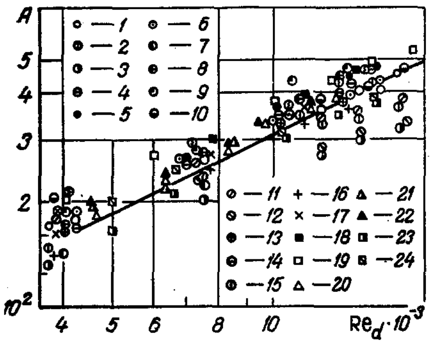


Fig. 3

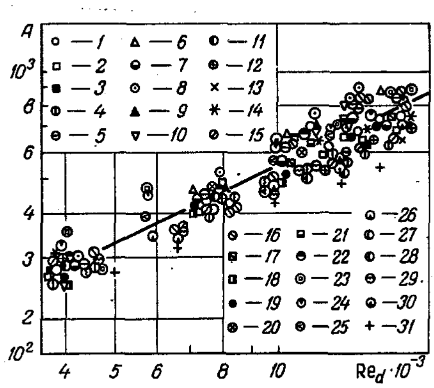


Fig. 4

Fig. 3. Generalized dependence on heat transfer of a cylinder to a system of round jets with $\bar{h}$ = 2–4 [$A \equiv Nu_d(S_1/d)^{1.17}\bar{h}^{0.38}(D/2R)^{1.82}$)].

D/2R = 0.78: 1) $S_1/d$ = 6, $\bar{h}$ = 2; 2) 6 and 3; 3) 6 and 4; 4) 11.8 and 2; 5) 11.8 and 3; 6) 11.8 and 4; 7) 17.6 and 2; 8) 17.6 and 3; 9) 17.6 and 4; D/2R = 0.89: 10) 6 and 2; 11) 6 and 3; 12) 6 and 4; 13) 11.8 and 2; 14) 11.8 and 3; 15) 11.8 and 4; 16) 17.6 and 2; 17) 17.6 and 3; 18) 17.6 and 4; D/2R = 1: 19) 6 and 2; 20) 11.8 and 2.44; 21) 11.8 and 3; 22) 11.8 and 4; 23) 17.6 and 3.16; 24) 17.6 and 4.

Fig. 4. Generalized dependence on heat transfer of a cylinder to a system of round jets with $\bar{h}$ = 0.1–2 [$A \equiv Nu_d(S_1/d)^{1.45}(D/2R)^{1.18}$]. D/2R = 0.78: 1) $S_1/d$ = 6, $\bar{h}$ = 0.1; 2) 6 and 0.5; 3) 6 and 1; 4) 6 and 2; 5) 11.8 and 0.5; 6) 11.8 and 1; 7) 11.8 and 2; 8) 17.6 and 0.1; 9) 17.6 and 0.5; 10) 17.6 and 1; 11) 17.6 and 2; D/2R = 0.89: 12) 6 and 0.1; 13) 6 and 0.5; 14) 6 and 1; 15) 6 and 2; 16) 11.8 and 0.1; 17) 11.8 and 0.5; 18) 11.8 and 1; 19) 11.8 and 2; 20) 17.6 and 0.1; 21) 17.6 and 0.5; 22) 17.6 and 2; D/2R = 1: 23) 6 and 1; 24) 6 and 1.34; 25) 6 and 1.6; 26) 6 and 2; 27) 11.8 and 0.15; 28) 11.8 and 0.5; 29) 11.8 and 1.00; 30) 11.8 and 1.65; 31) 17.6 and 1.5.

The heat transfer from cylinders was studied with electrocalorimeters 28, 32, and 36 mm in diameter; the length of the heated sections, which had the same construction, was 180 mm. An electrical heater was placed inside a stainless steel pipe. The detector was thermally insulated at the ends with asbestos and Textolite plugs. In this case the heat losses from the ends did not exceed 1%. The surface temperature of the calorimeters was measured with copper—constantan thermocouples with electrode diameters of 0.1 mm. The values of the temperatures were averaged over the surface.

The heat transfer was studied at a constant value of the specific heat flux. The heat-transfer coefficient was determined from the heat-transfer equation with allowance for heat losses. Heat losses by emission were neglected. The difference between the average surface temperature and the air temperature in the chamber was taken as the temperature head. The rms error in the determination of the heat-transfer coefficient from a cylinder did not exceed 5%.

The average heat transfer from cylinders to a multijet stream was investigated in a range of variation of the velocity of gas discharge from the openings of the jet grid of $w = 10.6-262.4$ m/sec with variation of the height of rise of from 0.1d to 4d.

On the basis of the experiments it was established that the heat-transfer intensity is affected by the jet velocity, the geometrical parameters of the distribution device, the diameter of the cylinder, and the height of its rise above the jet grid. The average heat-transfer coefficient $\alpha$ grows monotonically with an increase in the jet velocity with the other parameters unchanged. The tests also show that with w, $S_1/d$, and h = const the values of $\alpha$ are larger for a cylinder with a smaller diameter. The value of the heat-transfer coefficient grows with an increase in the open cross section of the nozzle grid (with a decrease in $S_1/d$). For cylinders of all diameters the heat-transfer intensity hardly depends on $\bar{h} = h/d$ in the range of rise heights of (0.1-2)d when different nozzle devices are used. A further increase leads to a pronounced decrease in $\alpha$.

Curves of the distribution of the local heat-transfer coefficient $\alpha_\varphi$ over the perimeter of a cylinder at different jet velocities and different positions of the detector relative to the jets are presented in Fig. 2a, b. It was established that the height of rise of the cylinder also affects the character of the dependence $\alpha_\varphi = f(\varphi)$. With an increase in the height of rise in the range h = (0.1-2)d the increase in the intensity of heat transfer in the lower part of the cylinder is accompanied by a decrease in local heat transfer in the region of $\varphi = 75-80°$. At h > 2d the decrease in the intensity of heat transfer in the upper half of the cylinder is more pronounced, and a tendency toward a decrease in $\alpha_\varphi$. is also noted in the lower half.

As shown by tests on visualization and hydrodynamics, the influence of the factors discussed above is due to the difference in the hydrodynamic conditions, connected with a change in the constriction of the jets and in the exhausted air, as well as in the angle of flow of the jets onto the surface.

As a result of the analysis of the test data we obtained criterial dependences (Figs. 3 and 4) describing the average heat transfer from the surface of a cylinder when a system of round jets flows over it: for $0.1 \leqslant \bar{h} \leqslant 2$.

$$\mathrm{Nu}_d = 0.79\,\mathrm{Re}_d^{0.71}\left(\frac{S_1}{d}\right)^{-1.45}\left(\frac{D}{2R}\right)^{-1.18};$$

for $2 \leqslant \bar{h} \leqslant 4$,

$$\mathrm{Nu}_d = 0.44\,\mathrm{Re}_d^{0.71}\left(\frac{S_1}{d}\right)^{-1.17}\left(\frac{D}{2R}\right)^{-1.82}(\bar{h})^{-0.38}.$$

The equations are valid in the following ranges of variation of the determining criteria: $\mathrm{Re}_d = (3.7-18)\cdot 10^3$; $S_1/d = 2S_2/d = 6-17.7$; $D/2R = 0.78-1$; they approximate the test data with standard deviations of 16 and 14%, respectively.

The results of the investigations can be used in the design and calculation of highly efficient heat exchangers.

## NOTATION

D, d, diameters of cylinders and of openings of jet grid, m; R, radius of jet grid, m; h, $\bar{h} = h/d$, absolute and relative heights of rise of cylinder above jet grid; $S_1$, $S_2$, longitudinal and transverse distances between rows of openings in jet grid, m; w, average discharge velocity of jets, m/sec; $\alpha$, $\alpha_\varphi$, average and local coefficients of heat transfer, $W/m^2\cdot deg$; $\lambda$, $\nu$, coefficients of thermal conductivity and kinematic viscosity, W/m·deg, $m^2$/sec; $\mathrm{Nu}_d = \alpha d/\lambda$, Nusselt number; $\mathrm{Re}_d = wd/\nu$, Reynolds number.

## LITERATURE CITED


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