# HEAT TRANSFER COEFFICIENT IN TURBULENT FLOW OF HEAT-RELEASING LIQUID

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In Kutateladze's well-known monograph [1] the expression

$$\frac{\alpha}{\alpha_0}=\frac{1}{1+AZ}, \qquad Z=\frac{dq_v}{4q_w} \tag{1}$$

was obtained analytically for the correction factor allowing for internal heat release or heat absorption in calculation of the heat transfer coefficient in a round tube.

Here Z is the relative density of the internal heat source. The constant coefficient A is expressed in the following way in terms of quadratures of the distributions of the dimensionless velocity $\omega(\xi)=\omega/\langle\omega\rangle$ and the turbulent thermal conductivity $\lambda_t(\xi)$ over the radius $\xi=2\,r/d$

$$A=\left\{\int_0^1 \omega\xi\left[\int_\xi^1\left(\frac{\Omega}{\xi}-1\right)\frac{d\xi}{1+\lambda_t/\lambda}\right]d\xi\right\}\left\{\int_0^1 \omega\xi\left[\int_\xi^1\frac{\Omega}{\xi}\,\frac{d\xi}{1+\lambda_t/\lambda}\right]d\xi\right\}^{-1}$$

$$\Omega(\xi)=\int_0^\xi \omega\xi\,d\xi \tag{2}$$

Numerical values of the coefficient A were obtained in [1] for special cases of laminar flow with a parabolic velocity profile (A=0.272) and turbulent flow with a velocity distribution conforming to a 1/7 law and Prandtl number P=0 (A=0.0834).

We give the results of calculation of this coefficient for the case of a turbulent flow with $P \neq 0$.

Integrating by parts in the numerator and denominator of Eq. (2) we obtain

$$A=1-\frac{1}{2}\left[\int_0^1\frac{\xi\Omega}{1+\lambda_t/\lambda}d\xi\right]\left[\int_0^1\frac{\Omega^2}{(1+\lambda_t/\lambda)\,\xi}\,d\xi\right]^{-1} \tag{3}$$

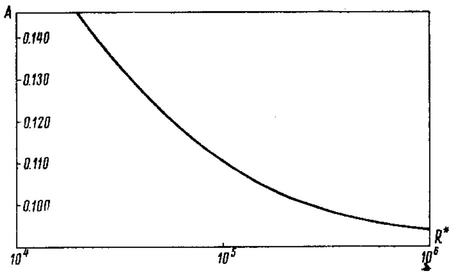


Fig. 1

The main difficulty in reducing Eq. (3) to a form convenient for numerical calculations lies in the choice of an approximating relationship giving the distribution of $\lambda_t/\lambda$ over the tube radius. It should be noted that

$$\frac{\lambda_t}{\lambda}=\frac{P}{P_t}\,\frac{\mu_t}{\mu} \tag{4}$$

where $P_t$ is the turbulent Prandtl number.

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We use the Prandtl expression for the turbulent tangential stress in terms of the mixing length $l$ and also its representation in terms of the turbulent viscosity coefficient $\mu_t$

$$\tau_t = \rho \left( l \frac{dw}{dr} \right)^2, \qquad \tau_t = -\mu_t \frac{dw}{dr} \tag{5}$$

By comparison we have

$$\frac{\mu_t}{\mu} = -\frac{\rho}{\mu} l^2 \frac{dw}{dr} \tag{6}$$

According to I. Nikuradze's measurements, at $R = \rho \langle \omega \rangle d/\mu > 10^5$ the distribution of the mixing length over the tube radius is independent of R. The well-known interpolation formula [1] gives in this case

$$2l / d = 0.14 - 0.08\, \xi^2 - 0.06\, \xi^4 \tag{7}$$

It is assumed in what follows that the velocity distribution over the cross section of the tube conforms to a 1/7 law

$$\omega = w / \langle w \rangle = 1.22 \; (1 - \xi)^{1/7} \tag{8}$$

Using (4), (6), (7), and (8) and performing the necessary transformations we put Eq. (3) in a form suitable for numerical calculations on an electronic digital computer. The results of these calculations are given in the form of a relationship between the coefficient A and the criterion $R^* = RP/P_t$ in Fig. 1. It should be remembered that these results are valid for $R > 10^5$.

## LITERATURE CITED


1. S. S. Kutateladze, Fundamentals of Heat Transfer Theory [in Russian], Mashgiz, Moscow-Leningrad, 1962.