FREE CONVECTION FROM A VERTICAL PLATE WITH GIVEN HEAT FLUX IN A MEDIUM WITH A CONSTANT TEMPERATURE GRADIENT

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An analysis is given of time-independent free convection from a semiinfinite vertical plate on the surface of which there is a time-independent and uniformly distributed heat flux q. The plate is placed in a liquid with a temperature gradient **A** which is independent of height and is opposite in direction to the gravitation acceleration **g**. The problem is solved by the method of successive approximations, as described by Shvets [1], on the assumption that a laminar boundary layer exists on the plate.

Equations are written out for the i-th approximation. Formulas are obtained for the distributions of temperature and of the longitudinal velocity component U over the thickness δ of the boundary layer in the second approximation, and for the boundary layer thickness. In terms of the rectangular coordinates with origin on the lower face of the plate and the x-axis parallel to the temperature gradient (see Fig. 1)

$$F = \ln\frac{1+\Delta}{1-\Delta} + 2\,\mathrm{arctg}\,\Delta - 4\Delta,$$

where

$$\Delta = 0.452\left(\frac{g\beta}{\nu a}A\right)^{0.25}\delta;$$

$$F = 0.678\,\frac{\lambda}{q}\left(\frac{g\beta}{\nu a}\right)^{0.25}A^{1.25}x;$$

and β, ν, a, and λ, are, respectively, the coefficients of volume expansion, kinematic viscosity, temperature diffusivity, and thermal conductivity of the liquid.

It is noted that, in contrast to the case of constant liquid temperature outside the boundary layer (when the thickness of the boundary layer increases in proportion to $x^{0.2}$ within the laminar region), the situation when the liquid temperature gradient is independent of height is such that the thickness of the boundary layer tends to an asymptotic value given by

$$\delta = 2.21\left(\frac{\nu a}{g\beta A}\right)^{0.25},$$

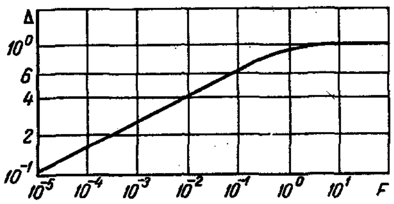

Fig. 1. Δ as a function of F.

which differs from that derived in [2] by the integral method only by the fact that the factor 2.91 is now replaced with 2.21.

LITERATURE CITED

1. M. E. Shvets, Prikl. Matem. i Mekh., 13, No. 3 (1949).
2. L. B. Evans, R. G. Reid, and E. M. Drake, AIChE Journal, 14, No. 2 (1968).

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