# ABSTRACTS OF ARTICLES DEPOSITED AT VINITI*

## RATIONALIZING RADIANT-FLUX CALCULATIONS IN SIMPLE SYSTEMS OF BODIES

S. P. Detkov, N. N. Ponomarev,
and L. V. Petrak

UDC 536.3

In heat engineering, neutron physics, atmospheric optics, astrophysics, and other branches of science, the energy-transfer equations for radiation of various kinds in systems that are two-dimensional and close to two-dimensional very often include the functions

$$E_n(x) = \int_0^1 \exp\left(-\frac{x}{\mu}\right)\mu^{n-2}d\mu;\ K_n(x) = \frac{4}{\pi}\int_0^{\pi/2} \exp\left(-\frac{x}{\cos\alpha}\right)\cos^{n-1}\alpha d\alpha.$$

In heat engineering, these functions are used in describing the degree of blackness of spaces, angular coefficients, radiation coefficients, and other dimensionless radiant fluxes. In the present work, so as to rationalize the calculations without significant loss of accuracy, fractionally rational approximations are given for the E and K functions. For $E_n(x)$ when n = 2, 3, 4, 5, and 6 the appropriate expression is

$$E_n(x) = \exp(-x)\,P_m/Q_t,\ P_m = \sum_{i=0}^{m} a_i x^i,\quad Q_t = \sum_{i=0}^{t} b_i x^i.$$

The maximum absolute error of all the formulas over the whole range [0, ∞] of x does not exceed $3 \cdot 10^{-6}$ (when x = 0). The relative error over the segment x = 0–7 investigated is considerably less than 0.01%, as a rule. A new approximate formula for $E_1(x)$ is given.

The corresponding expression for $K_n$, when n = 1, 2, 3, and 4, is

$$K_n(x) = \exp(-x)\sqrt{1+x}\,P_m/Q_t.$$

The maximum absolute error of all these formulas over the whole range [0, ∞] of x does not exceed $1.3 \cdot 10^{-5}$ (when x = 0). The relative error on the segment x = 0–7 investigated is considerably less than 0.005%, as a rule.

The use of this formula in programs for the calculation of radiant fluxes is a great economy, in terms of simplification of the programming and reduction in machine time, without significant loss of accuracy.

Dep. 784-77, July 19, 1976 [sic].
Original article submitted July 19, 1976.

*All-Union Institute of Scientific and Technical Information.

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 33, No. 2, pp. 356-362, August, 1977.

*This material is protected by copyright registered in the name of Plenum Publishing Corporation, 227 West 17th Street, New York, N.Y. 10011. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, microfilming, recording or otherwise, without written permission of the publisher. A copy of this article is available from the publisher for $7.50.*

## DRYING KINETICS OF A CAPILLARY-POROUS BODY IN AN ELECTRIC FIELD

M. S. Panchenko, A. L. Panasyuk,
I. L. Karpovich, and N. Ya. Kisel'chuk

UDC 536.423:537.523.3

The possibility of using a corona discharge to provide the electric field and the energy supply in the drying of a model capillary-porous body (KSM-5 silica gel) is considered. Experimental thermograms and energy diagrams of the drying process show that the position of the kinetic curves of drying depends significantly on the action of the corona discharge. The total duration of the process is reduced almost threefold in comparison with convective drying at the minimum electrical-energy consumption ensuring maintenance of the corona discharge.

The data obtained indicate that the use of a corona discharge as a source of energy supply and as a means of intensification reduces the energy consumption and duration of drying, while at the same time decreasing the temperature of the dried material. An attempt is made to establish the physical mechanism of the phenomenon.

Dep. 719-77, February 2, 1977.
Original article submitted September 8, 1976.

## TEMPERATURE DISTRIBUTION IN POROUS MEDIUM DURING HEAT TREATMENT

G. A. Gamidov and I. A. Nasrullaev

UDC 622.276.038.5

To establish the effect of heat treatment on an oil deposit, an investigation is made of axisymmetric temperature propagation in an infinite bed of constant width and constant thermophysical properties, taking into account heat losses through the roof and floor. The temperature distribution is studied at successive stages of heat treatment (warming of the borehole region, injection of hot liquid, and cooling of the heated region). The differential equations describing the propagation of the temperature field are as follows:

$$\frac{\partial^2 u}{\partial r^2} + \frac{1-2\nu}{r}\frac{\partial u}{\partial r} + \alpha\frac{\partial u}{\partial z} = \frac{1}{a_0^2}\frac{\partial u}{\partial t},\ t>0,\ z=0,$$
$$\frac{\partial^2 u}{\partial z^2} = \frac{1}{a_1^2}\frac{\partial u}{\partial t},\ t>0,\ 0\leqslant z<\infty. \quad (1)$$

Boundary and initial conditions are specified separately for each stage. For the first stage

$$u(r_b, t) = \varphi_1(t),\ u(\infty, t) = 0,\ u(r, 0) = \varphi_2(r). \quad (2)$$

An operational method is used to solve Eqs. (1) and (2) setting $\nu = 0$. For the injection (second stage), the initial condition is the solution of Eqs. (1) and (2) at the initial moment of injection $t = t_1$. The condition as $r \to \infty$ is as in Eq. (2) and the condition at the borehole is related to the flow rate of the hot liquid ($\nu \neq 0$).

In the cooling of the hot zone (third stage) the solution of the second stage is taken as the initial condition. At the borehole, values of the temperature at various times are specified. The solution obtained for this stage is simplified and presented in a form convenient for practical calculations, using the following approximation for the initial distribution,

$$F(r) = \sum_{i=1}^{m} B_i \exp(b_i r^2), \quad (3)$$

and the mechanical quadrature formula. The solution for the cooling process then takes the form

$$u(r,\,0,\,t)=\frac{1}{\sqrt{\pi}}\sum_{k=1}^{n}\sum_{i=1}^{m}\frac{A_kB_i}{1+z_i(x_k)}\exp\left[-\frac{b_ir^2}{1+z_i(x_k)}\right],$$
$$z_i(x)=\frac{8b_ia_0^2t}{1+\sqrt{1+\frac{t}{x}}}. \tag{4}$$

The values of $A_k$ and the points $x_k$ are given in tables of the numerical Laplace transform. The formulas obtained are used for calculations and practical conclusions are made.

NOTATION

u, normalized temperature; $a_0^2$, $a_1^2$, thermal diffusivities of the bed and the surrounding medium; ν, Peclet number; $\alpha = 2\lambda_1/\lambda_0 h$; $\lambda_0$, $\lambda_1$, thermal conductivities of bed and surrounding medium; h, bed depth; $r_b$, borehole radius; t, time; $B_i$, $b_i$, parameters determined using experimental and calculated data.

Dep. 786-77, January 7, 1977.
Original article submitted September 7, 1976.

# DETERMINATION OF SURFACE FRICTION IN A BOUNDARY LAYER USING EXTENSIBLE-STRIP DETECTORS

A. G. Prozorov

UDC 533.6.071.08:532.526

The paper considers the determination of the friction $\tau_w$ at the surface of a body in a flow of gas or liquid from the pressure difference Δp at the wall on both sides of a strip

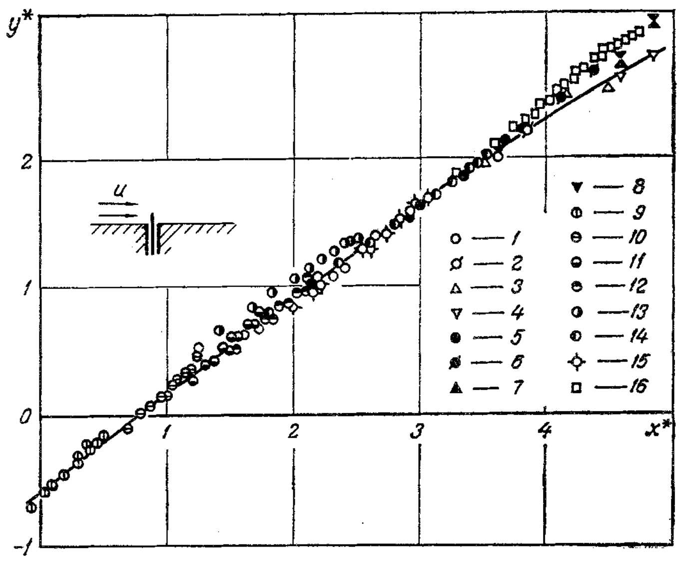


Fig. 1. Extensible-strip detector (u, m/sec). The auxiliary relation y*(x*) for determining surface friction using an extensible-strip detector; 1) h = 0.1 mm; 2) 0.2; 3) 0.3; 4) 0.4 (1-4 — laminar boundary layer at the plate); 5) h = 0.1 mm; 6) 0.2; 7) 0.3; 8) 0.4 (5-8 — turbulent boundary layer at plate, results of present experiment); 9) h = 0.01 mm; 10) 0.02; 11) 0.03; 12) 0.04 (9-12 — turbulent boundary layer at plate [1]); 13) h = 0.05 mm; 14) 0.13 (13-14 — turbulent flow in tube [2]); 15) h = 0.1 mm, laminar flow at plate; 16) h = 0.1 mm, turbulent flow at plate [3].

that can be extended along a normal to the wall (Fig. 1). The aim of the paper is to obtain from experimental results for much-studied flows a universal relation $y^*(x^*)$, where $x^* = \log\cdot[(\Delta p/\rho)(h^2/\nu^2)]$, $y^* = \log[\tau_w/\rho)(h^2/\nu^2)]$. For known values of the strip height h, the density $\rho$, and the kinematic viscosity $\nu$ of the medium, this relation can be used to determine the surface friction in any flow from the measured value of the pressure difference, proceeding analogously to the Stanton and Preston methods.

The data required to determine the relation $y^*(x^*)$ are obtained by appropriate treatment of the dimensional dependences $\tau_w(\Delta p)$ for various extensible-strip detectors [1-3] and by setting up a special experiment on a plate. The relations $y^*(x^*)$ shown in Fig. 1 are approximated by a single curve over most of the range of $x^*$ investigated. This curve is compared with the similar curves used in the Stanton and Preston methods. It is also shown that the extensible-strip detector is suitable for the determination of the surface-friction vector in three-dimensional flow.

The relation obtained may be used to interpret experimental results obtained with the extensible-strip detector.

LITERATURE CITED

1. N. I. Konstantinov and G. L. Dragnysh, in: Proceedings of the Leningrad Polytechnic Institute [in Russian], No. 176 (1955).
2. I. Rechenberg, Z. Flugwissenschaften, No. 11 (1963).
3. D. Wiesner, Schiffbauforschung, 9, Nos. 5-6 (1970).

Dep. 720-77, January 31, 1977.
Original article submitted November 22, 1976.

# BOUNDARY-LAYER DEVELOPMENT AT A CIRCULAR CYLINDER MOVING CONTINUOUSLY IN A LONGITUDINAL FLOW OF INCOMPRESSIBLE FLUID

G. A. Danilin

UDC 532.526:677.4

The paper considers the determination of the principal characteristics of a boundary layer at a circular cylinder of radius R moving continuously at a constant velocity $u_w$ in a homogeneous flow of incompressible fluid moving at velocity $u_e$ along the direction of motion of the cylinder. It is assumed that the flow is initially unperturbed but that at a certain moment, as a result of viscous drag, it begins to interact with the moving surface of the cylinder, and enters the flow mode characteristic for a boundary layer.

The motion of the liquid in the boundary layer is described by the equations

$$\frac{\partial ru}{\partial x}+\frac{\partial rv}{\partial y}=0,\ u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\frac{\nu}{r}\frac{\partial}{\partial y}\left(r\frac{\partial u}{\partial y}\right) \quad (1)$$

and boundary conditions

$$y=r-R,\ \nu=\mu/\rho;\ u=u_w,\ v=0\ (y=0,\ x>0);$$
$$u\to u_e\ (y\to\infty,\ x>0);\ u=u_e\ (y>0,\ x=0),$$

where x and r are cylindrical coordinates related with the axis and direction of motion of the cylinder; u and v are the velocity components of the liquid along the x and r axes; and $\rho$, $\mu$, and $\nu$ are the density, dynamic, and kinematic viscosities of the liquid.

A solution of Eq. (1) is obtained by the Pohlhausen single-parameter method and another by a numerical method [1]. The single-parameter family of velocity profiles is determined as follows:

$$u=u_e+(u_w-u_e)\varphi,\ \varphi=1-\alpha^{-1}\ln(1+n)\ (0\leqslant n<n_e),$$
$$\varphi=0\ (n\geqslant n_e),\ n=y/R,\ n_e=\delta/R=\exp(\alpha)-1,$$
$$\tau=\mu\left(\frac{\partial u}{\partial y}\right)\bigg|_{y=0}=\frac{\mu(u_e-u_w)}{R\alpha}.$$

Here $\alpha$ is the form parameter determined from the Kármán integral equation; $\tau$ is the tangential frictional stress at the cylinder surface; and $\delta$ is the boundary-layer thickness.

To find the numerical solution of Eq. (1), the following variables and functions are used:

$$\zeta=\sqrt{\frac{\nu x}{u_1R^2}},\ \eta=\frac{n}{\zeta},\ u_1=u_w\,(u_w\geqslant u_e),\ u_1=u_e\,(u_w<u_e),$$

$$u=u_1\frac{\partial f}{\partial\eta},\ v=-\frac{\nu}{2R\zeta}\left(F-\frac{\zeta}{1+\zeta\eta}\int\limits_0^\eta Fd\eta\right),\ \tau=\frac{\mu u_1}{R\zeta}f''(\zeta,0),$$

$$F(\zeta,\eta)=f+\zeta\frac{\partial f}{\partial\zeta}-\eta\frac{\partial f}{\partial\eta},\ u(x,\delta)=0{,}01u_w+0{,}99u_e,\ '=\frac{\partial}{\partial\eta}.$$

The distributions of the functions f, f', and f" in the boundary layer as a function of $\zeta$ and the parameters $\Lambda_w = u_w/u_1$, $\Lambda_e = u_e/u_1$ are obtained. The values of $\Lambda_w$ and $\Lambda_e$ are varied over a wide range. The variable $\zeta$ takes values from 0 to 70. The distribution $f''(\zeta, 0)$ over the surface of the cylinder is approximated as follows

$$f''(\zeta,0)=(\Lambda_e-\Lambda_w)\,[0.332\,(\Lambda_e+1.786\Lambda_w)^{0.5}+0.438\,(\Lambda_e+0.117\Lambda_w)^{0.09}\zeta^{0.82}],$$

the error of which does not exceed 5% for any $\zeta$, $\Lambda_w$, and $\Lambda_e$.

The difference between the solutions of the boundary-layer equation by the single-parameter and numerical methods is insignificant.

LITERATURE CITED

1. I. V. Petukhov, in: Numerical Methods of Solving Differential Equations and Quadrature Formulas [in Russian], Nauka, Moscow (1964), p. 304.

Dep. 783-77, February 7, 1977.
Original article submitted November 1, 1976.

# CALCULATION OF TEMPERATURE FIELDS IN KERAMZIT* CONCRETE DURING THERMAL TREATMENT

N. I. Gamayunov, R. A. Ispiryan,
and A. V. Klinger

UDC 666.973

The two-stage heating of an infinite plate of keramzit concrete is considered. The temperature of the medium varies linearly with time in the first stage and remains constant in the second stage. The heat-transfer conditions at the surface differ and are characterized by the Biot numbers $Bi_1$ and $Bi_2$. Because of the high rate of heating and the negligible moisture loss characteristic of light concretes, the effects of the internal heat source and heat loss on evaporation are disregarded. Solving the Fourier equation with boundary conditions of the third kind and zero initial condition gives the following expression for the calculation of the temperature field in the first stage:

$$\vartheta(\chi,\mathrm{Fo})|_{\mathrm{Fo}\leqslant\mathrm{Fo}_1}=\mathrm{Pd}\left[\mathrm{Fo}+\frac{1}{2}\chi^2+\frac{\mathrm{Bi}_2-\mathrm{Bi}_1}{\mathrm{Bi}_1+\mathrm{Bi}_2+2\mathrm{Bi}_1\mathrm{Bi}_2}\chi-\frac{3(\mathrm{Bi}_1+\mathrm{Bi}_2)+2\mathrm{Bi}_1\mathrm{Bi}_2+4}{2(\mathrm{Bi}_1+\mathrm{Bi}_2+2\mathrm{Bi}_1\mathrm{Bi}_2)}+\sum_{n=1}^{\infty}A_nB_n\exp(-\mu_n^2\mathrm{Fo})\right]. \quad (1)$$

Here $\vartheta(\chi, \mathrm{Fo})$ is the dimensionless excess temperature; $\chi$ is a dimensionless coordinate (the coordinate origin is at the center of the plate); Fo is the Fourier number ($\mathrm{Fo}_1$ is the value corresponding to the end of the first stage); Pd is the Predvoditelev number, characterizing the rate of temperature increase of the medium; $\mu_n$ is the root of the characteristic equation

$$(\mathrm{Bi}_1+\mathrm{Bi}_2)\,\mathrm{ctg}\,2\mu=\mu-\frac{\mathrm{Bi}_1\mathrm{Bi}_2}{\mu};$$

*Keramzit: a porous clay filler.

$A_n$ is the initial thermal amplitude,

$$A_n = \sin 2\mu_n \left\{\mu_n^3 \left[\mathrm{Bi}_1 + \mathrm{Bi}_2 + \frac{1}{2}\left(1+\frac{\mathrm{Bi}_1\mathrm{Bi}_2}{\mu_n^2}\right)\sin^2 2\mu_n\right]\right\}^{-1};$$

and $B_n$ is a factor,

$$B_n = \mathrm{Bi}_1 \cos(1-\chi)\mu_n + \mathrm{Bi}_2\cos(1+\chi)\mu_n + \frac{\mathrm{Bi}_1\mathrm{Bi}_2}{\mu_n}[\sin(1-\chi)\mu_n + \sin(1+\chi)\mu_n].$$

The initial temperature distribution for the second stage is given by Eq. (1) on setting Fo = $\mathrm{Fo}_1$. Replacing Fo by Fo* = Fo − $\mathrm{Fo}_1$ allows the temperature field in the second stage to be found:

$$\vartheta(\chi, \mathrm{Fo})|_{\mathrm{Fo}>\mathrm{Fo}_1} = \mathrm{Pd}\left\{\mathrm{Fo}_1 - \sum_{n=1}^{\infty} A_n B_n [1-\exp(-\mu_n^2 \mathrm{Fo}_1)] \exp[-\mu_n^2(\mathrm{Fo}-\mathrm{Fo}_1)]\right\}. \quad (2)$$

Using Eqs. (1) and (2), the temperature field is calculated for various values of $\mathrm{Bi}_1$ and $\mathrm{Bi}_2$. The theoretical results are compared with experimental data.

Dep. 721-77, January 24, 1977.
Original article submitted October 25, 1976.

## NEW METHOD OF CALCULATING COLD LINKAGE IN HEAT-INSULATING LAYERS

M. A. Gintsburg and Yu. N. Khromets

UDC 699.86

The simplest model of a cold linkage is a bolt tying two metallic plates (of thicknesses $L_1$ and $L_2$ and thermal conductivities $\lambda_1$ and $\lambda_2$) separated by a heated layer (of thickness $l$). The bolt axis is taken along the axis r = 0 of a cylindrical coordinate system. The temperature of the external air $T_0$ ($-50° < T_0 < -10°$C) and the temperature of the air enclosed within the plates $T = T_2$ ($T_2 = 18°$C) are given. The temperature of the hot end of the bolt $T_1$ is found.

The heat flux in an element of plate surface as a result of heat exchange with the hot air between the plates is equivalent to a source of heat uniformly distributed over the plate cross section with density $\alpha_1(T_2 - T)/\lambda_1 L_1$ ($\alpha_1$ is the heat-transfer coefficient between the plate and the air enclosed within the plates), and so the heat-conduction equation is

$$\frac{d^2T}{dr^2} + \frac{1}{r}\cdot\frac{dT}{dr} + k^2(T_2 - T) = 0, \quad (1)$$

with solution

$$T = T_2 - C_1 K_0(kr), \quad (2)$$

where $k^2 = \alpha_1/\lambda_1 L_1$; $K_0$ is a Bessel function.

The boundary condition at $r = r_0$ ($r_0$ is the bolt radius) gives the value of $c_1$: $c_1 = (T_2 - T_1)/K_0(kr_0)$.

The heat resistance of the plate is

$$R_i = (2\pi\lambda_i L_i F(x_i))^{-1};\ F(x) = \frac{xK_1(x)}{K_0(x)}; \qquad x_i = k_i r_0;\ k_i^2 = \frac{\alpha_i}{\lambda_i L_i} \quad (3)$$

(the subscript i = 1 corresponds to the inner plate and i = 2, to the outer plate). The resistance of the bolt is $R_0 = l/\pi r_0^2 \lambda_0$.

The inhomogeneity can be characterized by the coefficient of cooling of the walls by the bolt:

$$\beta = \frac{T_2 - T_1}{T_2 - T_0} = \frac{R_1}{R_1 + R_2 + R_0}. \quad (4)$$

Usually, in building structures, $x \ll 1$. Replacing $K_0$ and $K_1$ expansions for $x \ll 1$ gives

$$R_i = \frac{1}{2\pi\lambda_i L_i}(0.116 - \ln x_i). \tag{5}$$

Heating Sheet. Setting a thick sheet (under the bolt) on the inner plate from the warm side has the effect of shunting the resistance of the heat-conducting circuit formed by the plate and therefore β is decreased.

Let there be a component (plate, channel bar, etc.) of total heat resistance $\bar{\bar{R}}$ on a path of heat flux Q between the sheet (radius R, thickness $L_R$) and the air between the plates. Then $R_{in}$, the input resistance of this system on adding the sheet, is: $R_{in} = (T_2 - T_1)/Q_{r=r_0}$. The boundary conditions at $r = r_0$ and $r = R$ give

$$\begin{gathered} R_{in} = R_0 (I_0 (kr_0) + SK_0 (kr_0))/(I_1 (kr_0) - SK_1 (kr_0)); \\ S = (I_1 (kR) P + I_0 (kR))/(K_1 (kR) P - K_0 (kR)); \\ (P = 2\pi kR\lambda_{sh} L_R \bar{\bar{R}});\ R_0 = (2\pi\lambda_{sh} L_R kr_0)^{-1}. \end{gathered} \tag{6}$$

Dep. 781-77, January 10, 1977.
Original article submitted February 2, 1976.