turbulent exchange. This set has been found to give satisfactory predictions in many situations. Our purpose here is to demonstrate that the *same* set can successfully predict the cylindrical wall jet.

2.3. *The solution procedure*

The equations in Section 2.1 were solved by an implicit, finite-difference procedure described in [1]. The procedure uses a grid that expands or contracts to fit the important region of the flow. The computations reported here used 20 grid points in the cross-stream direction; the forward step in the x direction was one-fourth of the boundary-layer thickness. The computations were performed on the IBM 7044 computer at I.I.T. Kanpur.

3. COMPARISON WITH EXPERIMENTAL DATA

3.1. *The flow characteristics*

Starr and Sparrow [3] have reported flow measurements in a cylindrical wall jet having a curvature parameter C ($\equiv$ rod diameter/slot height) of 5.9. Figure 2 shows the growth of the wall jet and the decay of the maximum velocity. Our predictions are seen to agree very well with the experimental data.

Manian *et al.* [4] have conducted a more extensive experimental study which covers a large range of the curvature parameter C. The jet growth and velocity decay are compared with our predictions in Figs. 3 and 4; the agreement is once again satisfactory.

3.2. *The heat-transfer characteristics*

Manian *et al.* [4] also give heat-transfer measurements for cylindrical wall jets. They used a uniform heat flux from the cylinder wall. They show that the experimental data can be correlated by the dashed line in Fig. 5. The full lines show our predictions for some curvature parameters. The agreement can be seen to be very good.

4. CONCLUDING REMARKS

(1) The implications of the mixing-length hypothesis agree well with available experimental data for jet spread, velocity decay and heat transfer in cylindrical wall jets.

(2) It is emphasised here that the agreement mentioned above is *not* obtained by *adjusting* the constants in the hypothesis to fit the data. The physical hypotheses and the values of the constants are exactly the same as used in [1] and [2] for more conventional geometries.

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HEAT FLOW INTO A SEMI-INFINITE BODY WITH SURFACE TEMPERATURE A NON-INTEGER POWER OF TIME

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NOMENCLATURE

A, constant defined in equation (6);
B, constant defined in equation (7);
k, thermal conductivity;
q_t, surface heat flux at time t;
Q_t, total surface heat flow from time 0 to t;
t, time;
x, distance from surface;
α, thermal diffusivity;
Θ, temperature.

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In an approximate analysis of the very early stages of bubble growth a solution was required for the heat flow into a semi-infinite slab with surface temperature given by

$$\Theta_{x=0} = t^m, \quad m = \tfrac{1}{4}. \tag{1}$$

Carslaw and Jaeger [1] give solutions only for $m = n/2$, where n is a positive integer, but if the complete temperature distribution is not required a simple expression is obtainable for the surface heat flux for any $m > -1$. (Only values of $m \geqslant 0$ are of physical interest.) Since this result may be of use in other applications it is summarised below.

The Laplace transform of the solution of the one-dimensional conduction equation for a semi-infinite body, initial temperature zero, surface temperature $\Theta_{x=0} = \phi(t)$ is

$$\bar{\Theta} = \bar{\phi}(s)\exp\left[-x(s/\alpha)^{\frac{1}{2}}\right] \tag{2}$$

and of the temperature gradient at $x = 0$ is

$$\left(\frac{\partial\bar{\Theta}}{\partial x}\right)_{x=0} = -\left(\frac{s}{\alpha}\right)^{\frac{1}{2}}\bar{\phi}(s). \tag{3}$$

For $\phi(t) = t^m$,

$$\bar{\phi}(s) = \frac{\Gamma(m+1)}{s^{m+1}}, \quad m > -1. \tag{4}$$

The transform of the integrated heat flux Q_t from time 0 to t is

$$\mathscr{L}\left\{\int_0^t -k\left(\frac{\partial\Theta}{\partial x}\right)_{x=0} d\tau\right\} = -\frac{k}{s}\left(\frac{d\bar{\Theta}}{dx}\right)_{x=0} = \frac{k\,\Gamma(m+1)}{\alpha^{\frac{1}{2}}\,s^{m+\frac{3}{2}}} \tag{5}$$

whence

$$Q_t = \frac{Ak}{\alpha^{\frac{1}{2}}}t^{m+\frac{1}{2}}, \quad A = \frac{\Gamma(m+1)}{\Gamma(m+\frac{3}{2})}. \tag{6}$$

and the instantaneous heat flux at time t is

$$q_t = \frac{Bk}{\alpha^{\frac{1}{2}}}t^{m-\frac{1}{2}}, \quad B = (m+\tfrac{1}{2})\frac{\Gamma(m+1)}{\Gamma(m+\frac{3}{2})}. \tag{7}$$

Values of A and B for $0 < m \leqslant 1$ are tabulated below. Values of the Gamma function for computation of A and B when $m > 1$ are given in [2].

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m	0·05	0·10	0·15	0·20	0·25	0·30	0·35	0·40	0·45	0·50
A	1·0952	1·0647	1·0366	1·0105	0·9862	0·9636	0·9424	0·9225	0·9038	0·8862
B	0·6024	0·6388	0·6738	0·7073	0·7397	0·7709	0·8010	0·8303	0·8587	0·8862
m	0·55	0·60	0·65	0·70	0·75	0·80	0·85	0·90	0·95	1·0
A	0·8696	0·8538	0·8389	0·8247	0·8112	0·7983	0·7860	0·7743	0·7630	0·7523
B	0·9131	0·9392	0·9647	0·9896	1·0140	1·0378	1·0611	1·0840	1·1064	1·1284