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An Investigation Into Practical Aspects Of Transpiration Flows

Krieg, Mark Hans Robert Friedrich

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UNIVERSITY OF THE WITWATERSRAND
JOHANNESBURG

SCHOOL OF MECHANICAL ENGINEERING

AN INVESTIGATION INTO PRACTICAL ASPECTS OF TRANSPIRATION FLOWS

M KRIEG

A dissertation presented in fulfilment of the requirements for the Degree of Master of Science in Engineering

MARCH 1978

To my Mother and Father .....

and Summertime

DECLARATION

I, MARK HANS ROBERT FRIEDRICH KRIEG, hereby declare that the dissertation is my own work and has not been submitted by me for a degree at any other University.



M.H.R.F. KRIEG

ABSTRACT

It was felt that by attaching a porous matrix to a rigid base with metering holes or slots, these materials would become more viable in transpiration cooling. Such an alteration was expected to affect the mean velocity profile of the injected turbulent boundary layer. This, and the more basic study of turbulent transport, required attention. An investigation of the literature showed that although a great deal of work had been done, there was little to compare with the present problem.

A wind tunnel was designed and constructed which produced a 2-D incompressible turbulent shear layer on a porous plate, through which a secondary stream was injected. A flow situation with a step change in injection was thus modelled. A main stream velocity of 21 m/s (corresponding to Re_x = 1,178 x 10^6), and an average injection ratio (v_w/U_∞) of 0,017, was attained. Results indicated that blockage below the porous surface resulted in an apparently higher injection ratio for the same total flow rate.

To further the understanding of turbulent transport, a programme was written which solved the momentum equation. The eddy-viscosity formulation suggested by Cebeci was tested in this solution. It could be used to calculate the velocity profiles, with varying injection and pressure gradients, of either laminar or turbulent external boundary layers.

A numerically calculated profile and the experimental results of another researcher compared very well. The trend for the 'transition' region from flat plate turbulent flow to the injected turbulent boundary layer was established experimentally, and reflected in the computer

generated profiles. Exact comparison was not possible, owing to lack of time to rewrite part of the programme.

Experimental results were cross-plotted, and this indicated the possibility of a short-cut method for deriving velocity profiles with injection. Skin friction was not measured in the tests, and was found to be very inadequately documented in previous work. This must be a very important aspect of the injected turbulent shear layer, and requires further work.

A preliminary investigation of the flow in the porous matrix, especially the spread of an axisymmetric jet, was done. Initially experiment was expected to precede analysis, and a rig was built for future research.

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NOTATION

ROMAN

a	Pipe diameter
A	Van Driest damping length
A^+	Van Driest damping constant
$[A]$	Coefficient matrix in $[A]\{X\} = \{B\}$
$\{B\}$	Vector of constants
c_f	Skin friction coefficient
d	Orifice diameter
D	Pipe diameter
D_o	Particle diameter
E	Voltage drop across hot-wire
E_o	Voltage drop across hot-wire for zero velocity
E_n	Voltage drop, corrected for temperature
$E_1(n)$	Contribution to energy of fluctuation for frequency $n + dn$
$\underline{f}$	Force vector (per unit volume)
f	Dimensionless stream function, general function
F	Local injection ratio, v_w/U_∞
F_{av}	Average injection ratio, v_w/U_{C1}
g	General function
G	Main stream mass flux, $G = \rho_\infty U_\infty$
h	First step in η grid
H	Shape factor
k	Roughness height
k^+	Non-dimensionalised roughness height, $k^+ = ku_w^*/\nu$

K	Ratio of adjacent η intervals
l	Mixing length
L	Length scale, porous matrix thickness in direction of flow
m''	Injection mass flux
n	Frequency
$N-4$	Number of equations in system $[A]\{X\} = \{B\}$
p	Pressure
p^+	Pressure gradient term, $- dp/dx.\nu/\rho(u_\omega^*)^3$
Re_I	Reynolds number, $Re_L = U_\infty L/\nu$
t,	Temperature
T	Turbulence intensity
u	Axial velocity, $u^+ = u/u_\omega^*$
u_ω^*, u_τ	Wall shear velocity
$\underline{v}$	Velocity vector
v	Velocity normal to wall
v_ω	Injection velocity, $v_\omega^+ = v_\omega/u_\omega^*$
x	Co-ordinate parallel to flow
$\{X\}$	Vector of unknowns
XTR	Start of porous plate, measured from origin
y	Co-ordinate normal to flow, $y^+ = yu_\omega^*/\nu$

GREEK

α	Constant in outer eddy-viscosity formulation
β	Pressure gradient parameter, $\beta = (2\xi).(du_e/d\xi)/u_e$
γ	Intermittency term
δ	Boundary layer thickness

δ^*	Displacement thickness
Δ	Differential, e.g. $\Delta p = p_2 - p_1$
ε	Eddy viscosity, $\varepsilon^+ = \varepsilon/\nu$
η	Transformed y-co-ordinate
θ	Momentum thickness
κ	Universal constant in logarithmic portion of turbulent profile
μ	Dynamic viscosity
ν	Kinematic viscosity
ξ	Transformed x-co-ordinate
ρ	Density
τ	Shear stress
ϕ	Translated stream function
ψ	Stream function

SUBSCRIPTS

CL	Centre line at Working Section inlet
e	Edge of boundary layer
i	Inner region
o	Outer region, unblown condition
s	Static, laminar sub-layer
w	Wall condition
$\underline{\ }$	Vector
$=$	Second order tensor

SUPERSCRIPTS

+	Non-dimensional
'	Derivative with respect to η, fluctuating quantity
—	Integral averaged quantity (time based, unless otherwise stated)

MATHEMATICAL OPERATORS

grad, ∇	$(\delta/\delta x \ \delta/\delta y \ \delta/\delta z)$
div $\underline{v}$, $\nabla.\underline{v}$	$\delta u/\delta x + \delta v/\delta y + \delta w/\delta z$
∇^2	$\delta^2/\delta x^2 + \delta^2/\delta y^2 + \delta^2/\delta z^2$

CHAPTER 1

INTRODUCTION

The need for cooling engineering components becomes necessary when the components are in a high temperature environment. This problem frequently arises in flow situations. Important examples are :- turbine blades and combustion chambers in jet engines, exposed surfaces of supersonic vehicles such as aircraft, missiles and space craft. A further example is the lining of nuclear reactors. At present, turbine vanes and blades are film cooled by blowing cool air through discrete holes near the leading and trailing edge of the blades. This is a very important application, because the efficiency of the engine increases with cycle temperature.

An improvement in efficiency can have a dramatic effect in increasing the range of aircraft. Suciu (1970) showed that an aircraft with constant gross weight can transport a payload some 40% further if the cycle turbine inlet temperature is increased from 950°C to 1260°C. Metallurgical developments have resulted in much higher allowable metal temperatures, and film cooling has also made a significant contributior.

The coolant which is injected through the porous surface will certainly affect the boundary layer, skin friction, aerodynamic characteristics of an aerofoil (lift, drag) as well as the heat transfer coefficient. It was therefore decided that the mass transfer problem had to be investigated first. A great deal of work, both experimental and semi-analytic, has been done in this field. Unfortunately, because of the magnitude of the problem, and the large number of variables, tests have not been very systematic. Considerable thought was devoted to film cooling, and the

possibility of using porous materials for the manufacture of turbine blades. As a result, an experimental research programme was embarked on.

In particular, a turbulent boundary layer was established on a smooth flat plate before it reached a porous plate, where the flow encountered injection. A computer programme was written to simulate this situation. A deeper understanding of turbulent flow thus became possible, which is necessary not only for the abovementioned applications. In the design of air intake ducts for aircraft, turbulence and intermittency must be accounted for to ensure the required flow rate. Further applications are boundary layer control on aircraft wings, using suction or injection, and hence drag reduction.

The work of various authors is discussed. It was found that there were fundamental differences between this work and that of other researchers. This made comparison very difficult. A new approach to the use of porous materials in the manufacture of turbine blades is shown. A stable computational technique was developed and the existence of a new two-parameter family of curves for the injected turbulent boundary layer is presented.

CHAPTER 2

OBJECT

Investigation of existing turbine blades in aircraft gas turbines, e.g. Pratt and Whitney JT9, General Electric CF6 and Rolls Royce RB211, showed that film cooling has become an integral part in the design of first stage stator vanes and rotor blades. Impingement cooling is used in the second stage. Clearly, the technology for manufacturing these blades with internal ducting is fully developed. Welding a porous envelope onto a blade was suggested by Grootenhuis (1959).

Because the pressure distribution on an aerofoil would result in minimum transpiration at the leading edge, a complete envelope would be unsatisfactory. This could be overcome by having porous inserts at the leading edge and mid-chord positions. A configuration of solid wall, followed by porous wall thus arose. Furthermore, the porous wall is notoriously weak, and would require to be bonded to a solid wall at the inner surface to maintain the aerodynamic loads.

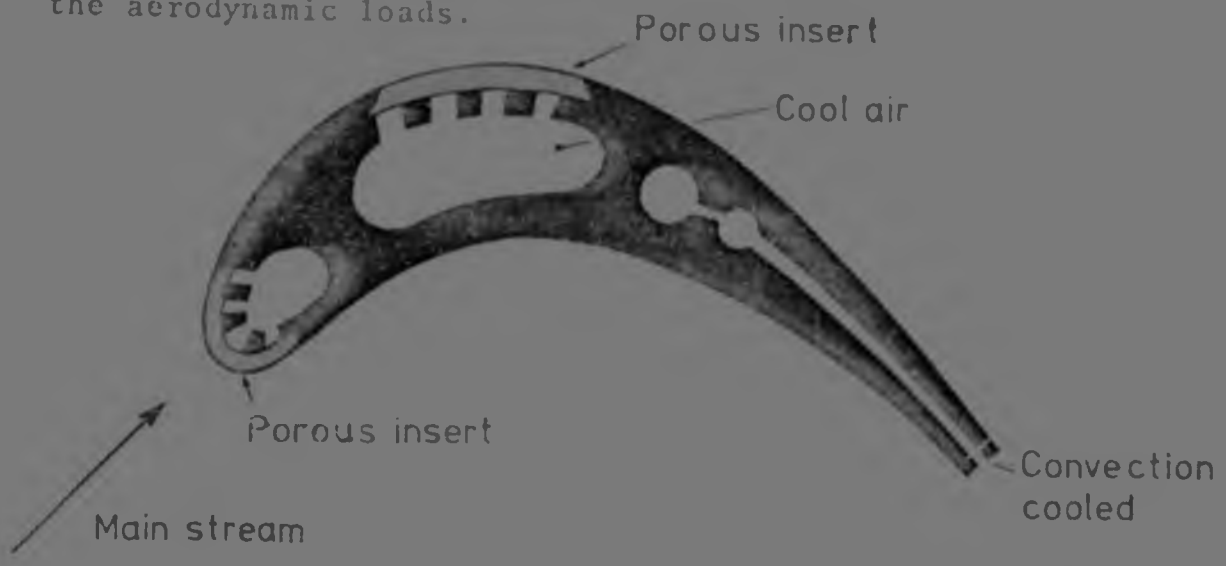


FIG 2.1 : CROSS SECTION OF BLADE WITH POROUS INSERTS

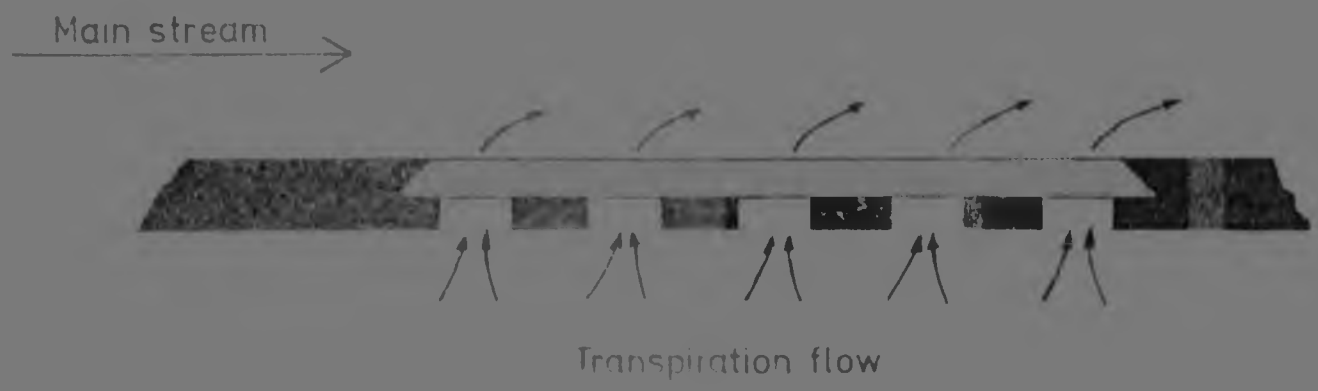


FIG 2.2 : BOUNDARY LAYER WITH STEP CHANGE IN ROUGHNESS AND INJECTION

It may be expected that the heat transfer from the metal to the coolant would be improved because the surface area is greatly increased in the porous medium. Furthermore, the webs between discrete holes in film cooling are very thin and hence prone to melting or combustion.

A great deal of research has been done in the field of transpiration cooling. However, the effect of a short porous insert with blockage below the porous matrix still remained to be explored.

To achieve this, an experimental rig, shown in Fig 2.3, was designed. This enabled tests on a flat plate in 2-D flow to be carried out. A set of data for uniform blowing was to be established, with which results for non-uniform injection could be compared.

The first stage was to consider only the effect of sudden mass transfer into an established turbulent boundary layer, without heat transfer.

The spread of the jet of coolant from the restricted inner porous surface to the open exposed surface clearly is an important consideration.

CHAPTER 3

REVIEW OF LITERATURE ON THE TURBULENT BOUNDARY LAYER WITH INJECTION

3.1 Introduction

One of the earliest papers to appear on transpiration cooling was published by Duwez and Wheeler (1948). The authors concentrated on a porous tube with high temperature axial flow and cold air injection through the walls. Their results compared well with that of Krieg (1975). In 1956 Mickley and Davis followed with an extensive experimental investigation which is still used for qualifying rigs, and for comparison with analytical or computer profiles. Chemical engineers have shown great interest in fluidized beds, ie. the flow inside a porous matrix. This latter line of investigation was considered relevant to the present work (see Appendix A3). The research may be categorised as follows :

(i) Fluidized beds;

(ii) Turbulent boundary layers with suction or injection at the wall :

  a) in channels
  b) in tubes
  c) on a flat plate.

Each of these may be further subdivided into experimental, analytic and numerical results, with or without heat transfer, and into compressible or incompressible flow.

Note that injection through discrete holes or slots has enjoyed much attention (e.g. Hartnett *et al* 1961), but is not reported on here.

3.2 Experimental Work

As mentioned above, the first thorough experimental investigation was that of Mickley and Davis (1956). Free stream velocities ranged from 5,2 m/s to 18,3 m/s, Re_x from 4 x 10^4 to 3 x 10^6 and v_w / U_∞ values of 0; 0,001; 0,002; 0,003; 0,005 and 0,010. They found that the boundary layer decreased in thickness near the outlet of the tunnel. This latter problem was overcome by adding a flow divider to the outlet of the tunnel. The estimated values of $c_f/2$ were shown plotted against Re_x. Where c_f tended to 0 or to negative values, the results were not reported. This occurred at values of F = 5 x 10^{-3} and above. Negative c_f would indicate reverse flow, however, as will be discussed later, this need not be the case. Up to F = 3 x 10^{-3}, the values of c_f compare with those predicted by McQuaid (1967), if these curves are extrapolated. Their plot of u^+ vs log y^+ fitted the universal turbulent boundary layer profile acceptably. Graphs of u/U_∞ vs y/δ were shown for F = 0,003 and F = 0,005. To predict these profiles, it was necessary to allow κ, the mixing length constant, to vary. κ increased with F. The trend today is to assume κ constant, and to introduce a function in v_w.

Grootenhuis (1959) concentrated on heat transfer, as did most early investigators. Apart from the experimental results and correlation, this paper points out numerous applications of effusion cooling, discusses types of porous materials, shows thermal conductivity vs porosity for sintered bronze and stainless steel, and the internal heat transfer correlation for porous bronze. A list is given of manufacturers of porous materials, both sintered and woven, the various grades, their porosity and U.T.S. Blade designs were suggested, but required a complete porous envelope, spot welded to a hollow stem (see Fig 3.1).

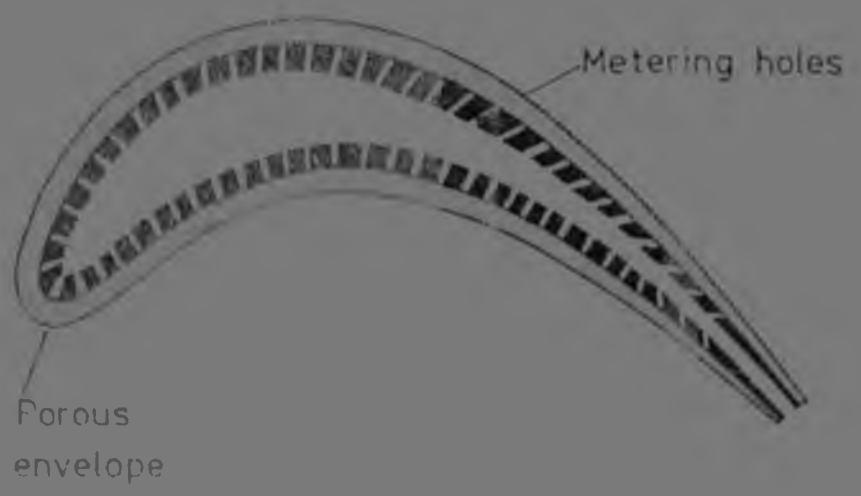


FIG 3.1 : PROPOSED DESIGN FOR A POROUS TURBINE BLADE OR VANE

A new wind tunnel was described by Moffat and Kays (1969). Their research was to establish a basis of experimental data for skin friction and heat transfer. Reynolds number, blowing fraction and Stanton number were varied systematically on a flat, porous plate. This floor was supported on 24 plenum chambers which allowed F to be controlled as a function of x. Electric heaters were installed below the porous plates, so that the transpiration flow could be heated. This unfortunately results, for an injected boundary layer, in an incorrect temperature profile. Results were presented for Stanton number varying with blowing fraction; these values showed good correlation.

The second part of this work was reported by Simpson *et al* (1969). Skin friction results were presented for v_w constant, $v_w \propto x$, $v_w \propto x^{-0.5}$ and $v_w \propto x^{-0.5}$. c was presented as a function of $\dot{m}''/\rho(c_{fo}/2)$. Various techniques for calculating c_f from profile data were suggested. These included a momentum integral equation method, viscous sublayer model method and the heat transfer analogue method, which was the only method to yield results for

blowing fractions above 0,0078. Indications were that for $b[-\dot{m}''/G(c_{fo}/2)]$ greater than 4, c_f tended to zero. Surface roughness was not included in the skin friction calculations.

Schetz and Nerney (1977) performed tests on an axisymmetric model. A skin friction balance was built into the porous wall : the floating element had its own transpiration supply. A crystal strain gauge was attached to the floating element support. The velocity profiles were obtained with a pitot rake. It was mentioned that the effect of roughness should first be ascertained for the porous wall without injection or suction. Note that the floating element is one of the more attractive techniques for measuring skin friction. Once true values are established, semi-analytic methods may be tested against these. It was found that blowing through the porous floating element made no difference to the results. The porous wall without injection showed significantly higher values of c_f than the equivalent smooth wall. The roughness increased the turbulence intensity in the boundary layer. With the new skin friction results, the laws of the wall, one by Simpson, one by Stevenson, could be tested. It was shown clearly that these laws are inadequate. The "deductive" approach of Van Driest (1956) could not be extended as had been suggested, but a new formulation using the Reichardt model $\{\rho\varepsilon = \kappa\rho\nu[y^+ - y^+_a \tanh(y^+/y^+_a)]$ was presented. This new approach should yield significantly better results.

3.3 Analytical Developments

Before commencing this subsection, it should be noted that turbulent flow is of such a random nature that any analysis must contain empirical or experimentally determined constants. When considering quantities such as velocity, a time based average value is implied.

Mickley and Davis (1956) concentrated on experimental work, and the determination of c_f. This was done by evaluating $d\theta/dx$, and solving for c_f from :

$$\frac{d\theta}{dx} - \frac{v_w}{U_\infty} + \left(2 + \frac{\delta^*}{\theta}\right) \frac{\theta}{U_\infty} \frac{dU_\infty}{dx} = \frac{\tau_w}{\rho_\infty U_\infty} = \frac{c_f}{2} \qquad \ldots\ldots [3.3.1(a)]$$

For neglible pressure gradient, this reduces to :-

$$\frac{d\theta}{dx} - \frac{v_w}{U_\infty} = \frac{\tau_w}{\rho_\infty U_\infty^2} = \frac{c_f}{2} \qquad \ldots\ldots [3.3.1(b)]$$

The difficulty unfortunately lies in determining $\frac{d\theta}{dx}$.

The remainder of the analysis attempted to extend the mixing length theory for flow with $v_w \neq 0$. Reasonable correlation was obtained up to $F = 0{,}005$, but κ was no longer constant, but increased with F. To plot experimental data non-dimensionalized with respect to u_τ^*, when this quantity is calculated from semi-analytic considerations, seems very unsatisfactory. Only if τ_w is measured directly can an estimate of the reliability of the analysis be made.

It was assumed that there was only a laminar sublayer and a turbulent region (ie. no buffer layer), with a transition point at y_a. As do most researchers, they assumed the predominance of the $v_w \delta u/\delta y$ term in the equation

$$u\frac{\delta u}{\delta x} + v\frac{\delta u}{\delta y} = \frac{1}{\rho}\left(\frac{\delta \tau}{y} - \frac{dp}{dx}\right) \qquad \ldots\ldots [3.3.2]$$

For an incompressible layer, the following expressions were obtained :

Sublayer $$\frac{u_\tau y}{\nu} = 2\frac{u_\tau}{v_w} \ln\left(1 + \frac{v_w u_\tau}{u_\tau^2}\right) \qquad \ldots\ldots [3.3.3]$$

Turbulent region $$\ln \frac{u_\tau y}{\nu} - \ln \frac{u_\tau y_a}{\nu} = 2\kappa\frac{u_\tau}{v_w}\left[\left(1 + \frac{v_w u_a}{u_\tau^2}\right)^{\frac{1}{2}} - \left(1 + \frac{v_w u_a}{u_\tau^2}\right)^{\frac{1}{2}}\right] \qquad \ldots\ldots [3.3.4]$$

Black and Sarnecki (1958) approached the problem in a very similar manner. The mixing length was considered proportional to distance from the wall,

$$l = \kappa y \qquad \ldots\ldots\ldots [3.3.5]$$

Assuming incompressible, two dimensional flow, Prandtl's boundary layer equation [3.3.2] above, again forms the foundation of the analysis, with $v_w \delta u/\delta y$ a dominant term.

The continuity equation is $\frac{\delta u}{\delta x} + \frac{\delta v}{\delta y} = 0$ ..... [3.3.6]

and the shear is $\tau/\rho = \nu \frac{\delta u}{\delta y} - \overline{u'v'}$ ..... [3.3.7]

with boundary conditions $u = 0$, $v = v_w$ at $y = 0$ [3.3.8]

Close to the wall, with $dp/dx \to 0$, equation [3.3.2] reduces to

$$v_w \frac{\delta u}{\delta y} = \frac{1}{\rho} \frac{\delta \tau}{\delta y} \qquad \ldots\ldots\ldots [3.3.9]$$

[3.3.9] was integrated, to yield :

$$v_w u = \frac{\tau - \tau_w}{\rho} \qquad \ldots\ldots\ldots [3.3.10]$$

and using the definition $\frac{\tau_w}{\rho} = u_\tau^2$ ..... [3.3.11]

[3.3.12] was obtained :-

$$u_\tau^2 + v_w u = \tau/\rho \qquad \ldots\ldots\ldots [3.3.12]$$

The momentum integral equation for the transpired boundary layer is thus :

$$\frac{d}{dx}(U_\infty^2 \theta) + \frac{dU_\infty}{dx} U_\infty \delta^* = \frac{\tau_w}{\rho} + v_w U_\infty \qquad \ldots\ldots\ldots [3.3.13]$$

Using the vorticity transfer theory of G.I. Taylor with $\ell = \kappa y$ resulted in an expression which, for $v_\omega = 0$, did not reduce to the generally accepted law for flat plate flow. Prandtl's momentum transfer theory in conjuntion with a linear mixing length yielded what Black and Sarnecki (1958) called the bilogarithmic law. This referred to the squared logarithmic term in their expression, derived as fcllows :

Substitute the momentum transfer formulation,

$$\frac{\tau}{\rho} = \kappa^2 y^2 \left(\frac{\delta u}{\delta y}\right)^2 \qquad \ldots\ldots\ldots [3.3.14]$$

into [3.3.12] :

$$u_\tau^2 + v_\omega u = \kappa^2 y^2 \left(\frac{\delta u}{\delta y}\right)^2 \qquad \ldots\ldots\ldots [3.3.15]$$

From [3.3.9],

$$\frac{\delta u}{\delta y} = \frac{1}{\rho v_\omega} \frac{\delta \tau}{\delta y} = \frac{1}{v_\omega} \frac{\delta (\tau/\rho)}{\delta y}$$

$$u_\tau^2 + v_\omega u = \kappa^2 \left[\frac{y}{v_\omega} \cdot \frac{\delta (u_\tau^2 + v_\omega u)}{\delta y}\right]^2 \qquad \ldots\ldots\ldots [3.3.16]$$

$$(u_\tau^2 + v_\omega u) = \left(\frac{\kappa}{v_\omega}\right)^2 \left[\frac{\delta (u_\tau^2 + v_\omega u)}{\delta (\ln y)}\right] \qquad \ldots\ldots\ldots [3.3.17]$$

This integrates to :

$$u_\tau^2 + v_\omega u = \left(\frac{v_\omega}{2\kappa} \ln y/d\right)^2 \qquad \ldots\ldots\ldots [3.3.18]$$

where d is a constant of integration.

Equation [3.3.18] is expected to hold for 2-D incompressible flow, with $\delta p/\delta y$ negligible (Prandtl's assumption for [3.3.2], and a thin laminar sublayer.

[3.3.18] was expressed in a manner which allows both u_τ and d to be determined from the slope and the intercept on the ordinate of a straight line drawn through the experimental points in the bilog region. κ was treated as a univer·al constant.

Thus

$$\frac{u}{U_\infty} - \frac{1}{4\kappa^2}\frac{v_w}{U_\infty}\left(\ln\frac{U_\infty y}{\nu}\right)^2 = \left[\frac{1}{2\kappa^2}\frac{v_w}{U_\infty}\left(\ln\frac{U_\infty d}{\nu}\right)^2 - \frac{u_\tau^2}{v_w U_\infty}\right] - \left(\frac{1}{2\kappa^2}\frac{v_w}{U_\infty}\ln\frac{U_\infty d}{\nu}\right)\ln\frac{U_\infty y}{\nu} \quad \ldots\ldots [3.3.19]$$

Let $$\frac{1}{2\kappa}\sqrt{\frac{v_w}{U_\infty}}\ln\frac{U_\infty y}{\nu} = Y_i \quad \ldots\ldots [3.3.20]$$

$$n_i = -\frac{1}{2\kappa}\sqrt{\frac{v_w}{U_\infty}}\ln\frac{U_\infty}{\nu} \quad \ldots\ldots [3.3.21]$$

$$p_i^2 \quad \frac{u_\tau^2}{v_w U_\infty} \quad \ldots\ldots [3.3.22]$$

then $$\frac{u}{U_\infty} - Y_i^2 = (n_i^2 - p_i^2) + 2n_i Y_i \quad \ldots\ldots [3.3.23]$$

Clearly, if $\frac{u}{U_\infty} - Y_i^2$ is plotted against Y_i, and a straight line is fitted through the experimental points, the slope would be $2n_i$, and the ordinate intercept $n_i^2 - p_i^2$. This technique has numerous advantages over that of Mickley and Davis because the velocit, scale is now the known, measured valued of U_∞, rather than u_τ, obtained from the momentum integral equation. $d\theta/d$~ could be calculated from :

$$U_\infty^2\frac{d\theta}{dx} = u_\tau^2 + v_w U_\infty \quad \ldots\ldots [3.3.24]$$

(3.3.13 for $dU_\infty/dx = 0$)

$$\frac{d\theta}{dx} = \frac{v_w}{U_\infty}(p_i^2 + 1) \quad \ldots\ldots [3.3.25]$$

For values of F>0,005, it was found that the wall shear velocity became imaginary, ie. p_i^2<0. This gave c_f<0, which was what Mickley and Davis (1956) found, but ascribed to experimental error. It is very important to note that in the above technique, negative c_f does not imply reversed flow, as was found in un-injected flows with adverse pressure gradient.

This lengthy discussion has been given because the bilog technique is used for comparing the present results with those of Mickley and Davis (1956). Values of u_τ were not reported, as they were imaginary, and were only needed for the graphical presentation. Surface roughness was mentioned in the paper, but did not feature in the analysis.

McQuaid (1967) introduced intemittency into his formulation. A two parameter family of curves was mentioned, but not given in this paper. The velocity profiles generated from the family were compared with some experimental data. Results were good, also when fitted to the Mickley and Davis results.

The law of the wall for v_w = 0 is

$$\frac{u}{u_\tau} = f\left(\frac{u_\tau y}{\nu}\right) \qquad \text{..... [3.3.26]}$$

This could be extended for injected flows by adding v_w, e.g.

$$\left.\begin{aligned} &\frac{u}{u_\tau} = f\left(\frac{u_\tau y}{\nu}, \frac{v_w}{u_\tau}\right) \\ \text{or } &\frac{u}{v_w} = f_2\left(\frac{u_\tau y}{\nu}, \frac{v_w}{u_\tau}\right) \end{aligned}\right\} \qquad \text{..... [3.3.27]}$$

and to include surface roughness

$$\left.\begin{aligned} &\frac{u}{u_\tau} = f\left(\frac{u_\tau y}{\nu}, \frac{v_w}{u_\tau}, \frac{u_\tau k}{\nu}\right) \\ \text{ie. } &u^+ = f(y^+, v_w^+, k^+) \end{aligned}\right\} \qquad \text{..... [3.3.28]}$$

McQuaid, however, suggested a function using U_∞ as a velocity scale, and retained wall shear in the term c_f, thus :

$$\frac{u}{U_\infty} = g(y/\theta,\ H,\ Re_\theta,\ \frac{v_w}{U_\infty}) \qquad \ldots\ldots\ [3.3.29]$$

and

$$\left.\begin{aligned} c_f &= c_f(H,\ Re_\theta,\ \frac{v_w}{U_\infty}) \\ Re_{\delta_s} &= Re_{\delta_s}(H,\ Re_\theta,\ \frac{v_w}{U_\infty}) \end{aligned}\right\} \qquad \ldots\ldots\ [3.3.30]$$

(δ_s was defined as "twice the distance from the wall to the position where $\gamma = 0{,}5$").

McQuaid assumed the law presented by Black and Sarnecki for the sublayer [3.3.3], and modified Stevenson's 'law of the wall' for the turbulent region with suction or injection :

$$2\frac{u_\tau}{v_w}\left[\left(1 + \frac{v_w}{U_\infty}\cdot\frac{U_\infty^2}{u_\tau^2}\right)^{\frac{1}{2}} - 1\right] = A\log\frac{u_\tau \delta_s}{\nu} + B \qquad \ldots\ [3.3.31]$$

A pressure gradient term was also derived, and was shown to be analogous to the pressure gradient term for unblown flows. This was given as :

$$\Delta_i = \frac{\nu}{(u_\tau^2 + v_w u_\tau)^{3/2}}\cdot\frac{1}{\rho}\cdot\frac{dp}{dx} \qquad \ldots\ldots\ [3.3.32]$$

It was found that the model gave good agreement provided $-0{,}004 < \Delta_i < 0{,}006$. Furthermore, and this is of importance to the present work, the "fully developed state was not attained even at 33 boundary layer lengths downstream after a sudden change in injection rate".

Although this paper clearly indicates the importance of θ in transpired boundary layers, the objections raised previously to τ_w being calculated from the velocity profile, and not direct measurement, again apply.

Pletcher (1969) analysed an axisymmetric configuration, and developed a mixing length based on the Van Driest damping factor (Van Driest, 1956). An explicit finite difference technique is explained in the paper, and purports to give good results for flat plate, uninjected flows. The injected velocity profile shown agrees well with data from one of the Mickley and Davis tests. It was pointed out that the explicit method is more direct, and simpler to programme than an implicit method. Furthermore, it was not necessary to linearize the boundary layer equation before solving it, thus eliminating the need for an iterative process. However, it is well known that explicit methods are prone to instability, especially if the step length becomes too small.

Cebeci and Smith (1970a) also solved the Prandtl boundary layer equation for axisymmetric, compressible flow. This paper was preceded by numerous others that were very similar. This particular version showed the equations, boundary conditions, the finite difference grid and transformations in some detail. An implicit finite difference technique was employed to solve the linearized momentum equation with boundary conditions. A mixing length formulation based on Van Driest (1956) was used for the sublayer and the blending region, and a formulation using intermittency for the fully turbulent region. The energy equation was solved simultaneously, as this was a compressible flow situation. Grid spacing and CPU time required for solution were discussed.

Cebeci (1970b) showed how the Van Driest damping factor could be modified for pressure gradient and injection. Comparison with experimental results appeared excellent. The Van Driest velocity gradient relationship was extended to flows with injection :-

$$\frac{du^+}{dy^+} = \frac{2(v_w{}^+u^+ + 1)}{1 + \{1 + 4(v_w{}^+u^+ + 1)\kappa^2(y^+)^2[1 - \exp(-y^+/A^+)]^2\}^{\frac{1}{2}}} \quad \ldots\ldots [3.3.33]$$

where A^+ is the modified Van Driest damping constant.

Equation [3.3.33] suggests an iterative solution for u^+.

This work by Cebeci will be discussed in greater detail in Chapter 4.

Cebeci and Smith (1974) and Cebeci and Bradshaw (1977) continued the above work, but suggest changes to the Reynolds stress formulation, and a very much more sophisticated finite difference technique, known as Keller's box method. The Falkner-Skan equation requires additional transformation before computer solution is possible. The second book is of more general interest showing how Runge-Kutta can be used, and gives examples of computer programmes.

Bale (1975) concentrated on axial flow through a tube with mass extraction at the walls. A potential flow solution was obtained, which gave a good representation of the flow field inside the porous pipe, but gave no information with respect to shear stress at the wall.

Schetz and Nerney (1977), as mentioned above, concentrated on experimental work, and the direct measurement of skin friction. It was shown that an extension to the Van Driest mixing length could not account for surface roughness, but the Reichardt model could. The momentum equation could thus be written :

$$\frac{du^+}{dy^+} = \frac{1 + v_w{}^+u^+}{1 + \kappa[(1 + v_w{}^+u^+)(y^+ - y_a{}^+ \tanh(y^+/y_a{}^+)]} \quad [3.3.34]$$

(cf. equation 3.3.33)

y_a^+ is a length scale, and is of the order of the laminar sublayer thickness. It was expected that y_a^+ would decrease with roughness, and $y_a^+ = y_a^+(k^+)$ was determined. The relationship $y_a^+ = y_a^+(k^+, v_w^+)$ still needs to be found experimentally for various values of k, v_w and types of roughness. For the unblown case, the Clauser shift for roughness was confirmed :

$$\frac{u}{u_\tau} = A \log \frac{y u_\tau}{\nu} + B - \Delta(u/u_\tau) \qquad \ldots\ldots\ [3.3.35]$$

ie. roughness did not change the slope of the fully turbulent region, only the intercept on the ordinate.

Presented above are a few papers written on the subject of the transpired boundary layer. There are innumerable papers on this topic : studying each one would result in a great deal of repetition, and possibly be of little use until the skin friction for shear flows with transpiration has been truly established. From this section, it should be clear that the present situation bears close resemblance to the confusion which existed in the 1940's as regards the fully turbulent region of the solid-wall turbulent boundary layer. With the introduction of reliable skin friction transducers, that position was clarified.

CHAPTER 4

A THEORETICAL APPROACH TO THE TURBULENT BOUNDARY LAYER WITH TRANSPIRATION

4.1 Introduction

The analysis follows the classical treatment by Prandtl for the boundary layer on a flat plate. For the turbulent shear layer, the Prandtl momentum transfer theory is considered and is modified by introducing the Van Driest damping factor. This technique is used to extend the analysis to include transpiration and pressure gradient. For the fully turbulent region, intermittency is introduced into the transport equation.

It was felt that more information regarding the boundary layer could be obtained following this type of analysis than using a potential flow solution. Knowledge with respect to skin friction, boundary layer growth and intermittency became available, and the analysis could be extended to include heat transfer and compressible flows.

4.1.1 Definition of parameters featured in turbulent flow analysis

One of the most important quantities in any analysis of this type is τ_w, the shear stress at the wall. In non-dimensional form, τ_w appears in the local skin friction coefficient, c_f

$$c_f = \frac{\tau_w}{\rho u_\infty^2} \qquad \ldots\ldots\ [4.1.1]$$

When analysing the turbulent shear layer, the wall shear velocity is invariably the velocity scale. By definition,

$$u_*^2 = \frac{\tau_w}{\rho} \qquad \ldots\ldots\ldots [4.1.2]$$

$$u_\tau = u_e\sqrt{\frac{c_f}{2}} \qquad \ldots\ldots\ldots [4.1.3]$$

The thickness of the boundary layer is denoted by δ. $y \to \delta$ as $du/dy \to 0$. A more practical definition is

$$y = \delta \quad \text{when } u = 0{,}99 \qquad \ldots\ldots [4.1.4]$$

Thus $$u_e = 0{,}99U_\infty \qquad \ldots\ldots\ldots [4.1.5]$$

The displacement thickness, δ^*, is the mass flow deficit which occurs in the boundary layer owing to the reduced velocity near the surface :

$$\rho u\,\delta^* = \int_0^\delta \rho(u_e - u)\,du$$

$$\frac{\delta^*}{c} = \int_0^1 \left(1 - \frac{u}{u_e}\right)\left(\frac{x}{c}\right) \qquad \ldots\ldots\ldots [4.1.6]$$

A deficiency in momentum in the boundary layer may be expressed as a momentum thickness, θ:

$$\rho u_e^2\theta = \int_0^\delta \rho u(u_e - u)\,dy$$

$$\frac{\theta}{c} = \int_0^1 \frac{u}{u_e}\left(1 - \frac{u}{u_e}\right)\left(\frac{x}{c}\right) \qquad \ldots\ldots\ldots [4.1.7]$$

Note that the upper integrated limit is given here as δ, but is more correctly ∞.

The ratio of displacement to momentum thickness, H, is a very useful shape factor,*

$$H = \delta^*/\theta \qquad \ldots\ldots\ldots [4.1.8]$$

* see Addendum for further explanation.

4.2 The Continuity and Momentum Equations

The derivation of the Prandtl boundary layer equations for an incompressible, newtonian fluid is well known (see Schlichting, 1968).

Continuity : $$\frac{\delta \bar{u}}{\delta x} + \frac{\delta \bar{v}}{\delta y} = 0 \qquad \ldots\ldots [4.2.1]$$

Momentum : $$\bar{u}\frac{\delta \bar{u}}{\delta x} + \bar{v}\frac{\delta \bar{u}}{\delta y} = u_e \frac{du_e}{dx} + \frac{1}{\rho}\frac{\delta}{\delta y}(\mu \frac{\delta \bar{u}}{\delta y} - \rho\overline{u'v'}) \qquad [4.2.2]$$

The bar denotes a time based average quantity, and is assumed in the following equations.

At the edge of the boundary layer :

$$u_e \frac{du_e}{dx} = -\frac{1}{\rho}\frac{dp}{dx} \qquad \ldots\ldots [4.2.3]$$

4.3 Formulation for the Reynolds Stress

To solve equation [4.2.2], it is necessary to relate the Reynolds stress, $\rho\overline{u'v'}$ to the mean velocity. Following Schlichting (1968), a formulation analogous to the laminar shear stress is assumed :

$$\tau_t = \rho\varepsilon\frac{\delta \bar{u}}{\delta y} \qquad \ldots\ldots [4.3.1]$$

and then substitute Prandtl's momentum transfer theory for the eddy kinematic viscosity :

$$\varepsilon = l^2\left(\frac{\delta \bar{u}}{\delta y}\right) \qquad \ldots\ldots [4.3.2]$$

where $l = \kappa y$ $\ldots\ldots [4.3.3]$

This approach leads to a useful velocity distribution for the fully turbulent region. Near the wall the profile is linear. See Grimson (1971) for the derivation of [4.3.4] and [4.3.5].

Laminar sublayer : $u^+ = y^+$ ..... [4.3.4]

Fully turbulent region : $u^+ = \frac{1}{\kappa} \ln y^+ + B$ ..... [4.3.5]

The Buffer or Blending region is not predicted.

Van Driest (1956) derived a continuous velocity and shear distribution by modifying the mixing length. By considering Stokes flow (ie. an infinite plate oscillating sinusoidally parallel to itself).

The modified mixing length became :-

$$l = \kappa y[1 - \exp(-y/A)] \quad \text{..... [4.3.6]}$$

Clearly, as y increases, the exponential term decreases, and $l \to \kappa y$, as before, for the fully turbulent region.

Using [4.3.6], [4.3.2] and [4.3.1],

$$\tau_t = -\rho\overline{u'v'} = \rho\kappa^2 y^2[1 - \exp(-y/A)]^2 \left|\frac{\delta u}{\delta y}\right| \frac{\delta u}{\delta y} \quad \text{..... [4.3.7]}$$

A is the Van Driest damping length, dependent on the turbulence intensity and kinematic viscosity of the flow. It was determined experimentally, and in non-dimensional form, $A^+ = 26$ for $\kappa = 0{,}4$.

$$\tau = \tau_l + \tau_t \quad \text{..... [4.3.8]}$$

$$\tau = \mu\frac{\delta u}{\delta y} + \rho\kappa^2 y^2[1 - \exp(-y/A)]^2 \left|\frac{\delta u}{\delta y}\right| \frac{\delta u}{\delta y} \quad \text{..... [4.3.9]}$$

Cebeci (1970b) modified A to include injection and pressure gradient :

$$A^+ = \frac{A u_\tau^*}{\nu} \quad \text{..... [4.3.10]}$$

Modified, $A^+ = 26\{-\frac{p^+}{v_w^+}[\exp(11,8v_w^+) - 1] + \exp(11,8v_w)\}^{-\frac{1}{2}}$ ..... [4.3.11]

where $p^+ = -\frac{dp}{dx}\frac{\nu}{\rho(u_w^*)^3}$; $v_w^+ = \frac{v_w}{u_w^*}$ ..... [4.3.12]

4.4 Eddy Viscosity Formulation for the Fully Turbulent Region

In turbulent boundary layers, the potential core often extends well into the boundary layer. A pictorial representation of the instantaneous layer is depicted below :-

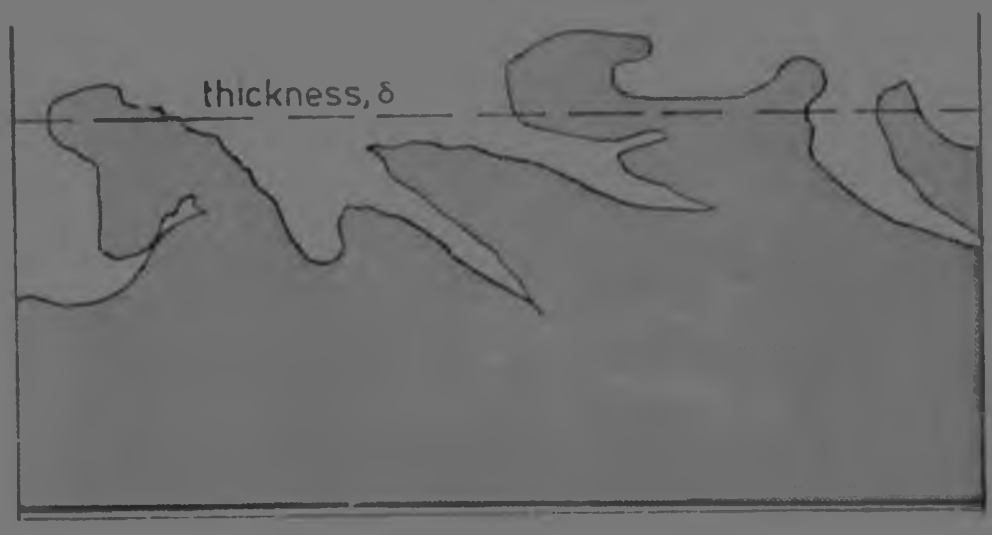


FIG 4.1 : SKETCH OF THE INSTANTANEOUS TURBULENT BOUNDARY LAYER, SHOWING THE EXTENSION OF THE POTENTIAL CORE BELOW THE AVERAGE THICKNESS

If the Reynolds stress in the potential core is zero, then the intermittent extension of this 'clean' flow into the boundary layer must influence the shear distribution across the outer turbulent region. Sarnecki postulated that γ, the intermittency, was the fraction of total time for which the flow was turbulent at a fixed distance from the plate. γ ranges from 0 to 1, where $\gamma = 1$ inside the continuously turbulent boundary layer, and $\gamma \to 0$ at the edge of the layer.

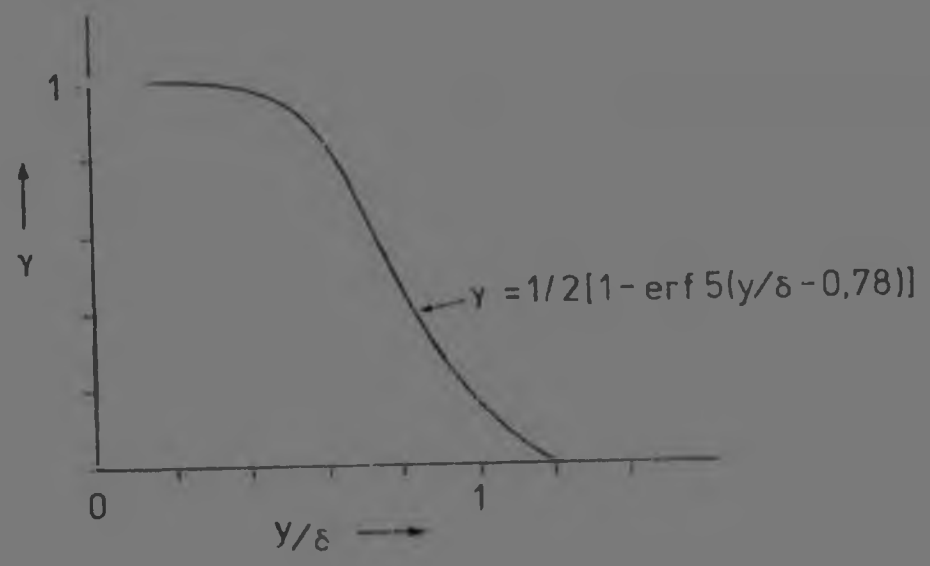


FIG 4.2 : INTERMITTENCY DISTRIBUTION ACROSS A TURBULENT BOUNDARY LAYER (CEBECI, 1974)

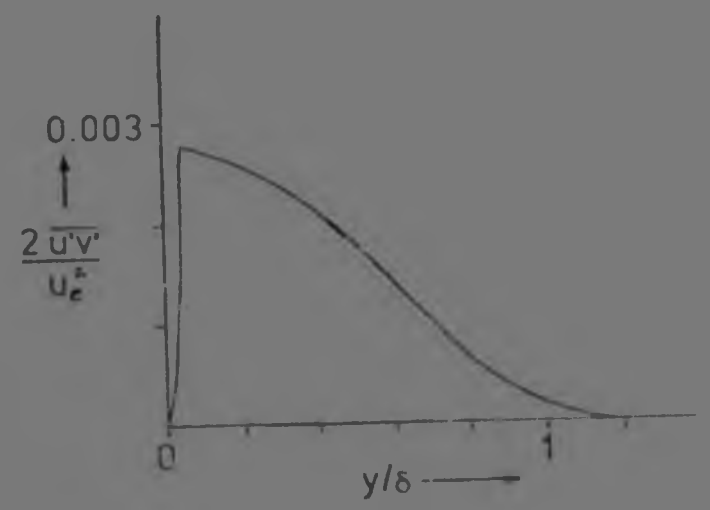


FIG 4.3 : REYNOLDS STRESS ACROSS THE BOUNDARY LAYER FOR A SMOOTH FLAT PLATE, ZERO PRESSURE GRADIENT

Intermittency and Reynolds stress were determined experimentally with hot wire anemometry by Klebanoff (Cebeci 1974, Schlichting 1968).

Clearly, even the modified mixing length theory cannot predict ε across the entire boundary layer. For in the outer region, ε must decrease, and experiments have shown that the decrease follows the intermittency curve, as could be expected. The eddy viscosity in the outer region was given as :

$$\varepsilon_0 = 2\left[\int_0^{\infty} (u_e - u)dy\right] \times \tfrac{1}{2}[1 - \text{erf } 5(y/\delta - 0{,}78)] \quad [4.4.1]$$

The intermittency curve may be approximated (Cebeci 1974) by :

$$\gamma \quad \frac{1}{[1 + 5{,}5(y/\delta)^6]} \qquad \ldots\ldots\ldots [4.4.2]$$

γ is a constant, with a value between 0,016 and 0,02. In the present work, γ = 0,0168 is used. In the programme, the turbulent transport eddy viscosity was used until it was equal to the outer eddy viscosity. From this point outwards, ε_0 was used.

[4.4.1] may be writte

$$\varepsilon_0 = \alpha u_e \delta^* \gamma \qquad \ldots\ldots\ldots [4.4.3]$$

4.5 Boundary Conditions

The boundary conditions for the turbulent shear layer are :-

$$u(x,0) = 0 \qquad \ldots\ldots\ldots [4.5.1]$$

$$v(x,0) = 0 \quad \text{or} \quad v_w \text{ with mass transfer} \qquad \ldots\ldots [4.5.2]$$

$$\lim_{y \to \infty} u(x,y) = u_e(x) \qquad \ldots\ldots\ldots [4.5.3]$$

4.6 The Transformed Momentum and Related Equations : A Summary

Only the transformed equations are given here. Details of the transformation appear in Appendix A1. ϕ is a transformed, non-dimensionalized stream function.

Momentum :

$$[(1 + \varepsilon^+)\phi'']' + (\phi + \eta)\phi'' - \beta(\phi' + 2)\phi' = 2\xi[(\phi' + 1)\frac{\delta\phi'}{\delta\xi} - \phi''\frac{\delta\phi}{\delta\xi}] \quad \ldots\ldots [4.6.1]$$

Boundary conditions :

$$\phi(\xi,0) = 0 \quad \text{for no transpiration} \quad \ldots\ldots [4.6.2a]$$

$$\phi(\xi,0) = -\frac{1}{(2\xi)^{\frac{1}{2}}}\int_0^{\xi}\frac{v_w}{\mu\rho_w}d\xi \quad \text{with } v_w \neq 0 \quad \ldots\ldots [4.6.2b]$$

$$\phi'(\xi,0) = -1 \quad \ldots\ldots [4.6.3]$$

$$\lim_{\eta\to\eta_\infty} \phi'(\xi,\eta) = 0 \quad \ldots\ldots [4.6.4]$$

Eddy viscosity equations :

$$\varepsilon_i = \kappa^2(2\xi)^{\frac{1}{2}}\eta^2\frac{\phi''}{\rho}[1 - \exp\{-\eta(\frac{(2\xi)^{\frac{1}{2}}}{\mu}\cdot\phi_w'')^{\frac{1}{2}}/A^+\}]^2 \quad \ldots [4.6.5]$$

$$\varepsilon_o = \alpha.[-\frac{(2\xi)^{\frac{1}{2}}}{\rho}\int_0^{\eta_\infty}\phi'd\eta] \times [1 + 5{,}5(\frac{\eta}{\eta_\infty})^6]^{-1} \quad \ldots\ldots [4.6.6]$$

Boundary layer parameters :

$$\sigma_f = \mu(\frac{2}{\xi})^{\frac{1}{2}}\phi''(\xi,0) \quad \ldots\ldots [4.6.7]$$

$$\delta^* = -\frac{(2\xi)^{\frac{1}{2}}}{\rho u_e}\int_0^{\eta_\infty}\phi'(\xi,\eta)d\eta \quad \ldots\ldots [4.6.8]$$

$$\theta = -\frac{(2\xi)^{\frac{1}{2}}}{\rho u_e}\int_0^{\eta_\infty}\phi'(\xi,\eta)[1 + \phi'(\xi,\eta)]d\eta \quad \ldots\ldots [4.6.9]$$

CHAPTER 5

COMPUTER SOLUTION OF THE MOMENTUM EQUATION

5.1 Introduction

If a generalised computer programme is developed and proved with respect to reliable experimental results, it becomes possible to calculate such parameters as boundary layer thickness, skin friction and heat transfer. Such a programme could be simple, e.g. for the case of a flat plate, and may be made more versatile to include transition, pressure gradient, roughness, transpiration, heat transfer, compressible flow, axisymmetric flow and three dimensional flow.

A finite difference technique, rather than a finite element method, is used in this dissertation to solve equation [4.6.1]. Because of the well known stability problems experienced with explicit methods, an implicit scheme was selected, with its attendant requirement to linearise the equation. In this chapter the linearisation and matrix solution are discussed.

5.2 Linearisation of the Momentum Equation

Linearisation is achieved by allowing those terms which make the equation non-linear to be set to values known from a previous station or interation. Clearly an iterative process is necessary, in which the latest value approaches that of the previous iteration. When linearising, care must be taken to retain at least one term of each derivative. The subscript o here denotes a previously known quantity :-

$$[(1 + \epsilon^{+})_{o}\phi'']' + (\phi_{o} + \eta)\phi'' - \phi'B(\phi_{o}' + 2) = 2\xi[(\phi_{o}' + 1)\frac{\delta\phi'}{\delta\xi} - \phi_{o}''\frac{\delta\phi}{\delta\xi}] \quad \ldots\ldots\ldots [5.2.1]$$

5.3 The Finite Difference Grid

Cebeci (1974) suggested a grid in which the step lengths normal to the wall were very small, near the wall, ie. in the region of rapid change in velocity, and increasing in size towards the edge. He proposed a grid of the form :-

$$\Delta n_{i} = K.\Delta n_{i-1} \quad \ldots\ldots\ldots [5.3.1]$$

Δn_{i} is the general step length, and for $K>1$, this step length is larger than the previous step. If the first step length is h, the distance to the ith grid point is :-

$$n_{i} = h\frac{K^{i-1} - 1}{K - 1} \quad \ldots\ldots\ldots [5.3.2]$$

The exponential growth in grid spacing ties up with the turbulent velocity profile.

An alternate expression for the ith grid spacing is :-

$$\Delta n_{i} = K^{i-3}.h \quad \ldots\ldots\ldots [5.3.3]$$

The programme was written in a manner to allow variable step length in the streamwise direction. This may be a completely random step length. Because the programme "marches" in the x-direction when solving, the grid points in this direction were called stations, and are denoted by, e.g. the nth station.

The ordinate was divided into points or steps, denoted by i. Note that the first η value, ie. at the wall, is point $i = 1$, therefore $\eta_{1} = 0$.

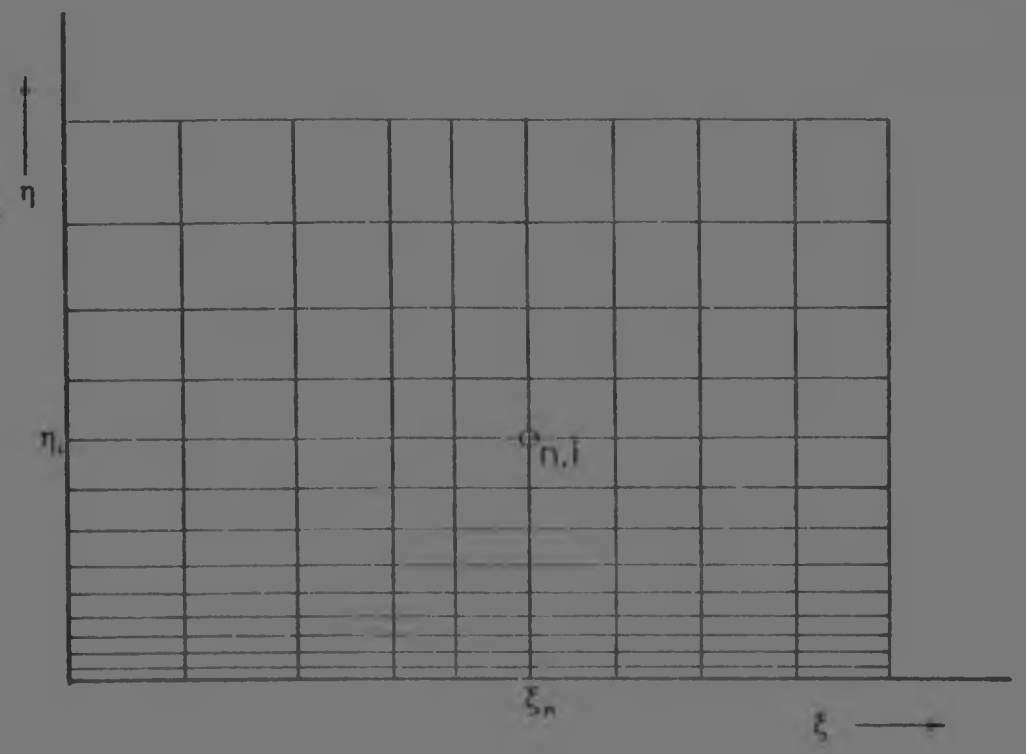


FIG 5.1 : THE FINITE DIFFERENCE GRID FOR k = 1,2 AND h = 1,5

5.4 The Momentum Equation in Finite Difference Form

Equation [5.2.1] is given with the subscripts as used in the programme :-

$$[(1 + \varepsilon^{+}_{n,i_0})\phi''_{n,i}]' + (\phi_{n,i_0} + \eta_i)\phi''_{n,i} - \phi'_{n,i}\cdot\xi_n(\phi'_{n,i_0} + 2)$$
$$= 2\xi_n[(\phi'_{n,i_0} + 1)\frac{\delta\phi'}{\delta\xi}\Big|_{n,i} - \phi''_{n,i_0}\frac{\delta\phi}{\delta\xi}\Big|_{n,i}] \quad \ldots [5.4.1]$$

By taking the derivative of the first term at this stage $d\varepsilon^{+}/dy$ would be introduced, which may be determined numerically, but with the attendant error inherent in any such calculation, with the added difficulty that ε was not a continuous function. $\phi'''_{n,i}$ would also appear. The derivative was solved implicitly in the final equation by treating the term as a separate function, say g. This is why the term $(1 + \varepsilon^{+})_{n,i-1_0}$ and at $(n,i + 1)$ feature in the following equation. Values of ϕ are known at n-1, n-2 and o. All these terms were kept on the right hand side, while

those in n,i were retained on the left hand side. The capital letters denote constants based on step size, and are defined in Appendix A2.

$$\phi_{n,i-3}\{A.X1.(1+\varepsilon_3^+)_{n,i-1}\}$$

$$+\phi_{n,i-2}\{A.X2.(1+\varepsilon_0^+)_{n,i-1}+B.D.(1+\varepsilon_0^+)_{n,i}+(\phi_{0_{n,i}}+\eta_i)D$$
$$-\beta.A.(\phi'_{0_{n,i}}+2)-2\xi_n(\phi'_{0_{n,i}}+1).A.N\}$$

$$+\phi_i\{A.X3.(1+\varepsilon_0^+)_{n,i-1}+B.E.(1+\varepsilon_3^+)_{n,i}+C.X4.(1+\varepsilon_0^+)_{n,i+1}$$
$$+E.(\phi_{0_{n,i}}+\eta_i)-\beta.B.(\phi'_{0_{n,i}}+2)-2\xi_n(\phi'_{0_{n,i}}+1)N.B$$
$$+2\xi_n\phi''_{0_{n,i}}.N\}$$

$$+\phi_{i+1}\{B.F.(1+\varepsilon^+)_{n,i}+C.X5.(1+\varepsilon_0^+)_{n,i+1}+F.(\phi_{0n,i}+\eta_i)$$
$$-\beta.C.(\phi'_{0_{n,i}}+2)-2\xi_n(\phi'_{0_{n,i}}+1).N.C\}$$

$$+\phi_{i+2}\{C.X6.(1+\varepsilon_0^+)_{n,i+1}\}$$

$$=2\xi_n\{(\phi'_{0_{n,i}}+1)[D.\phi'_{n-2,i}+M\phi'_{n-1,i}]-\phi''_{0_{n,i}}[L.\phi_{n-2,i}+M\phi_{n-1,i}]\}$$

..... [5.4.2]

Lumping the coefficients into single constants reduces [5.4.2] to :-

$$\phi_{n,i-2}.A_i+\phi_{n,i-1}.B_i+\phi_{n,i}.C_i+\phi_{n,i+1}.D_i+\phi_{n,i+2}.E_i=F_i$$

..... [5.4.3]

Remembering that $i=1$ denoted $\eta=0$, a system of linear simultaneous equations could be written starting with $i=3$. If N is the number of η steps, a total of N-4 equations can

be set up (because [5.4.3] must end with N-2). There are thus N unknowns and N-4 equations. Using boundary conditions, ϕ_1, ϕ_2, ϕ_{N-1} and ϕ_N were determined.

$$\phi_{n,1}A_3 + \phi_{n,2}B_3 + \phi_{n,3}C_3 + \phi_{n,4}D_3 + \phi_{n,5}E_3 = F_3$$

$$0 \qquad \phi_{n,2}A_4 + \phi_{n,3}B_4 + \phi_{n,4}C_4 + \phi_{n,5}D_4 + \phi_{n,6}E_4 = F_4$$

$$0 \qquad 0 \qquad \phi_{n,3}A_5 + \phi_{n,4}B_5 + \phi_{n,5}C_5 + \phi_{n,6}D_5 + \phi_{n,7}E_5 = F_5$$

$$\vdots \qquad\qquad\qquad\qquad \vdots$$

$$\phi_{n,N-4}A_{N-2} + \phi_{n,N-3}B_{N-2} + \phi_{n,N-2}C_{N-2} + \phi_{n,N-1}D_{N-2} + \phi_{n,N}E_{N-2} = F_{N-2} \qquad \ldots\ldots [5.4.4]$$

Because $\phi_{n,1}$ and $\phi_{n,2}$ are known from boundary conditions, they are taken to the right hand side :-

$$\left.\begin{aligned} \phi_{n,3}C_3 + \phi_{n,4}D_3 + \phi_{n,5}E_3 &= F_3 - \phi_{n,1}A_3 - \phi_{n,2}B_3 \\ \phi_{n,3}B_4 + \phi_{n,4}C_4 + \phi_{n,5}D_4 + \phi_{n,6}E_4 &= F_4 - \phi_{n,2}A_4 \end{aligned}\right\} \qquad [5.4.5]$$

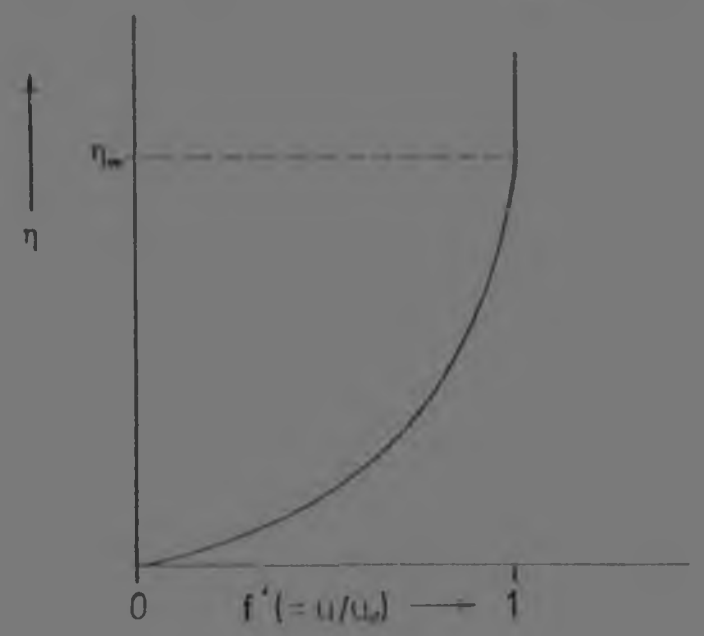


FIG 5.2 : SKETCH OF VELOCITY PROFILE IN TRANSFORMED CO-ORDINATES

From Fig 5.2 it is seen that as $\eta \to \eta_\infty$, $f'(\xi,\eta) \to 1$ and therefore $\phi'(\xi,\eta) \to 0$.

Equation [4.6.4] states that

$$\lim_{\eta \to \eta_\infty} \phi'(\xi,\eta) = 0 \qquad \ldots\ldots\ldots [5.4.6]$$

If $N-2$, $N-1$ and N are in this region, then using a simple finite difference approximation :-

$$\phi'_{N-1} = \frac{\phi_N - \phi_{N-1}}{\eta_N - \eta_{N-1}} = 0 \qquad \ldots\ldots\ldots [5.4.7]$$

$$\therefore \phi_N = \phi_{N-1} \qquad \ldots\ldots\ldots [5.4.8]$$

Similarly :-

$$\phi'_{N-1} = \frac{\phi_N - \phi_{N-2}}{\eta_N - \eta_{N-2}} = 0 \qquad \ldots\ldots\ldots [5.4.9]$$

$$\therefore \phi_N = \phi_{N-1} = \phi_{N-2} \qquad \ldots\ldots\ldots [5.4.10]$$

The $N-3$ equation is :-

$$A_{N-3}\phi_{n,N-5} + B_{N-3}\phi_{n,N-4} + C_{N-3}\phi_{n,N-3} + \phi_{n,N-2}(D_{N-3} + E_{N-3}) = F_{N-3} \qquad \ldots\ldots\ldots [5.4.11]$$

and the $N-2$ equation (last) is :-

$$A_{N-2}\phi_{n,N-4} + B_{N-3}\phi_{n,N-3} + \phi_{n,N-2}(C_{N-2} + D_{N-2} + E_{N-2}) = F_{N-2} \qquad \ldots\ldots\ldots [5.4.12]$$

The general equation may be stated :-

$$[A]\{\phi\} = \{B\} \quad i=3 \text{ to } i=N-2 \qquad \ldots\ldots\ldots [5.4.13]$$

5.5 The Finite Difference Molecule

The general finite difference molecule is shown in Fig 5.3

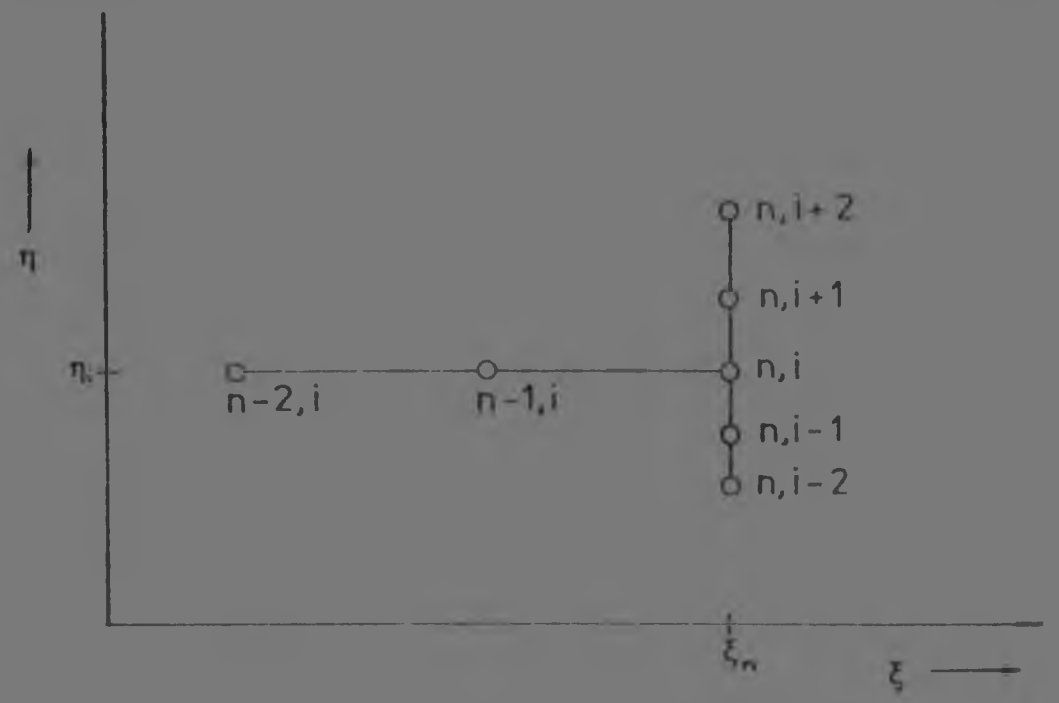


FIG 5.3 : THE FINITE DIFFERENCE MOLECULE

To solve for ϕ at station n, it is necessary to know the values of ϕ, ϕ' and ϕ'' at stations $n-2$ and $n-1$. Two profiles were therefore required to start the solution at the third station. The programme then marched to $n+1$ and used $n-1$ and n to solve for ϕ at $n+1$, and so on. For the first solution at say n, the values on the right hand side, denoted by o, were substituted by the values at $n-1$. Similarly in generating ε. The iterative process was based on the convergence of $\phi''_{n,1}$ and $\phi''_{0_{n,1}}$ and $\delta_n{}^*$ and $\delta_0{}^*$.

To economise on core storage on the computer, only four vectors for ϕ, ϕ', ϕ'' and ε' were used. Solutions at $n-2$, $n-1$ and n were stored in the first three vectors; the present iteration, o, in the fourth. The first three rotated cyclicly. If the vectors are denoted by V_1, V_2 and V_3, the solutions were stored :-

$n=1$, V_1

$n=2$, V_2

o, V_4

Once convergence was achieved, $V_4 \rightarrow V_3$ and print/plot V_1 could be overwritten and the solution march to $n=4$

$n=2$, V_2

$n=3$, V_3

o V_4

After convergence, $V_4 \rightarrow V_3$, print/plot, and delete V_2

$n=3$, V_3

$n=4$ V_1

o V_4

After convergence, $V_4 \rightarrow V_3$, print/plot, etc.

A tremendous saving was possible when storing matrix [A] because it was banded. It had two upper and two lower co-diagonals. Typically, the banded matrix required 500 storage locations, compared with 10 000 for full square matrix storage. In double precision, this is equivalent to 80 k bytes.

$n=1$, V_1

$n=3$, V_2

o, V_4

Once convergence was achieved, $V_4 \rightarrow V_3$ and print/plot V_1 could be overwritten and the solution march to $n=4$

$n=2$, V_2

$n=3$, V_3

o V_4

After convergence, $V_4 \rightarrow V_1$, print/plot, and delete V_3

$n=3$, V_3

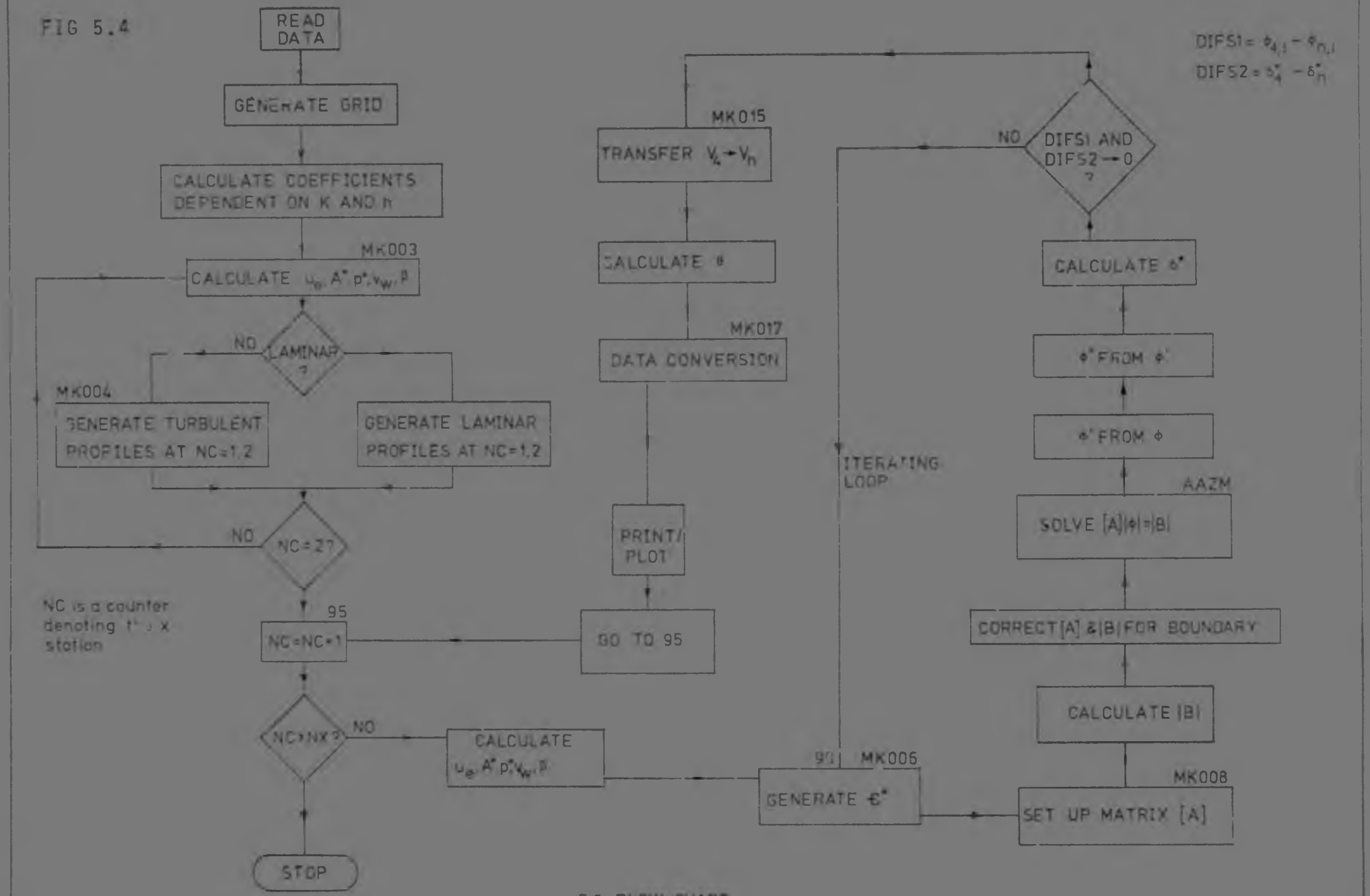
$n=4$ V_1

o V_4

After convergence, $V_4 \rightarrow V_2$, print/plot, etc.

A tremendous saving was possible when storing matrix [A] because it was banded. It had two upper and two lower co-diagonals. Typically, the banded matrix required 500 storage locations, compared with 10 000 for full square matrix storage. In double precision, this is equivalent to 80 k bytes.

FIG 5.4



5.6 FLOW CHART

5.7 Discussion of Various Features of the Programme

5.7.1 Initial profiles

As stated above, profiles at $n=1$ and $n=2$ were required to start the solution. These were generated in MK001L (laminar) or MK004 (turbulent) - see Fig 5.5. Distance along the abcissa was used as a criterion for laminar or turbulent flow. Various stability techniques, critical Reynolds numbers and shape factors have been suggested (Cebeci 1974). However, these are often limited, and not sufficiently accurate, e.g. critical Reynolds number is for flat plate flow with zero pressure gradient, and spans a large range ($3{,}5 \times 10^5$ to 10^6).

If $\varepsilon=0$, the solution is laminar, and from a given ξ station, $\varepsilon>0$ and the programme entered the transition and hence turbulent solutions.

The laminar profile was generated from an equation given by Grimson (1971) :-

$$\frac{u}{U_\infty} = f(y/\delta) = f(\bar{y}) \qquad \ldots\ldots\ldots [5.7.1]$$

If a fourth order polynomial is used, a pressure gradient may be included :-

$$\frac{u}{U_\infty} = A_0 + A_1\bar{y} + A_2\bar{y}^2 + A_3\bar{y}^3 + A_4\bar{y}^4 \qquad \ldots\ldots\ldots [5.7.2]$$

A pressure gradient related shape factor was introduced :-

$$\Lambda = \frac{\delta^2}{\nu}\cdot\frac{du}{dx} \qquad \ldots\ldots\ldots [5.7.3]$$

$$\frac{u}{U_e} = \bar{y}(2 - 2\bar{y}^2 + \bar{y}^3) + \frac{\Lambda}{6}\bar{y}(1 - 3\bar{y} + 3\bar{y}^2 - \bar{y}^3) \qquad \ldots [5.7.4]$$

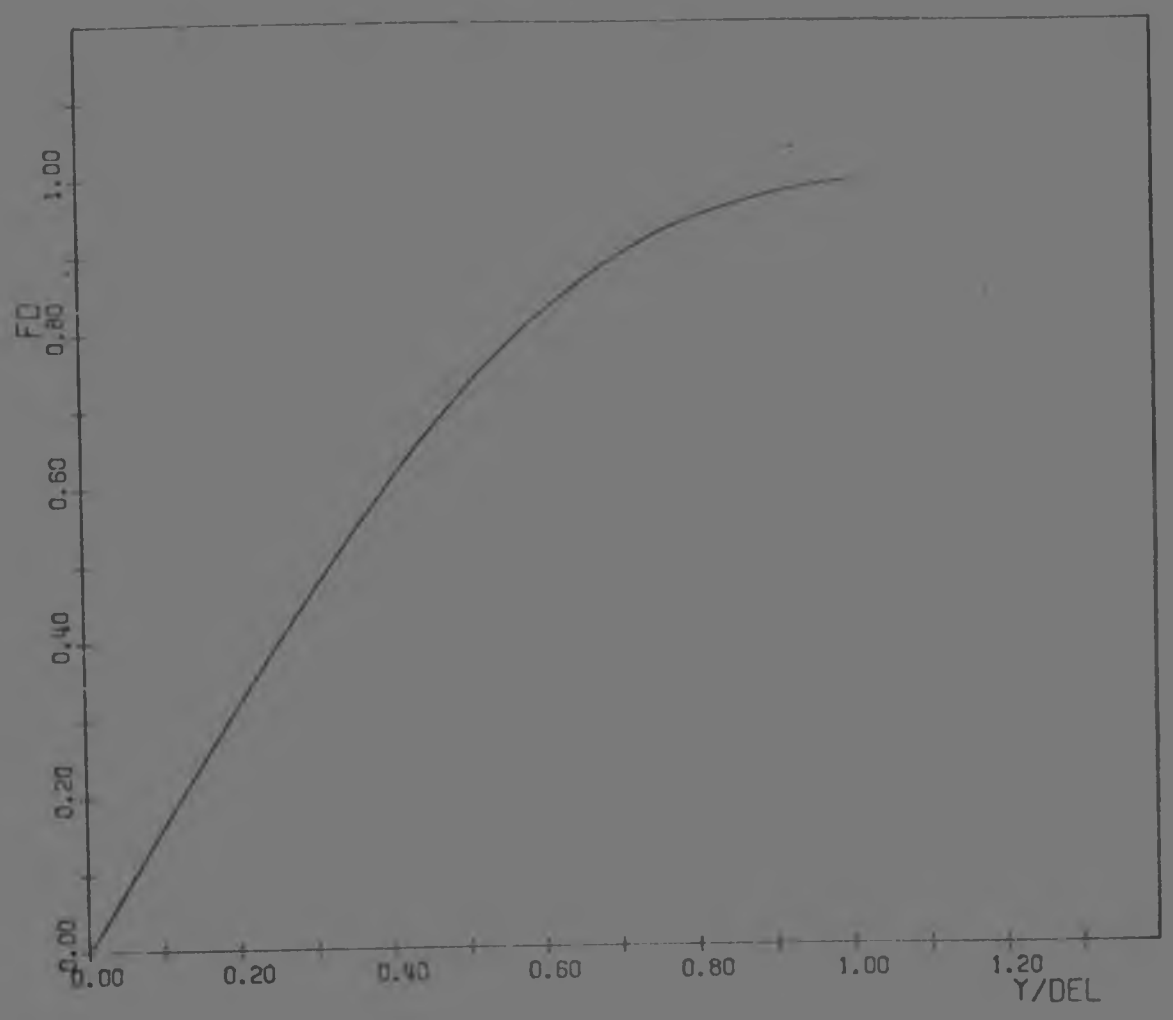


FIG 5.5 LAMINAR INPUT PROFILE

The turbulent profile was generated using Van Driest's mixing length theory. One difficulty here was that the edge of the boundary layer was over-estimated, and pressure gradient was not included. However, the programme would obtain the correct profile at $n=6$ after some iteration. In developing this subroutine, it was found that the results were significantly improved if the unequal, exponential type η grid was used. See Fig 5.6 for equal step length, and Fig 5.7 for exponential grid, using the well known semi-log plot. Fig 5.7 is reproduced on simple non-dimensionalised axes in Fig 5.8. The dashed lines on Fig 5.7 are for :-

$$u^+ = y^+ \qquad \ldots\ldots\ldots [5.7.5]$$

$$\text{and} \quad u^+ = 5{,}757 \log y^+ + 5{,}24 \qquad \ldots\ldots\ldots [5.7.6]$$

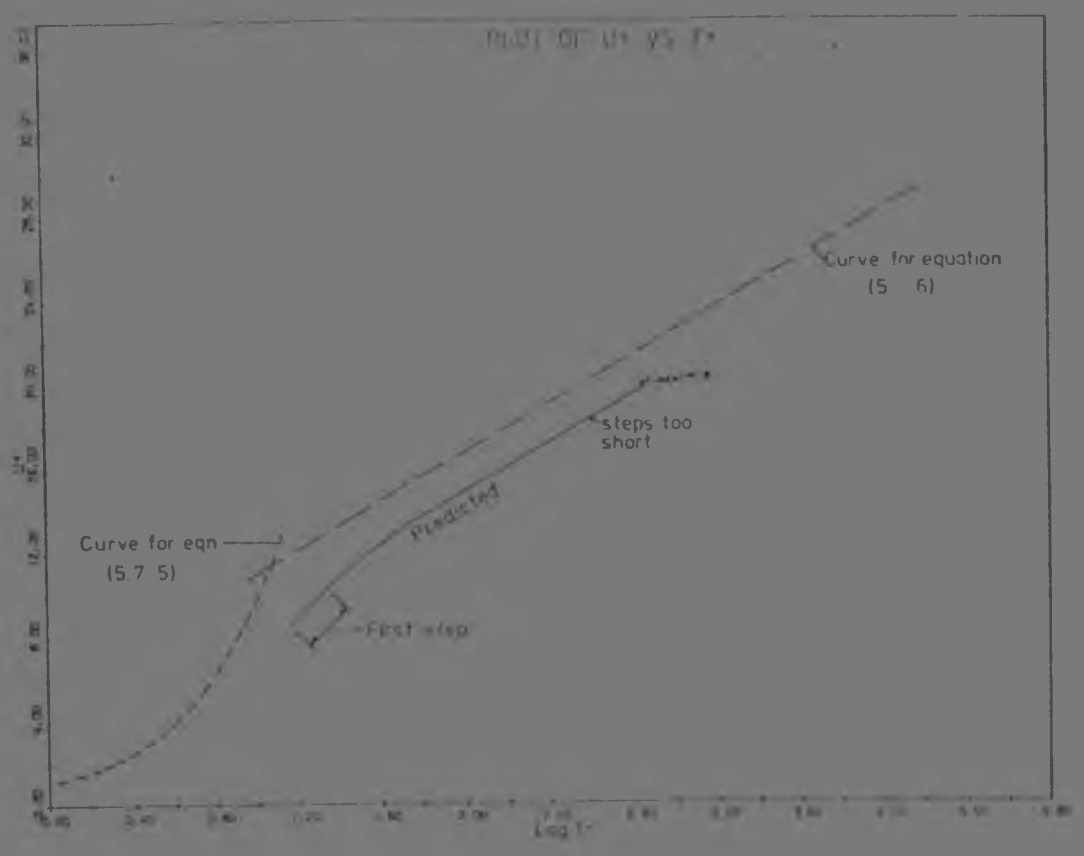


FIG 5.6 : TURBULENT PROFILE GENERATED WITH
EQUAL STEP LENGTH

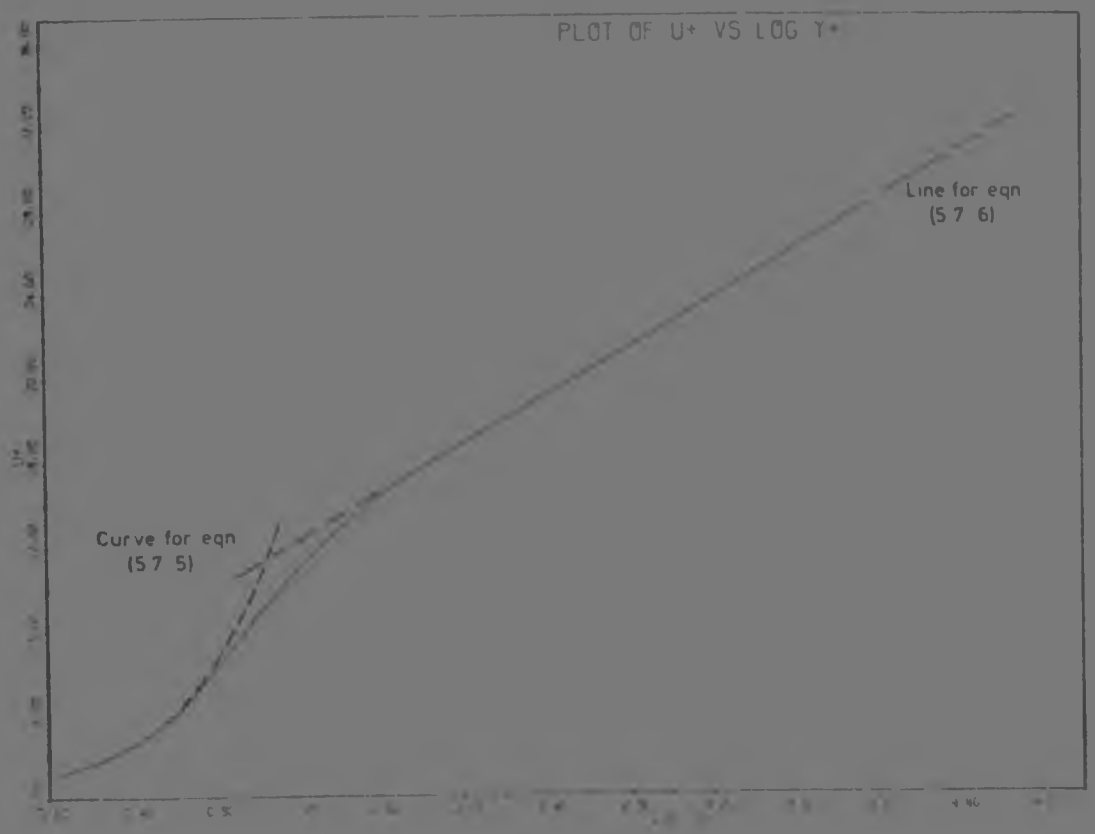


FIG 5.7 : TURBULENT PROFILE GENERATED WITH
UNEQUAL STEP LENGTH

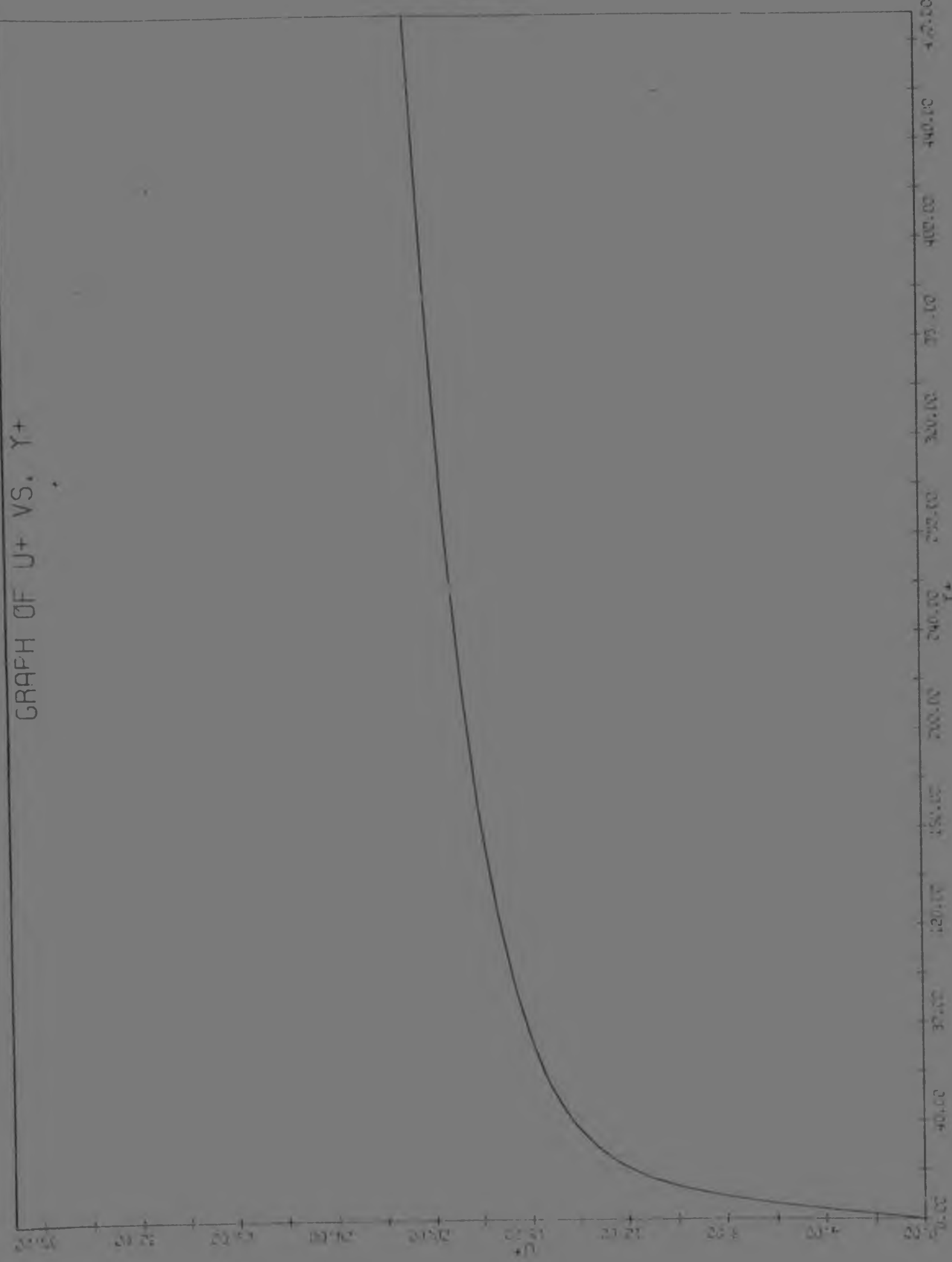


FIG 5.8 : TURBULENT PROFILE GENERATED WITH UNEQUAL STEP LENGTH

Equation [3.3.33], with $v_w^+ = 0$, simplified to that derived by Van Driest (1956) :-

$$\frac{du^+}{dy^+} = \frac{2dy^+}{1 + \sqrt{1 + 4\kappa^2 y^{+2}[1 - \exp(-y^+/A^+)]^2}} \quad \ldots\ldots [5.7.7]$$

by integrating this expression, $u_i^+ = \int_0^{y_i^+} f(y^+)$. This was performed numerically in subroutine MK004. u_i^+ had to be converted to u/u_e, ie. u_w^+ was required. c_f was estimated in subroutine TAUF from the simplified equation

$$c_f = \frac{0,0595}{Re_x^{1/5}} \quad \ldots\ldots\ldots [5.7.8]$$

In both laminar and turbulent profile generators, it was necessary to convert $u/u_e (=f')$ to ϕ', and to calculate ϕ and ϕ''. The edge of the boundary layer was taken to be where $\phi' < 0,0001$.

To obtain δ^* and θ, the profile had to be integrated. This was done by using the trapezoidal rule, which was considered sufficiently accurate because the step length was so small. Note that the experimental profiles were integrated in a similar manner, and for a very coarse grid (20 points compared with 100 for the computer programme) the difference in θ when using Simpson's rule was 1%. A typical equation appears in Appendix F1.

As the injection increased, the shear stress at the wall tends to zero, or even a negative value. However, reverse flow is not thought to occur. The programme was not designed to handle these possibilities. If ϕ'' was obtained from ϕ using Newtons Divided Difference technique at the wall, negative shear was indicated at values of $F \geq 0,005$. This is in accordance with experiment, but resulted in difficulties when calculating u_w^*, and hence also v_w^+ and p^+. The programme was written for a continuous velocity

profile and the condition of no-slip at the wall. Note too that the derivation of A^+ was for very small injection rates, and $y_0^+ = 11,8$ was the value for unblown flat plate flow.

By using a reasonably large initial η step (0,06 compared with values as low as 0,001 suggested by Cebeci (1970a), and calculating ϕ'' from ϕ', the programme remained stable up to values of $F = 0,017$.

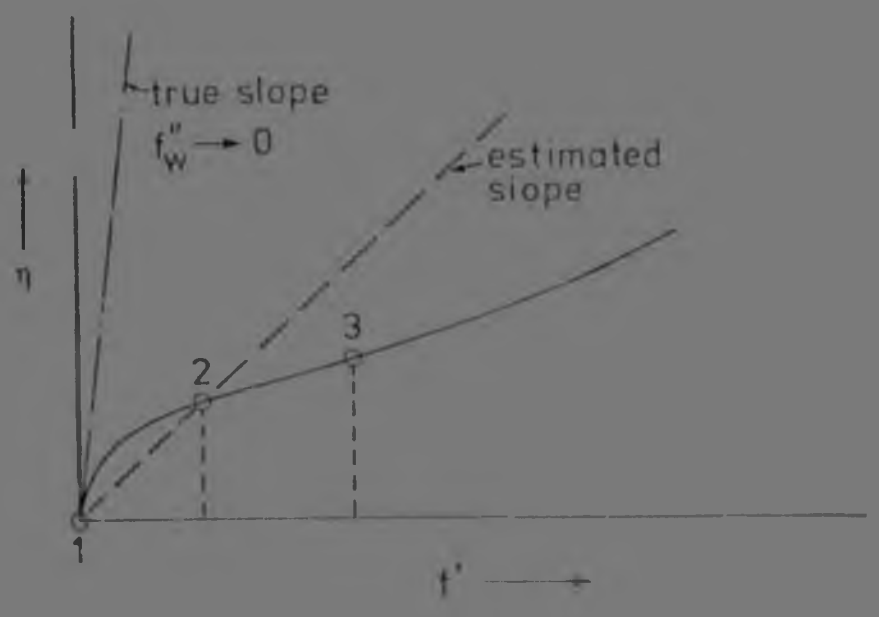


FIG 5.9 : u-VELOCITY PROFILE NEAR THE WALL

The numbers shown in Fig 5.9 denote η grid points. If 2 is outside the point of inflexion, the programme would effectively be unaware of this behaviour. ϕ'' would be predicted to be the dashed line (depending on the finite difference equation). This value is incorrect, but allows real values of u_w^+, v_w^+, p^+ etc. to be calculated. Although these errors are large, the effect of this on the complete solution of [5.4.13] appeared to be very small.

Because this technique produced results which appeared very promising, the loss of accuracy in u_w^*, and hence meaningless c_f for injected flows, was considered unimportant in the present phase of research. As will be pointed out later in Chapter 7, u_w^* as characteristic velocity for injected boundary layers may well require reconsideration.

For zero pressure gradient flat plate flow, c_f predicted by the programme was very close to that experimentally measured and fitted by [5.7.8].

CHAPTER 6

EXPERIMENTAL APPARATUS AND PROCEDURE

6.1 Introduction

The object of the experiments was to obtain a number of mean velocity profiles on a porous plate preceded by a solid plate, ie. to subject a fully developed turbulent profile to injection. The next step was to constrict the lower porous surface, to ascertain whether this made a measurable difference to the profiles. To this end an open circuit wind tunnel with rectangular working section was designed. Three different grades of porous plate were tested.

6.2 The Wind Tunnel

6.2.1 General

The open circuit wind tunnel consisted of a Sirrocco centrifugal fan (see Appendix B1 for the performance curve). Drive was provided by a Siemens A.C. induction motor rated at 22 kW, through three Fenner β type belts. By changing pulleys, the rotational speed of the fan could be varied, resulting in different flow rates and pressures. A flow damper at the fan inlet could be used to vary the flow rate, as could a by-pass at the beginning of the tunnel. This by-pass was only used at start-up (minimize starting load), because a power spectrum measured in the working section produced two additional spikes when the trap door was not fully closed (see 6.4).

The ducts leading to the Working Section were made up of a diffuser, settling chamber and contraction. Screens and honeycomb straightened the flow and decreased the turbulence intensity.



FIG 6.1 : GENERAL VIEW OF WIND TUNNEL SHOWING (1) THE SETTLING CHAMBER, (2) CONTRACTION, (3) ENTRY TO WORKING SECTION, (4) REAR OF INSTRUMENT PANEL (5) RETZ MANOMETER

6 2.2 The working section

A rectangular working section 209 x 496 mm was built. The side walls were made of perspex, the roof and solid floor sections of aluminium. A boundary layer bleed was installed in the floor in the entry section. The plate preceding the porous section was 800 mm long, the leading edge milled to 45^0. This configuration could be altered such that the initial solid plate was 150 mm long. Theoretically a laminar boundary layer would reach the porous plate, but tests were not done with the short plate installed.

A traversing rig (Disa type 55H01) was mounted on slides. The probe could be lowered through a slit in the roof of the working section. The distance of the probe from the wall was measured with a Mitutoyo Dial Gauge. This entire rig was mounted on a separate frame which was isolated from the tunnel to prevent vibration being transmitted to the probe. The traversing rig allowed 4 degrees of freedom.

Fig 6.2 shows the working section and the traversing rig. In the next photograph, Fig 6.3, a close-up of the working section interior is given. In this figure the hot wire probe can be seen mounted above the porous plate. Note that the short plate configuration is depicted.

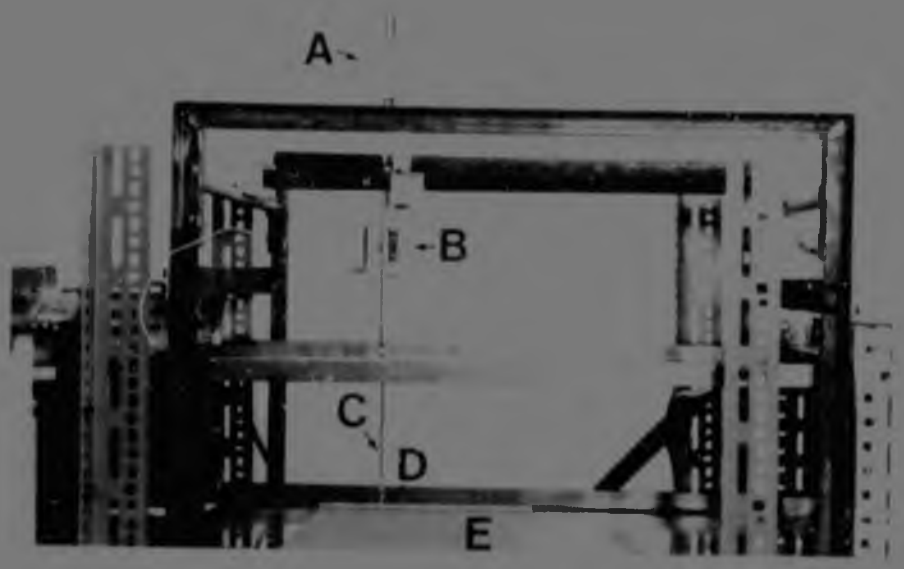


FIG 6.2 : THE WORKING SECTION AND THE TRAVERSING RIG :
(A) DIAL GAUGE, (B) DISA TRAVERSING MECHANISM,
(C) PROBE HOLDER, (D) HOT WIRE PROBE,
(E) POROUS PLATE



FIG 6.3 : INSIDE OF THE WORKING SECTION :(A) ENTRY TO WORKING SECTION, (B) PROBE HOLDER, (C) HOT WIRE PROBE, (D) SHORT LEADING PLATE, (E) POROUS PLATE

6.2.3 Transpiration flow supply

The transpiration or secondary flow was drawn from the laboratory compressed air supply. An Ingersoll-Rand compressor fed two receivers, from which a 50 mm i.d. pipe ducted the air to a pressure regulator (Norgren type AG20). The flow rate was measured with an orifice plate, preceded by an entry length of 30 diameters. The orifice plate was calibrated according to British Standards 1042. A fibre-type filter, supplied by Vokes, was placed in the plenum chamber below the porous plate. The filter removed particles down to 5 microns, as well as grease. The front cover of the plenum chamber had to be removed when changing porous plates. The height of the porous plate was adjusted with screws inside the chamber. The plates were made of sintered bronze by Sintered Products Ltd. of Nottingham, England. Each plate was 6,35 mm thick. The front and rear edges were milled to 45°. Grades E (highly porous) C and A were tested.



FIG 6.4 :
THE WORKING SECTION AND THE PLENUM CHAMBER SHOWN WITH ITS FRONT COVER IN PLACE

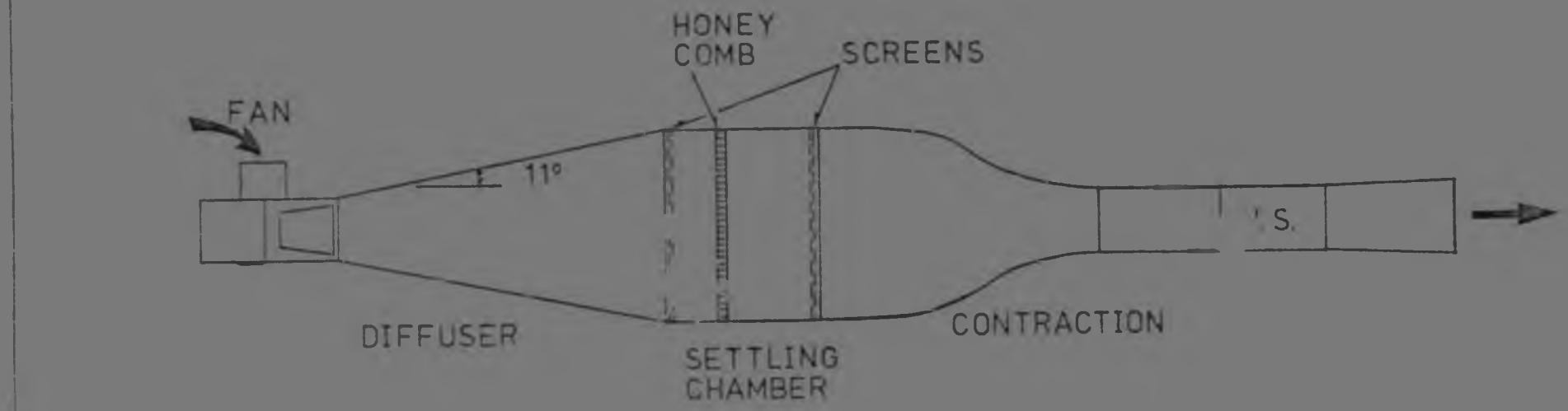


FIG 6.5 : PLAN VIEW OF THE WIND TUNNEL

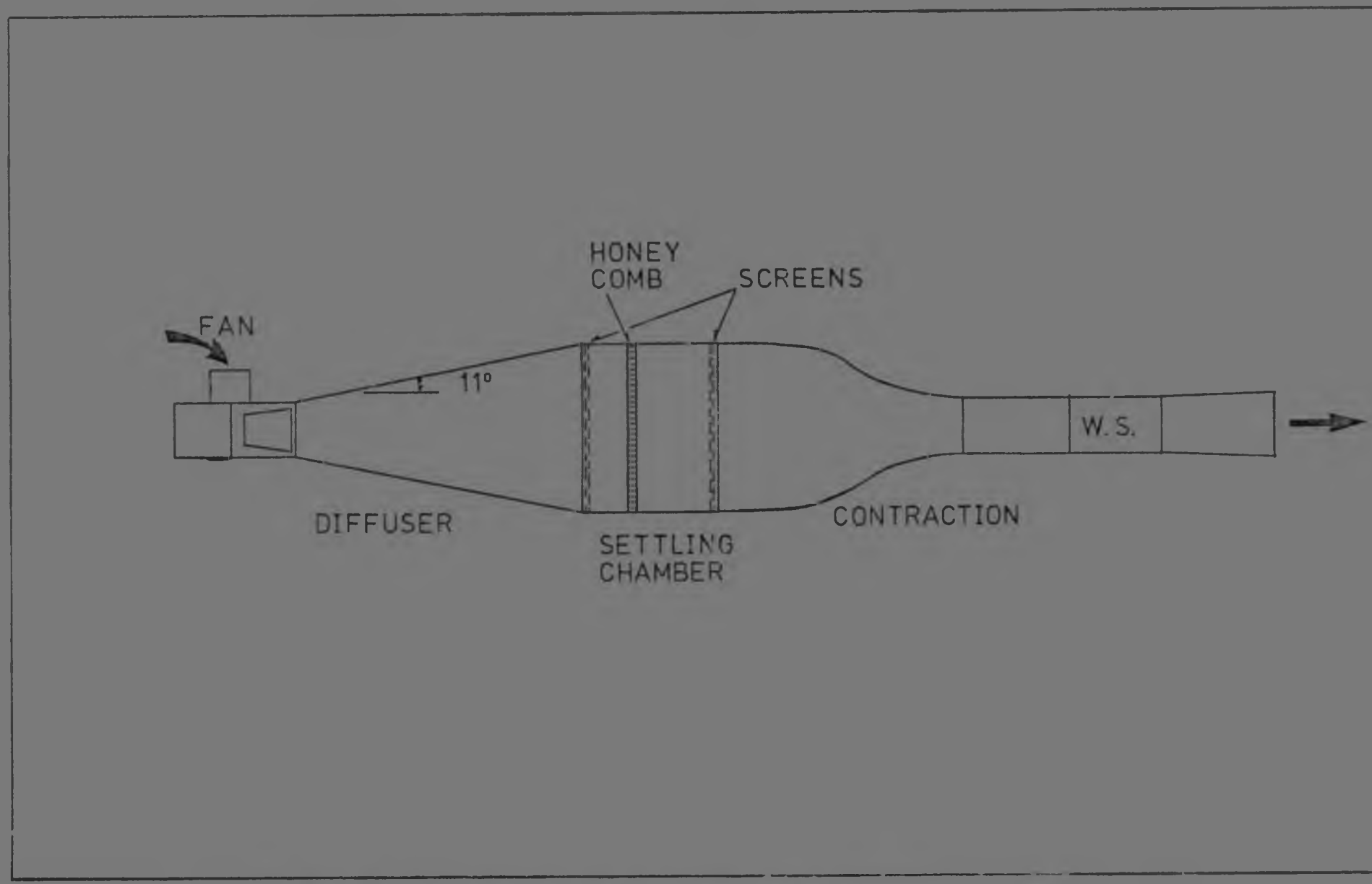


FIG 6.5 : PLAN VIEW OF THE WIND TUNNEL

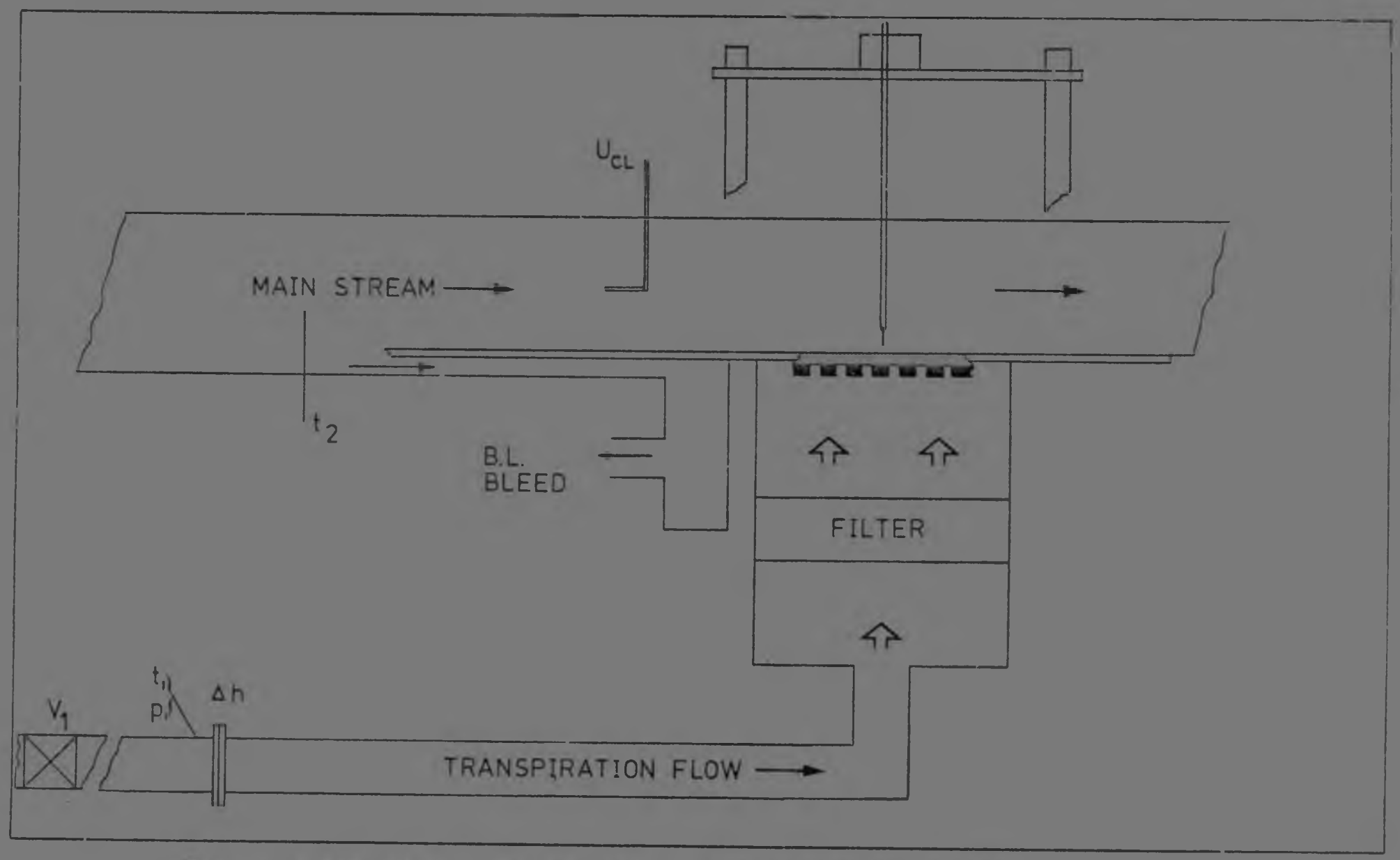


FIG 6.6 : SIDE VIEW OF THE WORKING SECTION SHOWING THE TRANSDUCERS

6.3 Hot-wire Anemometry

Velocity traverses were obtained using a Disa type 55D01 constant temperature anemometer. A single sensor, gold-plated wire probe (Disa type 55P01) was inserted in a probe holder with a protection pin attached. By adjusting this pin, it was possible to touch the pin on the working section floor, and treat that as the first point of traverse. By reading the dial gauge at that point, the height above the plate was determined, and subsequent increases in distance from the floor known to 0,01 mm.

The probe holder was held by the Disa traversing mechanism. This rig had a range of 100 mm, and was operated manually through a pinion drive, for slipless traversing. For increased accuracy, the dial gauge was mounted above the rig.

Apart from mean velocity, the turbulence intensity and power spectrum of the Working Section mainstream was measured. For this, the probe was mounted at a x-station, in the centre of the Working Section. Because the anemometer output is non-linear, it required processing. This was done with a Type 55D10 Linearisers. The linearised turbulent signal was integrated on a Type 55D35 R.M.S. Voltmeter, which gave $\sqrt{\overline{v'^2}}$. This unit, also made by Disa, had a voltage range of 0 - 300V. The integrator time constant could be set to 0,3, 1, 3, 10 and 30 seconds.

The calibration of the probes is discussed in Appendix C3.

To obtain the mean velocity in the boundary layer, a simple R.C. circuit was included in the circuit.

A Doric type DS100 digital voltmeter was used to measure the output from the anemometer.

6.4 The Energy Spectrum

Turbulent flow is so irregular that early investigators gave up hope of capturing the flow in universal expressions. In its very randomness lies the opportunity of using statistical methods to characterise the motion. Thus the time based mean velocity and thickness could be defined. The hot wire anemometer with its high frequency response, and oscilloscopes to record the output, made more sophisticated investigations possible. Thus the correlation function and energy spectrum are suitable means of presenting data.

$E_1(n)$ is defined such that $E_1(n)dn$ is the contribution to $\overline{u'^2}$ of the frequencies in the band n to $n + dn$.

$$\overline{u'^2} = \int_0^\infty E_1(n)dn \qquad \ldots\ldots\ldots [6.4.1]$$

As the frequency increases, $E_1(n)$ decreases rapidly because of the energy dissipation by viscous action.

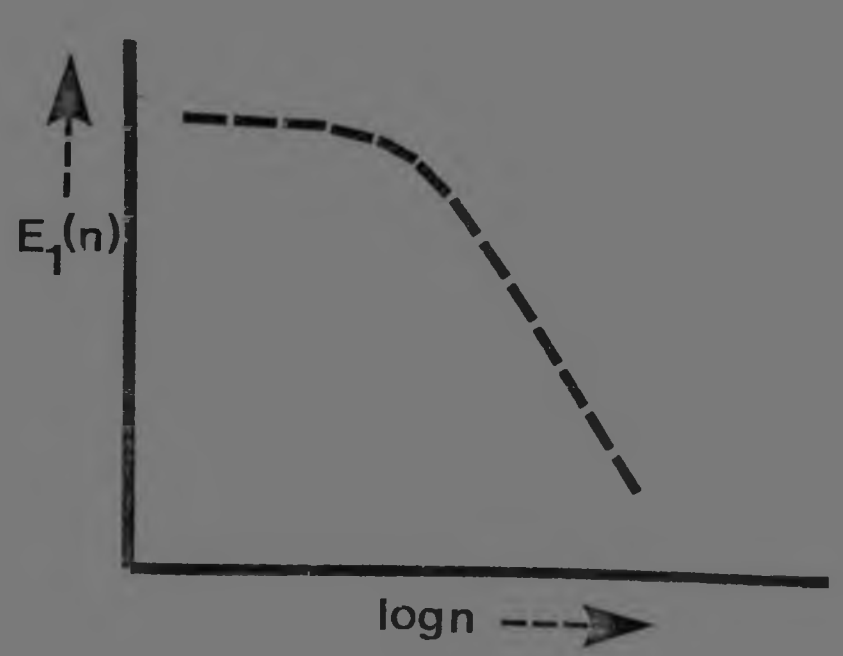


FIG 6.7 : SKETCH OF AN ENERGY SPECTRUM FOR TURBULENT FLOW

From Fig 6.7, $E_1(n)$ is c[illegible]ly greatest at low frequencies. The energy creating the [illegible]rtices is drawn from the mainstream, and eventually [illegible]ssipated through the action of viscosity.

Obtaining a plot of $E_1(n)$ vs n required the turbulent oscillations to be represented by a Fourier series, e.g.

$$f(n) = A_0 + A_1\cos\frac{\pi n}{L} + A_3\cos\frac{2\pi n}{L} + \ldots\ldots$$

and then plotting A_i vs n. Equipment employing a band pass filter could be used to generate the spectrum. For this work, a Hewlett-Packard Spectrum Analyser, model 3580A, was used in conjunction with the linearised output from the single sensor probe.

This unit produced a display on a screen, but a graphical output was obtained as well. The x-co-ordinate signal (frequency) was converted by a Hewlett-Packard Log Voltmeter/Converter, type 7562. Thus a log-log plot was produced directly on a Riken Denshi X-Y Recorder.

6.5 Experimental Procedure

It was found that the anemometer (in particular, the linearisers) was prone to drift with temperature. Before an experiment could be started, the linearisers was allowed a warm-up period of two hours (suggested by manufacturer). A linearised calibration curve was obtained, and the hot wire transducer transferred to the working section. It was essential that the anemometer was not switched off between calibration and test.

At the start of a test, valve V1 (see Fig 6.6) was opened, and the desired transpiration flow set.

After opening the by-pass, the fan was started. Once running, the trap door was closed, and the baffle at the fan inlet set for the required air velocity in the working

section. This was checked with a pitot tube in the entry length. The free stream temperature was monitored, and once steady it was assumed that the wind tunnel had reached operating conditions. Ten to fifteen minutes was usually required for steady state to be attained.

The hot wire transducer was then positioned at X1, y=1, and the anemometer switched on. The anemometer output required about two minutes to settle, during which time the parameters required for measuring the secondary flow rate were noted. These were : pressure drop across the orifice plate, and the upstream static pressure and temperature, Δh, p_1 and t_1 respectively.

V_{LIN} was read on the DVM, and y on the dial gauge, and then the hot wire was moved to the next y point. This was continued to the end of the velocity traverse. Finally the centre line velocity was measured, which was assumed to be the local U_∞, and the free stream temperature, t_2.

The traversing rig was shifted to X2, and the transducer was traversed to y=1. The entire operation was repeated. Velocity profiles were measured at X1, X2, X3 and X4.

Special care was taken to seal the plenum chamber. Prestik was used at the porous plate edges, to ensure that the secondary flow did pass through the porous plate, and not form jets at the edges. This was more important when testing the A grade plate, which had very low porosity.

TABLE 6.1 : x-co-ordinate positions

Position denoted by :-	Distance from leading edge (mm)
X1	780
X2	856
X3	945
X4	1045

CHAPTER 7

PRESENTATION AND DISCUSSION OF RESULTS

7.1 Introduction

This chapter is divided into three main sections : the proving of the tunnel, the experimental results and the computer runs.

A spanwise velocity traverse is presented, and some difficulties with regard to the tunnel are discussed. In the first part, turbulence intensity and the spectrum analysis are given.

Secondly, the velocity traverses are shown in the popular non-dimensional form, u/u_e vs y/θ. Graphs containing information more compactly are given to illustrate trends when the lower porous surface was partially blocked. The bilog plotting technique of Black and Sarnecki (1959) is used to show the development of the profile with injection ratio, and also to compare the present results with those of Mickley and Davis (1956). The possibility of a new two-parameter family of curves is discussed, which appear to be independent of u_w^* and F.

Plots obtained from the computer runs are included in the third section. Comparing these results with experimental work proved more problematic than was expected. For low injection ratio, it was possible to compare one of the profiles with that of Mickley and Davis (1959).

7.2 Initial Tests

7.2.1 Transverse velocity profile

The transverse velocity profile was measured to ensure that two dimensional flow was approximated at the centre line. The transducer was fixed at a particular value of y and x. The traversing rig was moved across the tunnel, taking readings at various intervals. One of these profiles is reproduced in Fig 7.2.

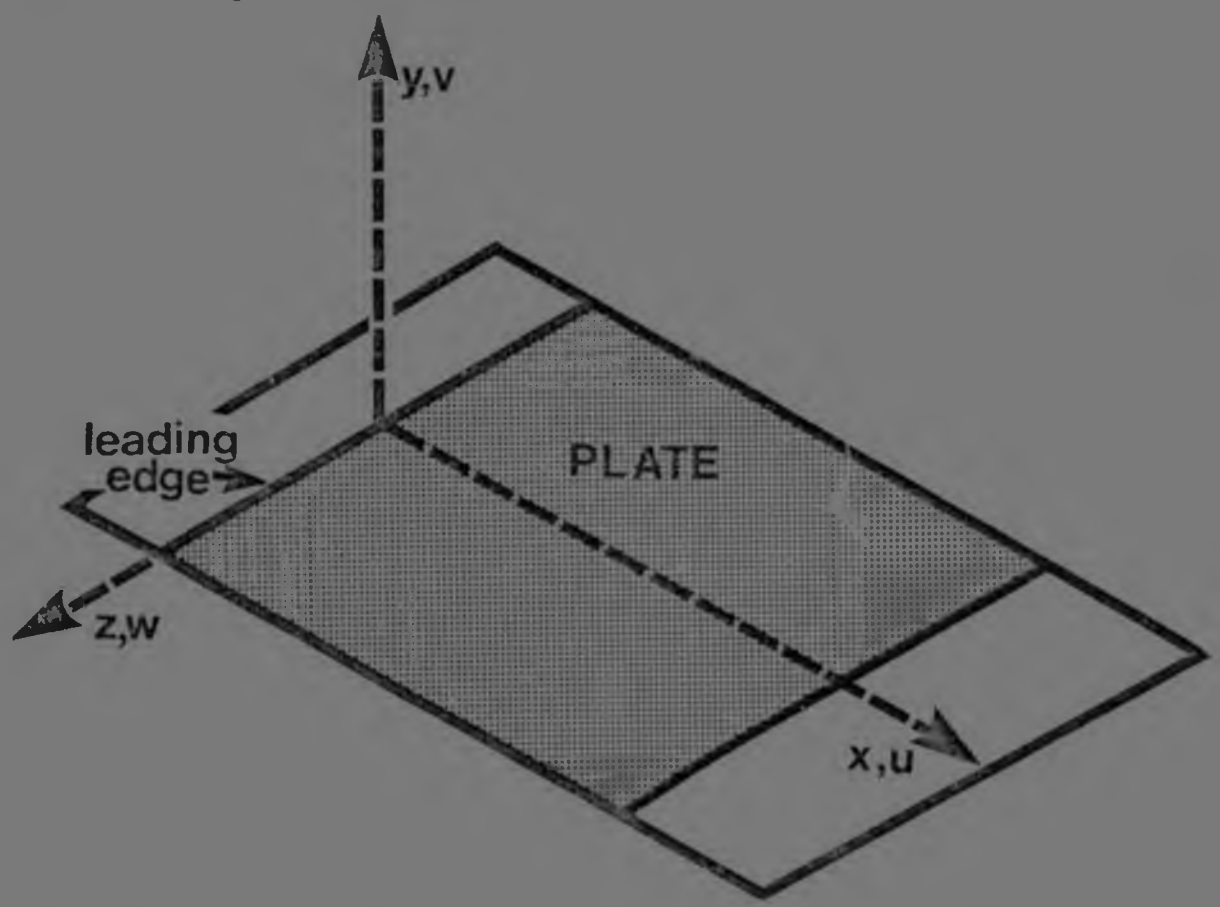


FIG 7.1 : DEFINITION OF AXES : THE X-AXIS LIES ON THE CENTRE-LINE OF THE WORKING SECTION, COINCIDING WITH THE FLOOR. Y WAS NORMAL TO THE FLOOR, AND Z TRANVERSELY COINCIDENT WITH THE FLOOR. THE VELOCITY COMPONENTS ARE INDICATED BY u, v AND w RESPECTIVELY

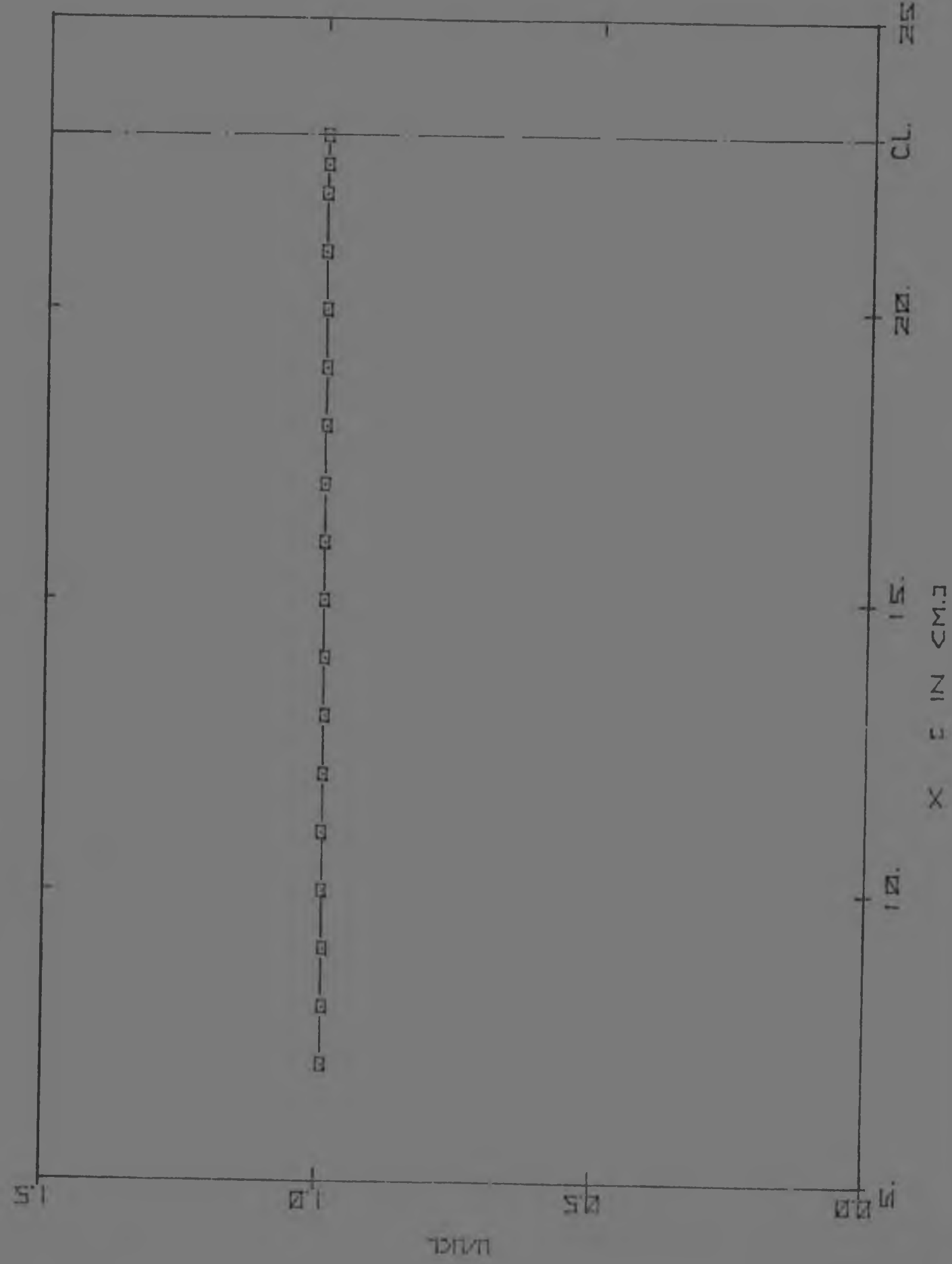


FIG 7.2 : TRANSVERSE VELOCITY PROFILE

The standard deviation of the transverse profile is s = 0,048 m/s, which is within the expected accuracy of the anemometer. The wind tunnel thus produced essentially two dimensional flow in the Working Section. All profiles were measured on the centre line, ie. at z = 0.

7.2.2 Turbulence and turbulence intensity

The turbulent fluctuations were observed by connecting the output of the linearisor to a Tektronix oscilloscope. This output was recorded and is presented in Figs 7.3 to 7.5. The first two traces show that the fluctuations were low in the main-stream. The trace depicted in Fig 7.5 was obtained by placing the probe 1 mm from the working section floor. It should be noted that the single wire sensor necessarily registered u', v' and a small percentage of w'. The probe was placed normal to the flow for all tests. Consideration of the results of Klebanoff, reproduced in Schlichting (1968), showed u', v' and w' all increased near the wall.

Figs 7.3 and 7.4 gave an indication of the autocorrelation, because the two superimposed traces were taken at time t and $t + \tau$. This was not quantified.

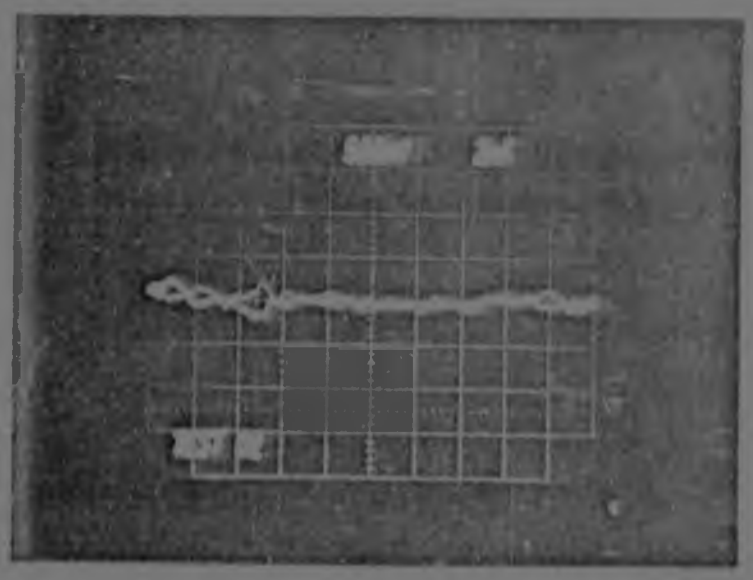


FIG 7.3 :
TWO TRACES FOR U_∞=16 m/s, PROBE AT CENTRE LINE

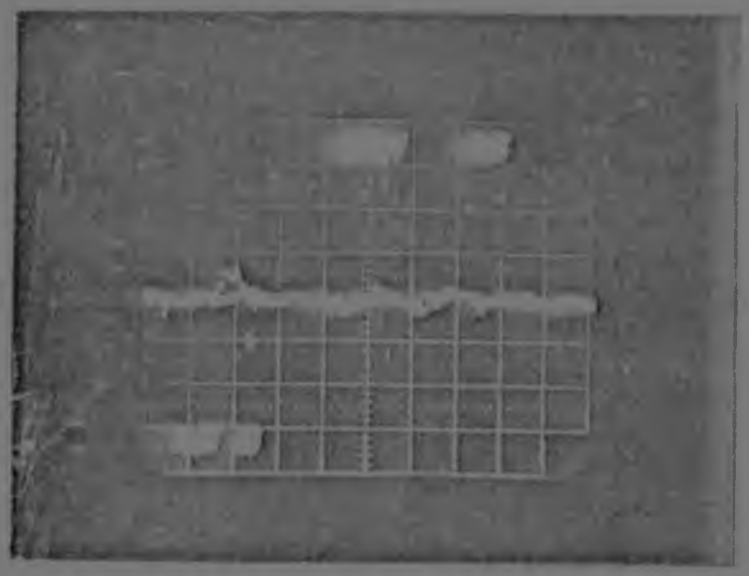


FIG 7.4 :
TWO TRACES FOR U_∞=12m/s, PROBE AT CENTRE LINE

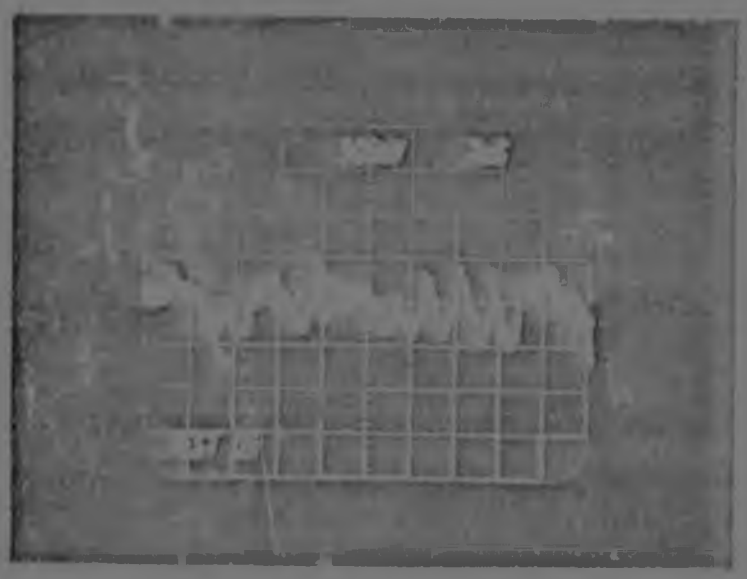


FIG 7.5 :
SINGLE TRACE FOR U_∞=16 m/s, PROBE 1 mm ABOVE SOLID WALL

A series of tests were performed to ascertain the turbulence intensity of the wind tunnel. By definition,

$$T = \sqrt{1/3(\overline{u'^2} + \overline{v'^2} + \overline{w'^2})}/U_\infty \qquad \ldots\ldots\ldots [7.2.1]$$

For isotropic flow (produced in wind tunnels behind a grid or screen) $\overline{u'^2} = \overline{v'^2} = \overline{w'^2}$, so for wind tunnels this equation becomes (Schlichting 1968)

$$T = \sqrt{\overline{u'^2}}/U_\infty \qquad \ldots\ldots\ldots [7.2.2]$$

The transducer was subject to u' and v'. Because w' was parallel to the sensor wire, this contribution should have been small. If $\overline{r'^2} = \overline{u'^2} + \overline{v'^2}$, then define a wind tunnel turbulence intensity

$$T = \sqrt{\tfrac{1}{2}\overline{r'^2}}/U_\infty \qquad \ldots\ldots\ldots [7.2.3]$$

The results of a number of runs at different velocities are given in Table 7.1. The integrator time constant was 10 sec. The probe was positioned at x = 800 mm, y = 112,5 mm, z = 0.

TABLE 7.1

Test	V_∞(volts)	U_∞(m/s)	$\sqrt{\overline{r'^2}}$(volts)	T%
A	3,190	15,359	0,891	0,59
B	2,558	12,335	0,640	0,53
C	2,191	10,579	0,504	0,49
D	1,835	8,876	0,457	0,53
E	1,392	6,756	0,368	0,56

U_∞ was varied by opening the by-pass. Considering Fig 7.6, it would be expected that T would have been lower had a more sophisticated method for decreasing U_∞ been employed. In the main test, this was done by closing the fan intake with a baffle plate. The increased angle of the trap door may explain why T dropped initially, but then increased in the last two tests.

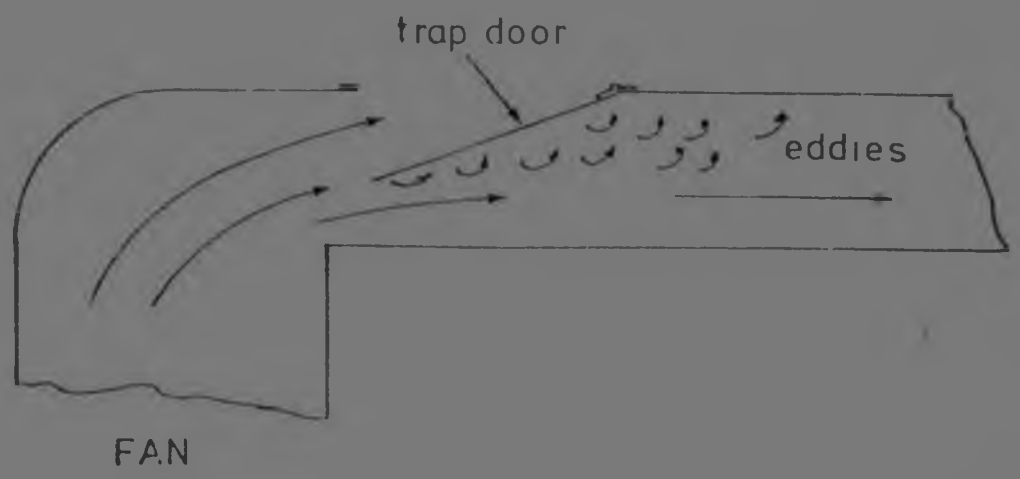


FIG 7.6 : DETAIL OF BY-PASS, SHOWING POSSIBLE EFFECTS OF OPENING THE TRAP DOOR

7.2.3 The energy spectrum

The energy spectrum was measured in tests A through E. The results are reproduced in Figs 7.7a to 7.7e. These are plots of log $E_1(n)$ vs log n. The inertial subrange was established ie. the portion of the curve which is fitted by the -5/3 law. This is a range in which vortices were neither generated or dissipated. It has been proposed that the large, low frequency eddies are formed by drawing energy from the main stream, creating the turbulent stresses. Because of the instability of the flow, smaller and smaller eddies appear until they are dissipated as heat (see Schlichting, 1968).

These plots show that a full spectral distribution of the energy of fluctuation was present in the tunnel, throughout the range of free stream velocities of interest.

In each spectrum the initial, eddy generating region can be seen. Furthermore, the function $E_1(n) \propto n^{-5/3}$ fitted the data in the inertial subrange. Noise from the anemometer and analyser disguised the high frequency range.

Fig 7.7b to Fig 7.7e show an energy bulge at high frequency. This occurred at approximately 6 and 10 Hz and is thought to have been caused by vortex shedding behind the trap door. This was discussed in section 7.2.2 in relation to Fig 7.6, and resulted in the discontinued use of the by-pass as a method of flow control.

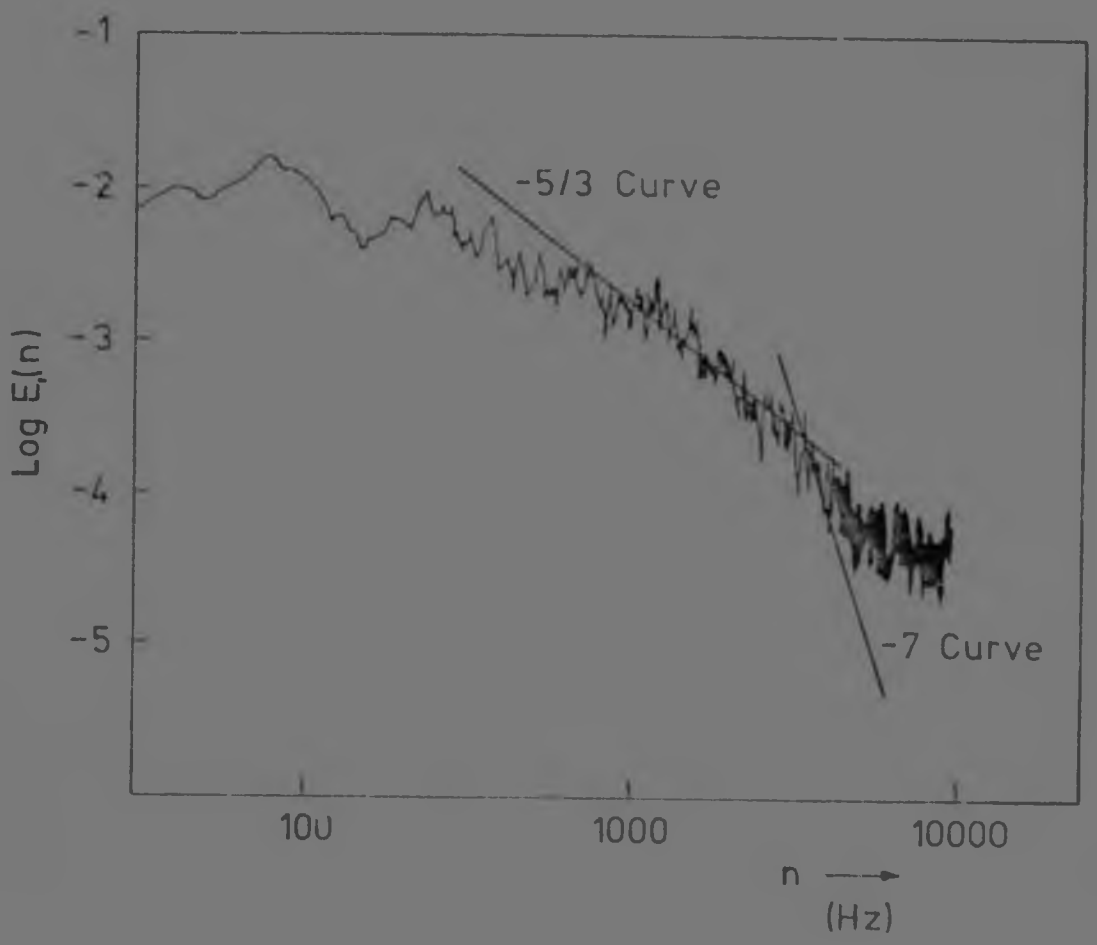


FIG 7.7a : TEST A

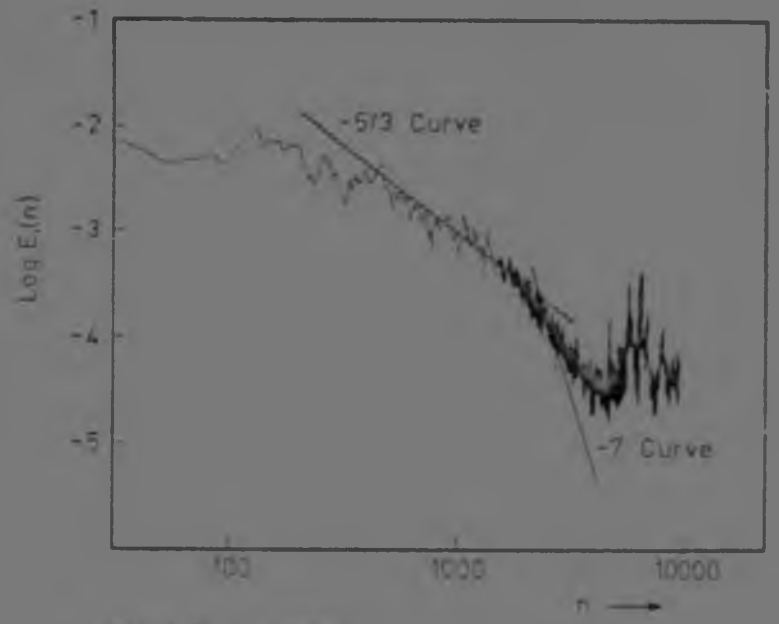


Fig 7.7a : TEST A

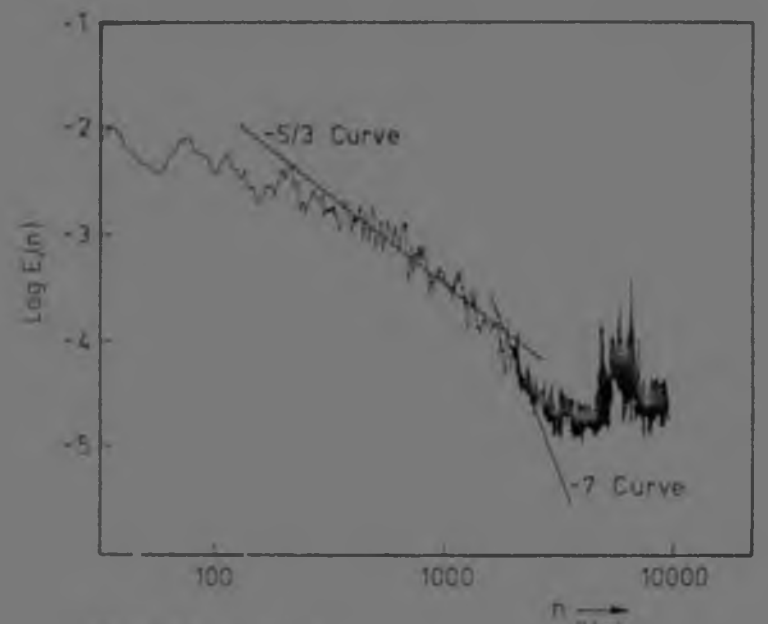


Fig 7.7d : TEST D

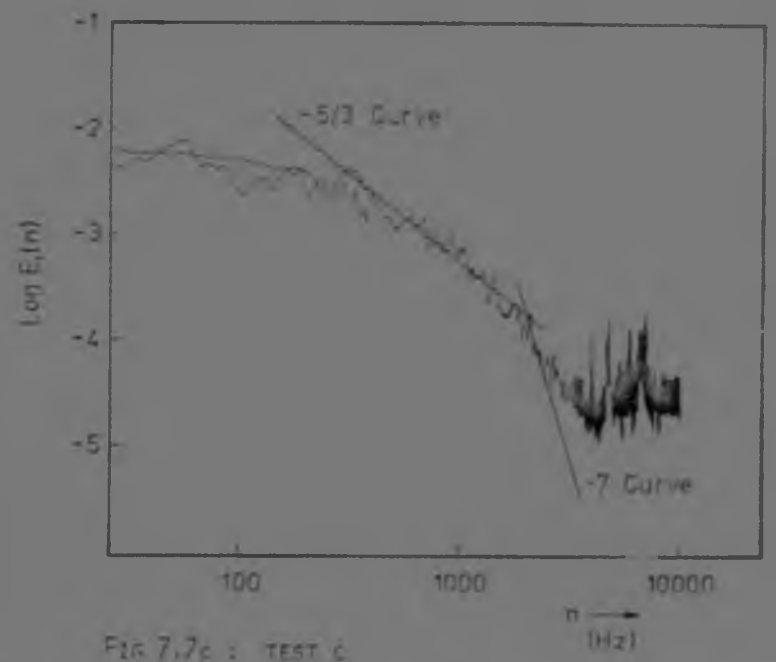


Fig 7.7c : TEST C

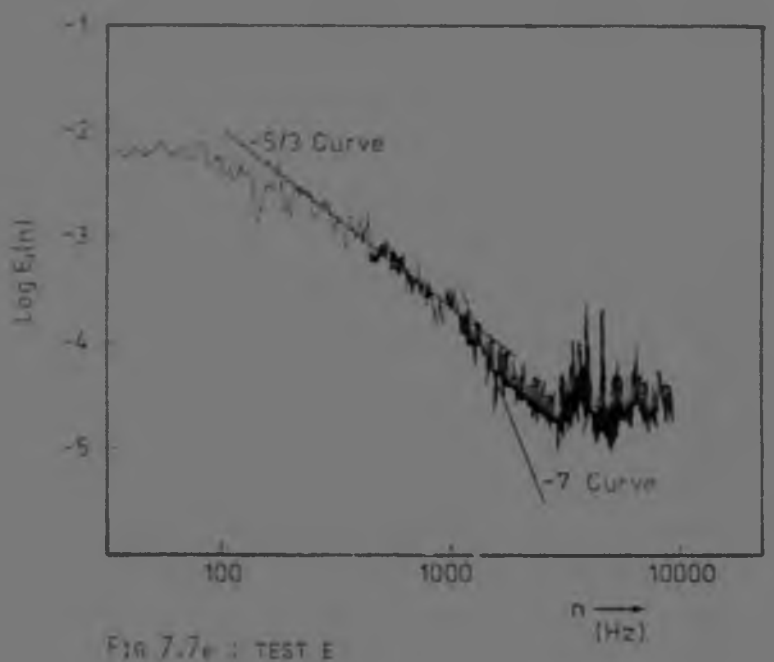


Fig 7.7e : TEST E

7.3 Experimental Work

In each test, the profile at a station just prior to the start of the porous section was measured. This station was denoted X1. The shape factor for these profiles ranged between 1,27 and 1,30, which is the correct value of H for the unblown, zero pressure gradient turbulent boundary layer. The simple Blasius profile was found not to fit the experimental data. Theoretical curves were constructed from Thompson's two parameter family (Thompson, 1965). Near the wall agreement was not as good, but it should be borne in mind that the given families had to be interpolated to obtain the approximate value of $u/0$. Two of these profiles are given in Figs 7.8 and 7.9.

The reason for this result is thought to be as follows. The contraction was in the XZ-plane, and thus the transverse profile was exceptionally flat. In the YZ-plane, the tunnel height remained constant from the start of the diffuser. This resulted in a very thick boundary layer arriving in the entry section. It was therefore not possible to draw the entire boundary layer off through the boundary layer bleed. Almost duct flow resulted, rather than the ideal "flat plate in a free stream". Large δ did have the advantage that the y measurement was less critical, and the rate of change of u with y was much smaller. The disturbance of a transducer in the shear layer was thus decreased.

It must be pointed out that numerous investigators used a pitot tube for measuring the velocity. Because this device is larger than the miniature hot wire transducer used in the present work, the disturbance to the flow in the region of measurement was necessarily greater. In addition, it was found to be essential that the pitot tube was exposed to the correct static pressure. When a pitot tube was used in the tunnel running at a pressure slightly higher than atmospheric, incorrect readings were obtained. The same comments would apply to a pitot rake.

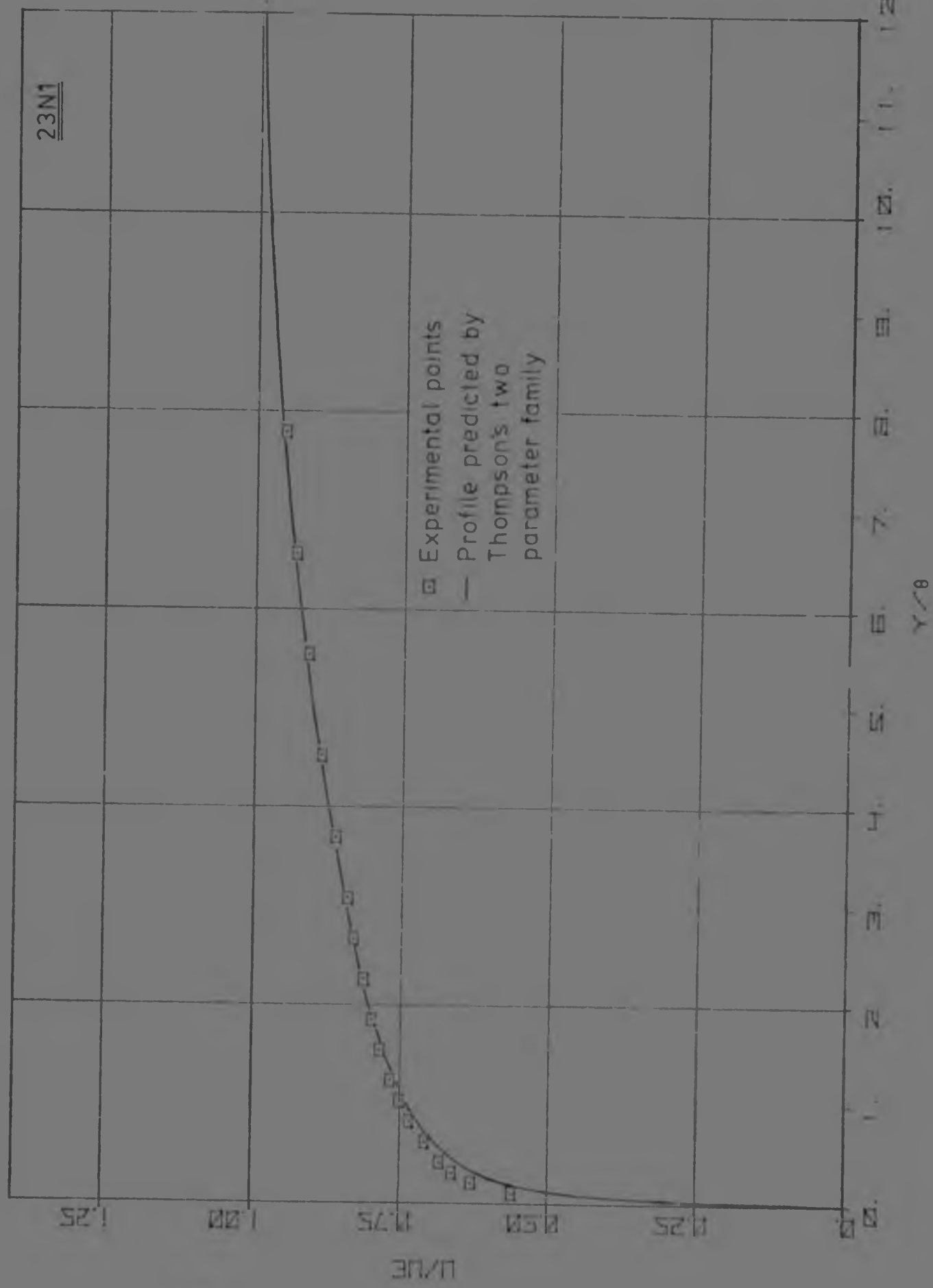


FIG 7.8 : EXPERIMENTAL PROFILE MEASURED ON THE SOLID PLATE FOR TEST 23N1

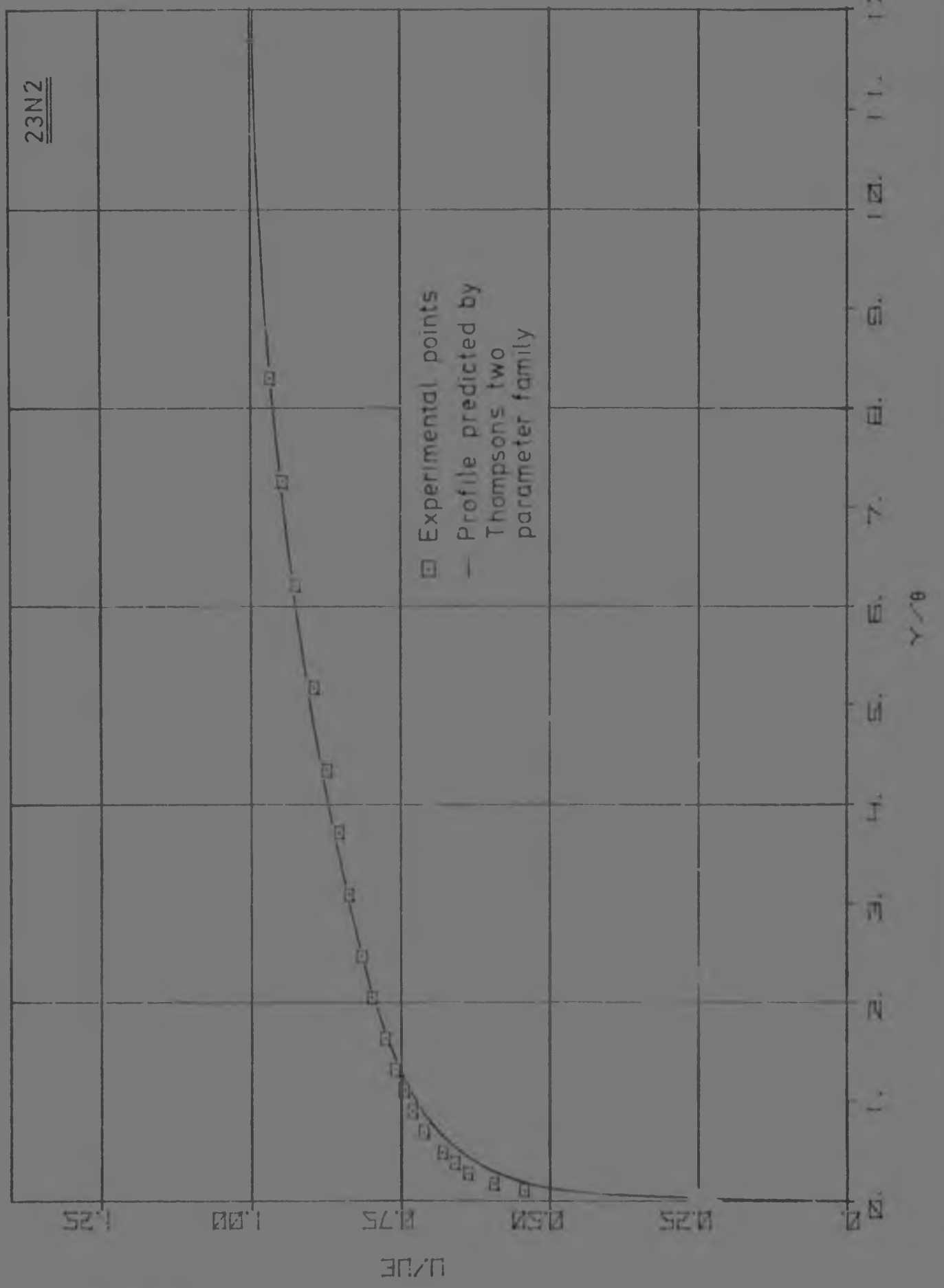


FIG 7.9 : EXPERIMENTAL PROFILE MEASURED ON THE SOLID PLATE FOR TEST 23N2

Great care was taken in measuring the profiles for the present work. The hot wire was re-calibrated for each run. A difficulty always present when using hot wires is that the transducer is not to be traversed to $y = 0$ to determine that point. A shield was attached to the probe holder with a broken probe. This probe was traversed down until it just touched the floor, and the dial gauge reading noted. The calibrated transducer was then placed in the holder. Since the two transducers were of equal length, y was calculated.

The results were processed on an IBM 370 computer, which printed and plotted the data.

7.3.1 The experimental results

The basic data is given in Appendix E1. The non-dimensionalized plots for all the tests, and baseline data for each test are given in Fig 7.10. The velocity profiles are followed by graphs of shape factor, H vs physical x for the maximum main stream velocity tests, and the tests with blockage. In these graphs the change in profile caused by blockage is indicated.

In the tables of Fig 7.10 the heading includes the date, e.g. test 28S1 was run on the 28th September, the 1 stands for the number of the test. The second part indicates the grade of porous plate, then F_{av} x 10^{-3} and finally the main stream velocity, U_{ref}, in m/s. Re_x was based on the distance measured from the leading edge. These were X1 = 0,7805 m, X2 = 0,8565, X3 = 0,9455, X4 = 1,0455. X1 was on the solid plate, X2 = 18,66%, X3 = 49,13% and X4 = 83,36% along the porous plate. F_{av} was based on the inlet velocity.

In Fig 7.10, the symbols used for plotting are :- A for X1, + for X2, X for X3 and ◇ for X4. The co-ordinates used are u/u_e vs y/θ. This is preferred to y/δ, because δ is less easy to determine.

The first five tests were run at maximum free stream velocity, with an E grade plate installed. Results are shown in Fig 7.10a to e. In all tests, the increasing 'laminarisation' with x is evident, the curves coinciding at approximately y/θ = 3,5→5, this value increasing with F. For high F, the profiles at X3 and X4 tended to be very similar (see Fig 7.10e).

In test 28S3, the profile at X3 showed a strange step. This profile was obtained with probe No.4, which appeared to be faulty, and was not used again. Although not broken, the calibration curve for this probe changed during a test. Possibly a particle in the stream collided with the transducer.

Five tests, very similar to the above, were performed on the E grade plate, but at the reduced free stream velocity; U_{CL} = 13 m/s at the Working Section inlet. Very similar results to the first set were obtained. but results were not identical. This indicates that the profile was not only dependent on F. Clearly Re_x was different, but probably also the effective roughness, k^+. These tests are shown in Fig 7.10f to j.

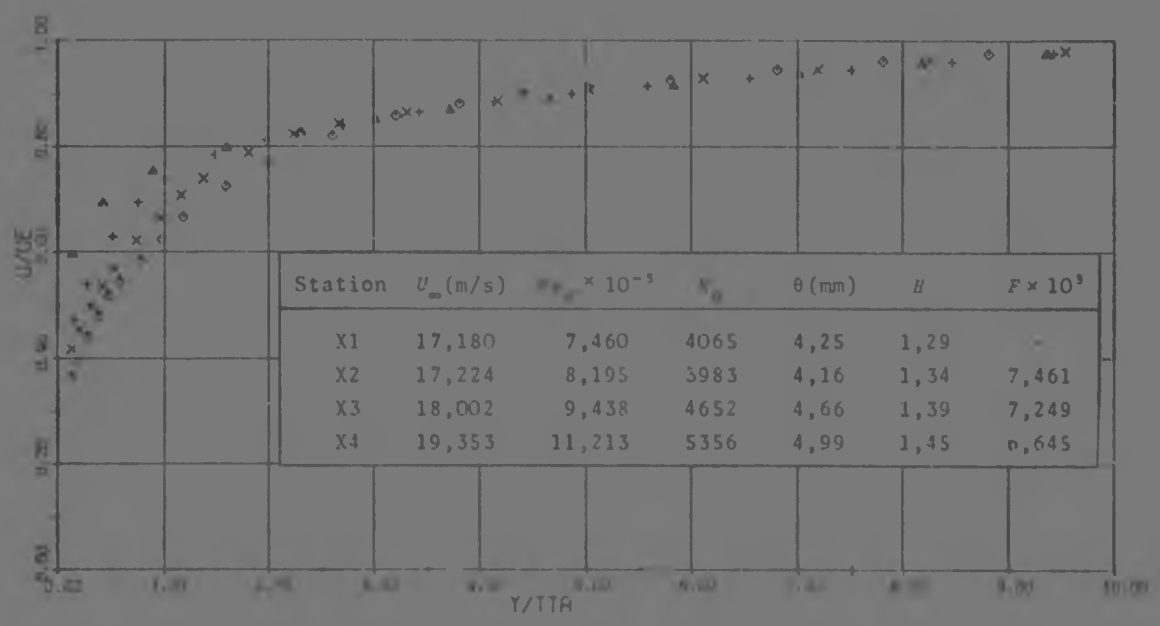
Tests 0701 and 0601 were also run over the unblocked E grade plate, but at U_{CL} = 9 m/s, and therefore at much lower Re_x.

The next set of tests, 09N1 to 11N2, shown in Fig 7.10m to q, were a repeat of the first 12 runs, but on the C grade, unblocked plate. The results were very similar, but showed a shift which was thought to have resulted from the change in roughness, k^+.

Finally, a sample test was performed, using the A grade plate. Because of the low porosity, and the resultant high pressure drop, great care was taken when sealing the plenum chamber. Powder metallurgy was used to make this plate, whereas the

PLOT OF U/UE VS Y/TTA

RUN 28-9 1,4-7,3-17

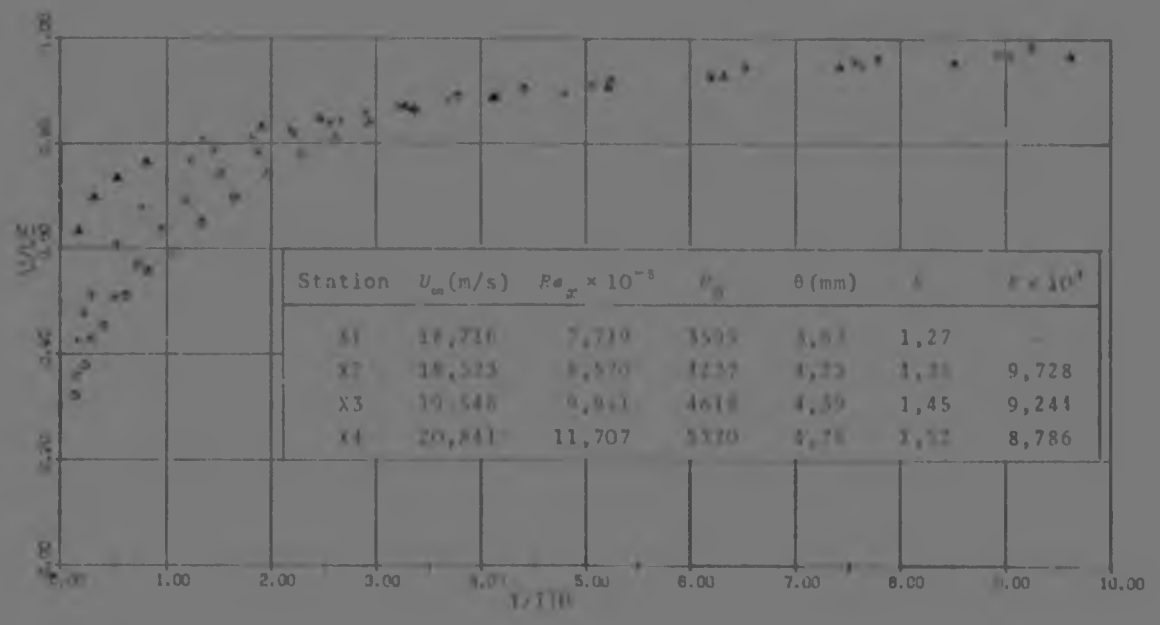


Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	17,180	7,460	4065	4,25	1,29	-
X2	17,224	8,195	3983	4,16	1,34	7,461
X3	18,002	9,438	4652	4,66	1,39	7,249
X4	19,353	11,213	5356	4,99	1,45	6,645

FIG 7.10a : TEST 28S1 E-7,58-17

PLOT OF U/UE VS Y/TTA

RUN 30-8/1,4-10,1-18

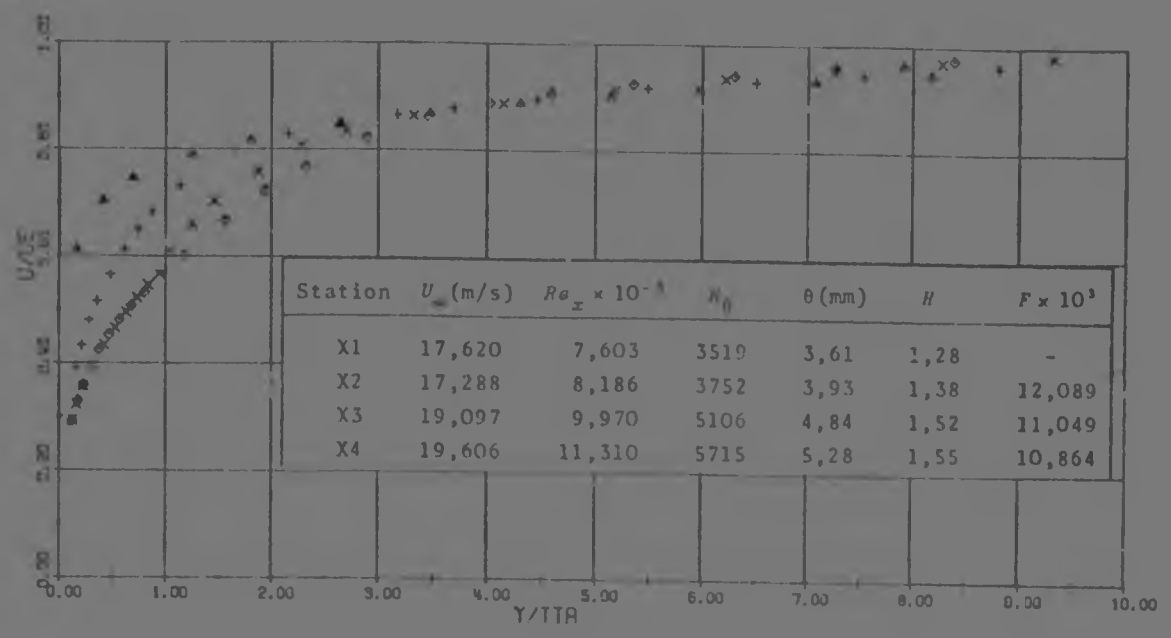


Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	18,716	7,719	3595	3,83	1,27	-
X2	18,523	8,570	4237	4,33	1,31	9,728
X3	19,548	9,941	4618	4,59	1,45	9,241
X4	20,841	11,707	5320	4,78	1,52	8,786

FIG 7.10b : TEST 28S1 E-7,58-17

PLOT OF U/UE VS Y/TTA

RUN 28-8/5.8-12.0-17

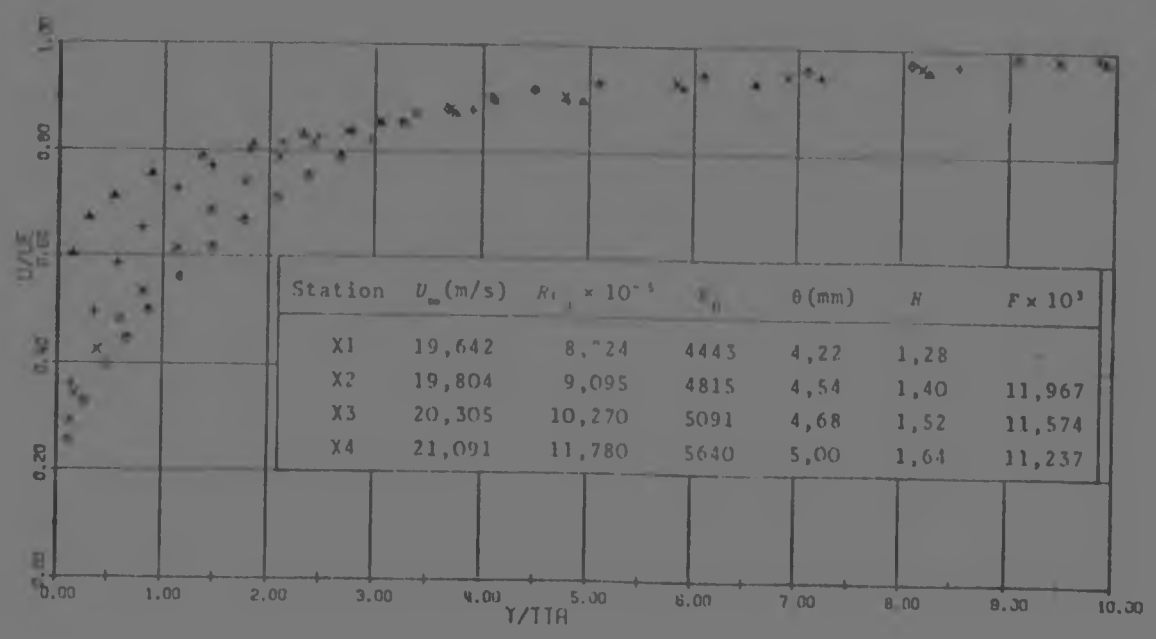


Station	U_∞ (m/s)	$Re_x \times 10^{-6}$	R_θ	θ (mm)	H	$F \times 10^3$
X1	17,620	7,603	3519	3,61	1,28	-
X2	17,288	8,186	3752	3,93	1,38	12,089
X3	19,097	9,970	5106	4,84	1,52	11,049
X4	19,606	11,310	5715	5,28	1,55	10,864

FIG 7.10c : TEST 2852 E-12,41-17

PLOT OF U/UE VS Y/TTA

RUN 30-8/5.8-12.1-17

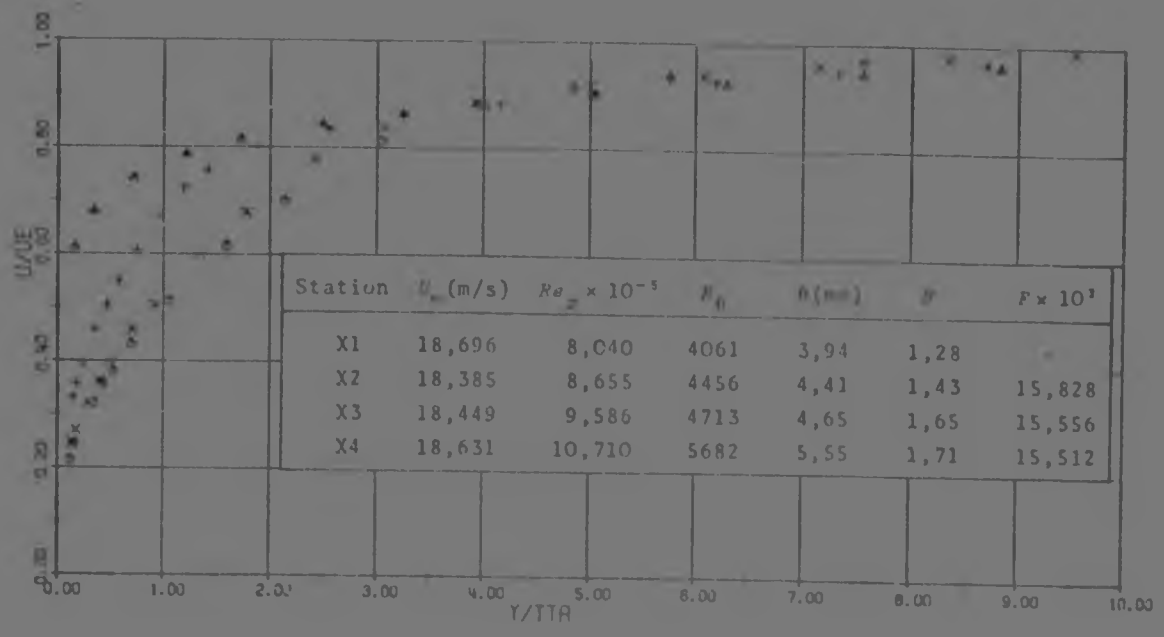


Station	U_∞ (m/s)	$Re_x \times 10^{-6}$	R_θ	θ (mm)	H	$F \times 10^3$
X1	19,642	8,724	4443	4,22	1,28	-
X2	19,804	9,095	4815	4,54	1,40	11,967
X3	20,305	10,270	5091	4,68	1,52	11,574
X4	21,091	11,780	5640	5,00	1,64	11,237

FIG 7.10d : TEST 3052 E-13,79-17

PLOT OF U/UE VS Y/TTA

RUN 28-9/9,12-15,5-17

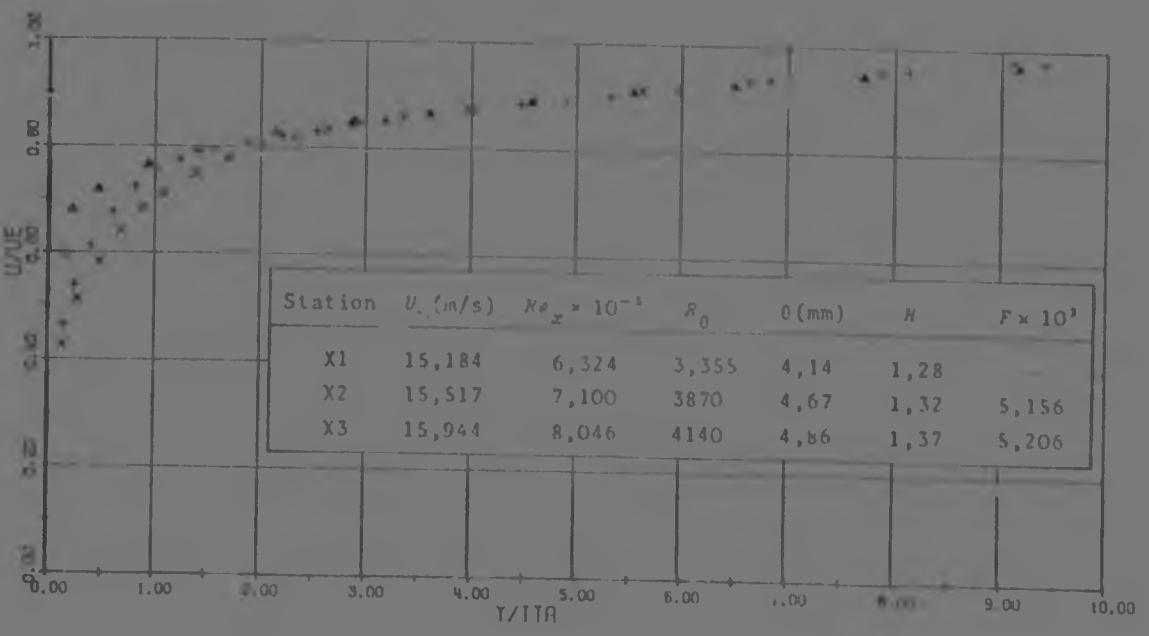


Station	U_∞ (m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	18,696	8,040	4061	3,94	1,28	
X2	18,385	8,655	4456	4,41	1,43	15,828
X3	18,449	9,586	4713	4,65	1,65	15,556
X4	18,631	10,710	5682	5,55	1,71	15,512

FIG 7.10e : TEST 2853 E-17,0-17

PLOT OF U/UE VS Y/TTA

RUN 03-10/5,8-5,3-13

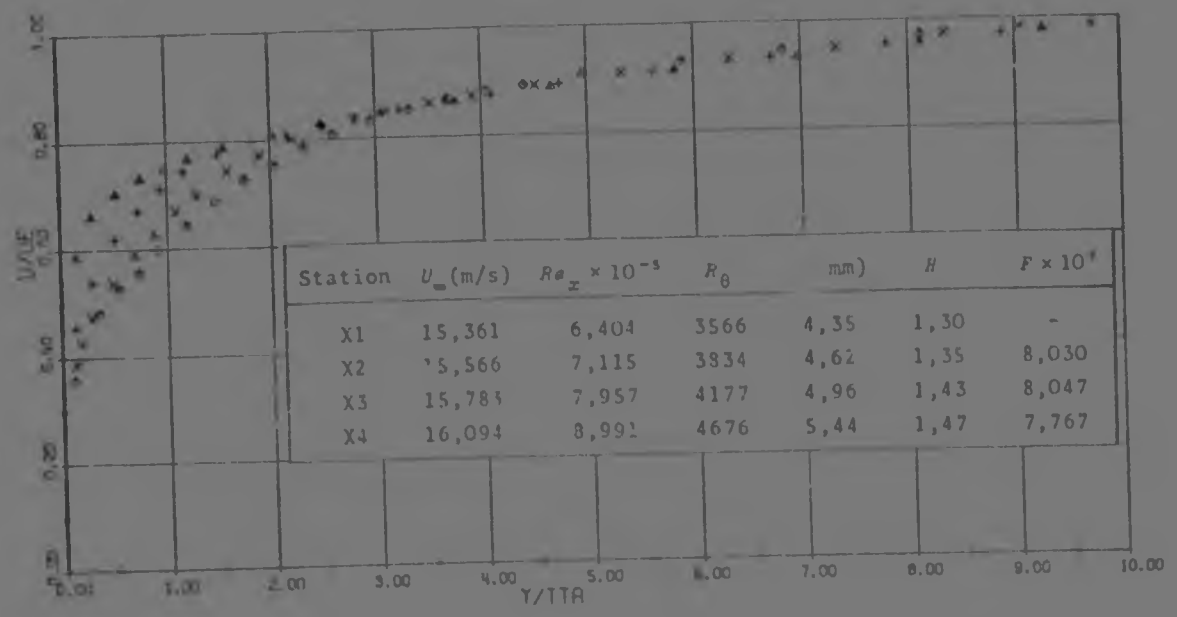


Station	U_∞ (m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	15,184	6,324	3,355	4,14	1,28	
X2	15,517	7,100	3870	4,67	1,32	5,156
X3	15,944	8,046	4140	4,86	1,37	5,206

FIG 7.10f : TEST 0302 E-6,43-13

PLOT OF U/UE VS Y/TTA

RUN 04-10/5,8-9.65-13

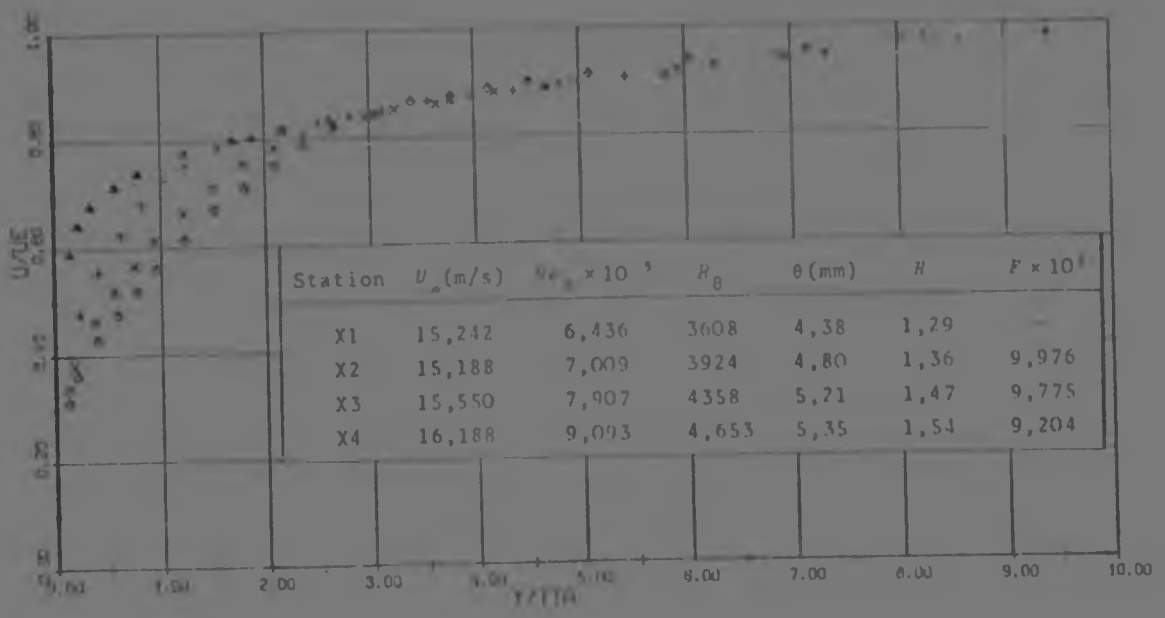


Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	mm)	H	$F \times 10^4$
X1	15,361	6,404	3566	4,35	1,30	-
X2	15,566	7,115	3834	4,62	1,35	8,030
X3	15,783	7,957	4177	4,96	1,43	8,047
X4	16,094	8,992	4676	5,44	1,47	7,767

FIG 7.10g : TEST 0402 E-9,69-13

PLOT OF U/UE VS Y/TTA

RUN 09-10/1,4-10.: 13

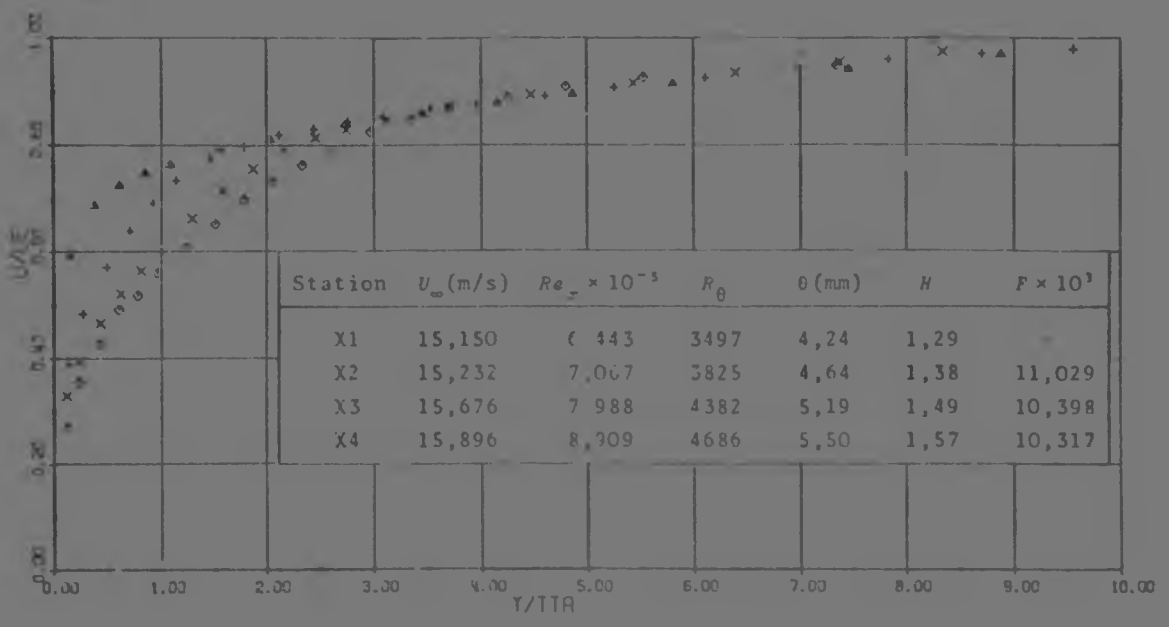


Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^4$
X1	15,242	6,436	3608	4,38	1,29	-
X2	15,188	7,009	3924	4,80	1,36	9,976
X3	15,550	7,907	4358	5,21	1,47	9,775
X4	16,188	9,093	4,653	5,35	1,54	9,204

FIG 7.10h : TEST 0301 E-11,59-13

PLOT OF U/UE VS Y/TTA

RUN 4-10/1,4-13.0-13

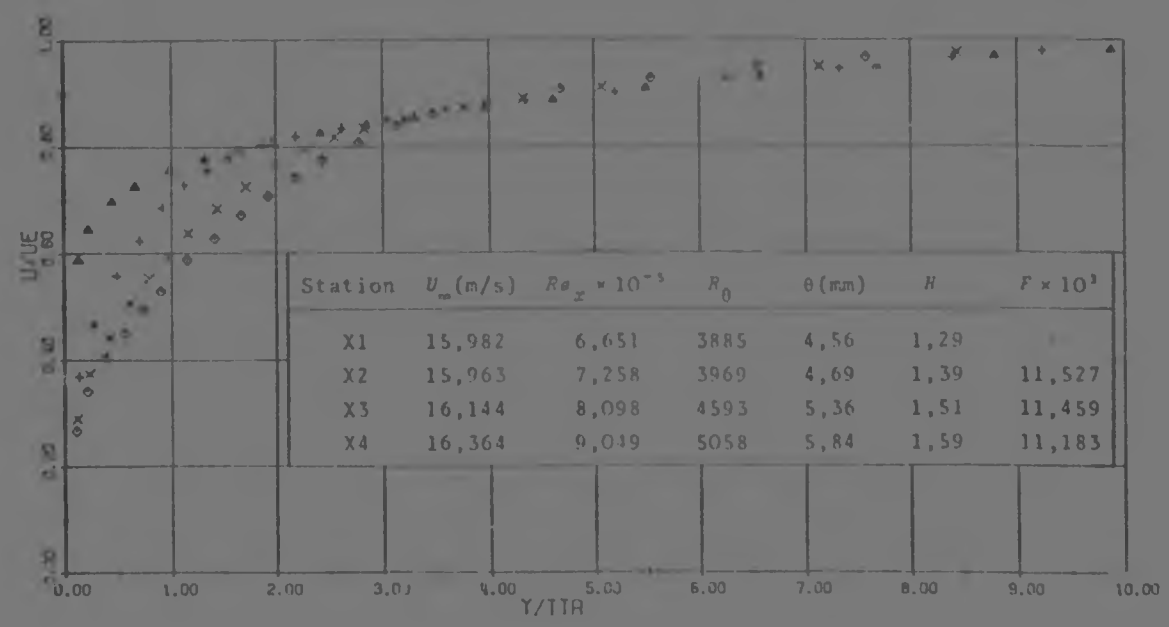


Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	15,150	6,443	3497	4,24	1,29	
X2	15,232	7,067	3825	4,64	1,38	11,029
X3	15,676	7,988	4382	5,19	1,49	10,398
X4	15,896	8,909	4686	5,50	1,57	10,317

FIG 7.10i : 0401 E-12,79-13

PLOT OF U/UE VS Y/TTA

RUN 5-0501 E-14.3-13

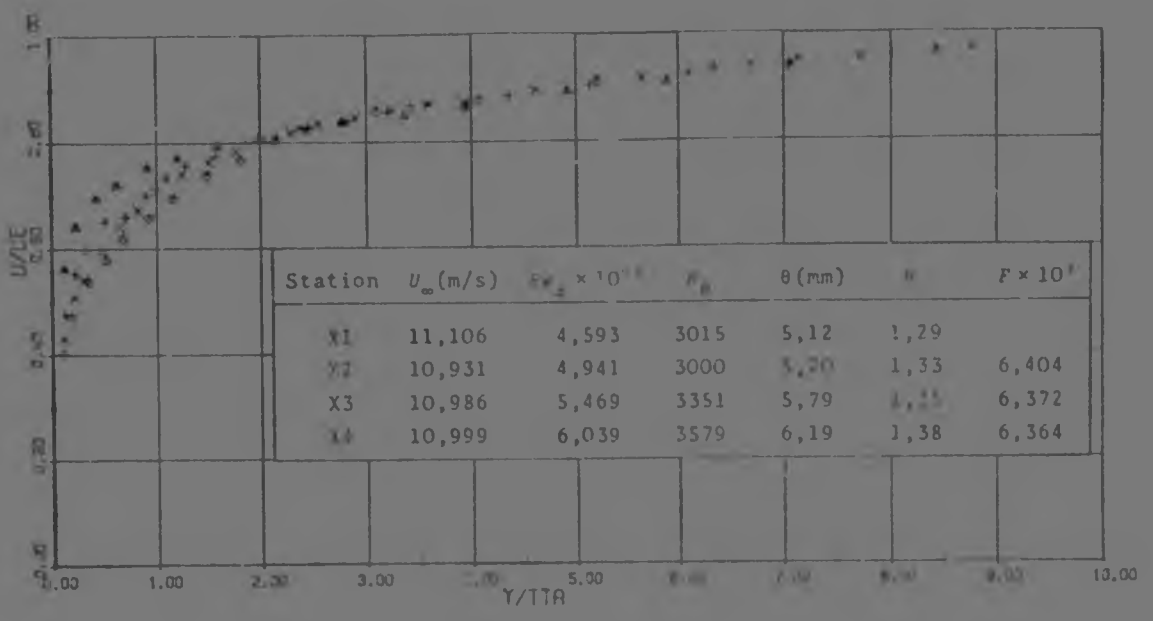


Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	15,982	6,651	3885	4,56	1,29	
X2	15,963	7,258	3969	4,69	1,39	11,527
X3	16,144	8,098	4593	5,36	1,51	11,459
X4	16,364	9,039	5058	5,84	1,59	11,183

FIG 7.10j : TEST 0501 E-14,13-13

PLOT OF U/UE VS Y/TTA

RUN 7-10/1.4-7.1-9.8

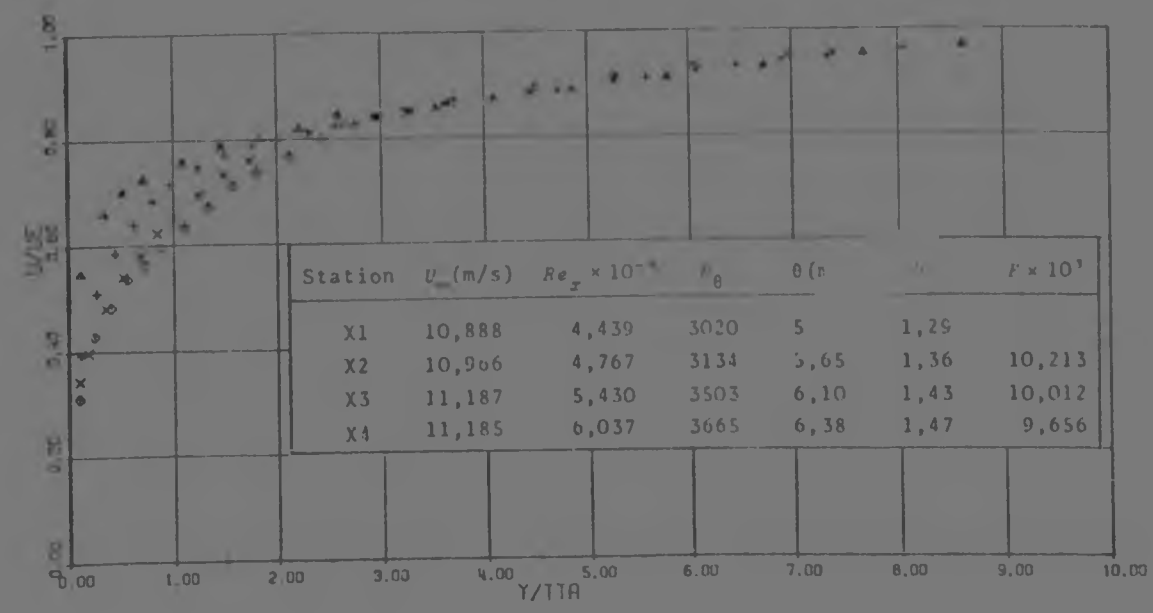


Station	U_∞(m/s)	$Re_x \times 10^{-6}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	11,106	4,593	3015	5,12	1,29	
X2	10,931	4,941	3000	5,20	1,33	6,404
X3	10,986	5,469	3351	5,79	1,35	6,372
X4	10,999	6,039	3579	6,19	1,38	6,364

FIG 7.10k : TEST 0701 E-7,74-9

PLOT OF U/UE VS Y/TTA

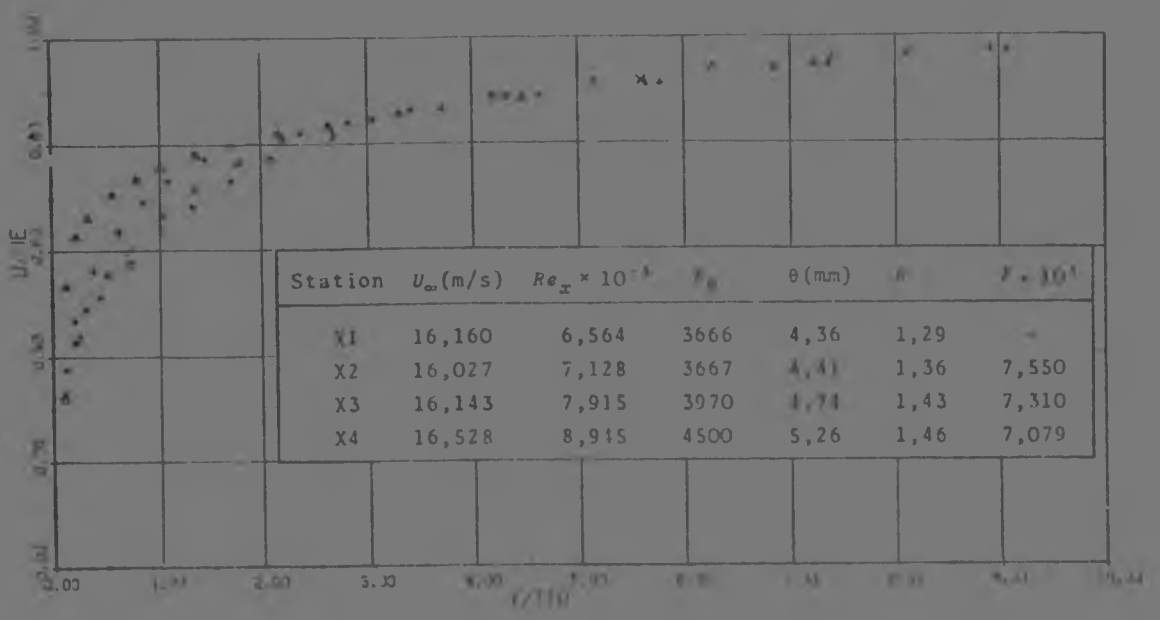
RUN 8-10/1.4-10.5-9.8



Station	U_∞(m/s)	$Re_x \times 10^{-6}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	10,888	4,439	3020	5	1,29	
X2	10,906	4,767	3134	5,65	1,36	10,213
X3	11,187	5,430	3503	6,10	1,43	10,012
X4	11,185	6,037	3665	6,38	1,47	9,656

FIG 7.10l : TEST 0601 E-12,03-9

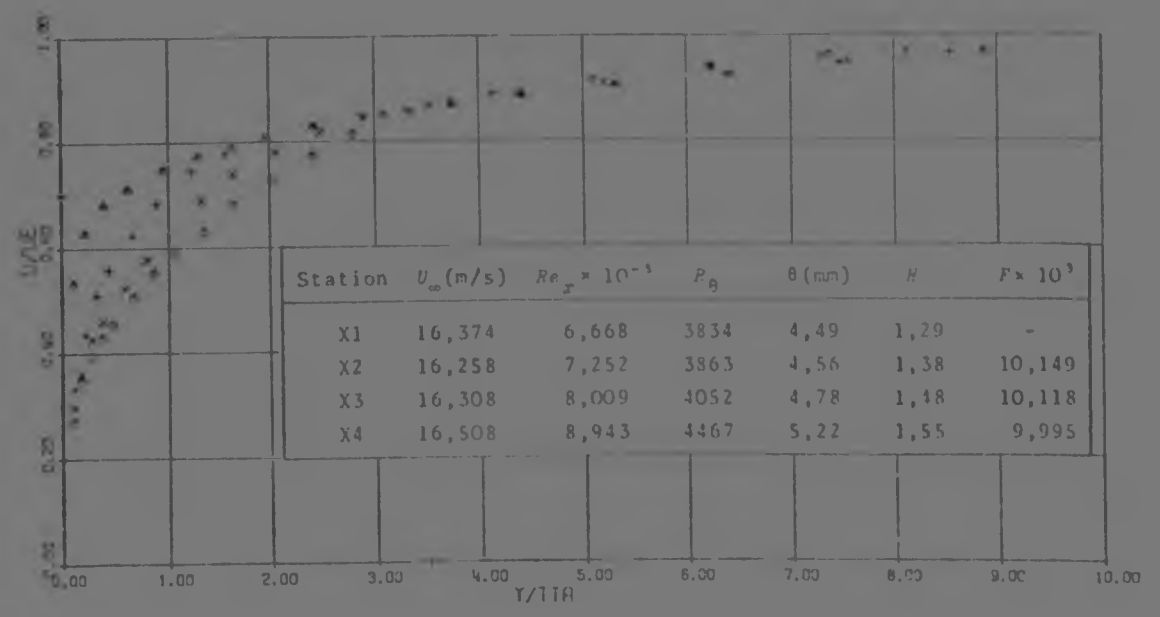
PLOT OF U/UE VS Y/TTA



Station	U_∞(m/s)	$Re_x \times 10^{-4}$	P_θ	θ(mm)	H	$F \times 10^3$
X1	16,160	6,564	3666	4,36	1,29	-
X2	16,027	7,128	3667	4,41	1,36	7,550
X3	16,143	7,915	3970	4,74	1,43	7,310
X4	16,528	8,945	4500	5,26	1,46	7,079

FIG 7.10m : TEST 09N1 C-7,07-17

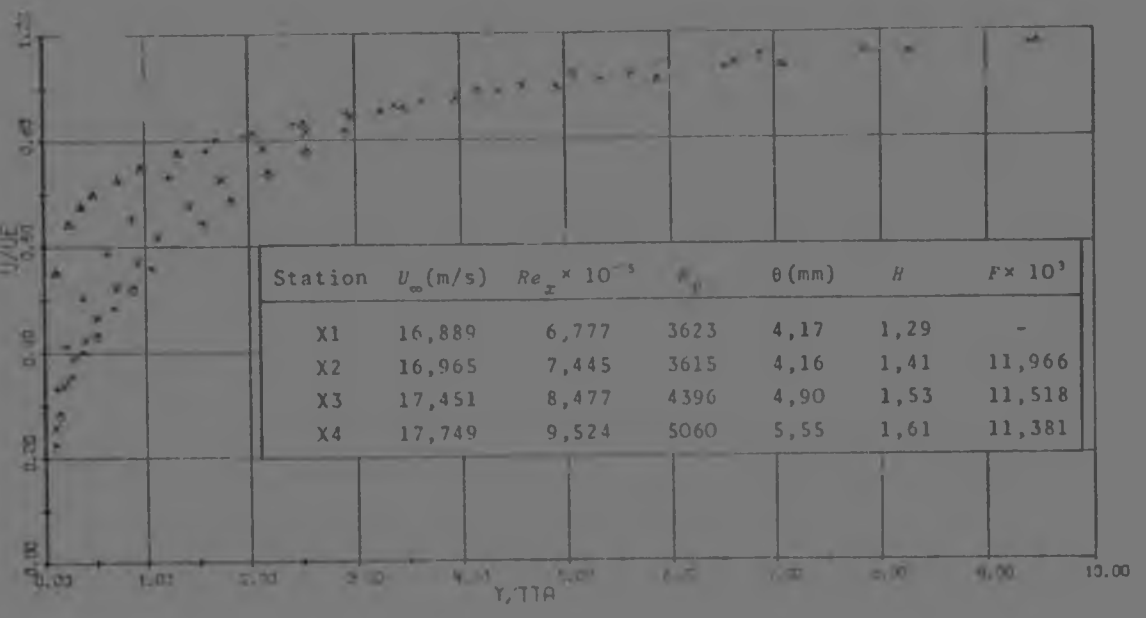
PLOT OF U/UE VS Y/TTA



Station	U_∞(m/s)	$Re_x \times 10^{-4}$	P_θ	θ(mm)	H	$F \times 10^3$
X1	16,374	6,668	3834	4,49	1,29	-
X2	16,258	7,252	3863	4,56	1,38	10,149
X3	16,308	8,009	4052	4,78	1,48	10,118
X4	16,508	8,943	4467	5,22	1,55	9,995

FIG 7.10n : TEST 10N1 C-9,82-17

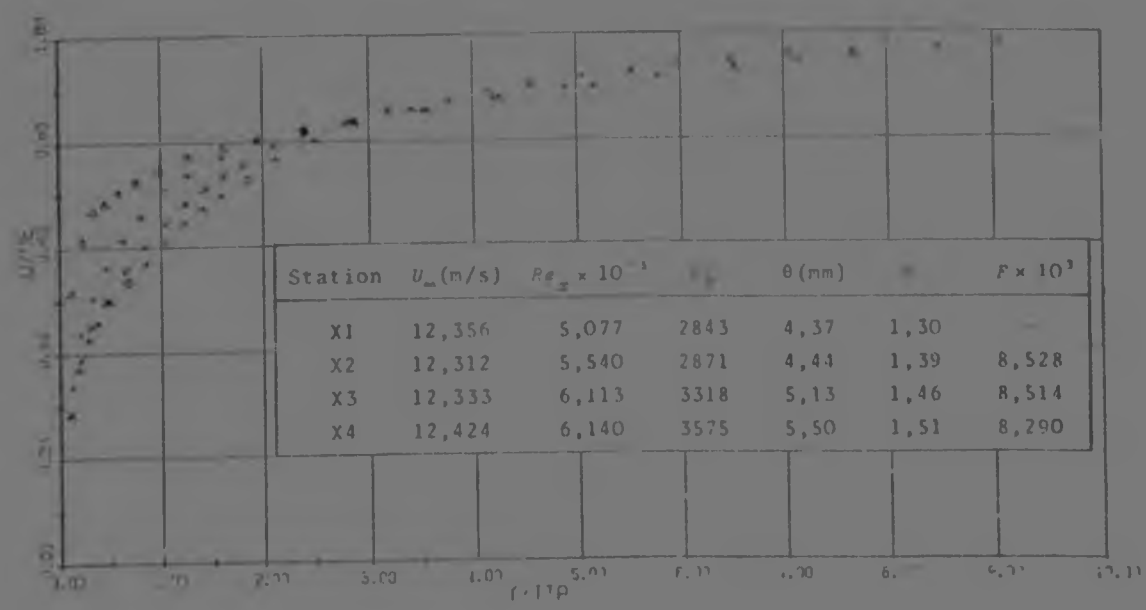
PLOT OF U/UE VS Y/TTA



Station	U_∞(m/s)	$Re_x \times 10^{-5}$	[illegible]	θ(mm)	H	$F \times 10^3$
X1	16,889	6,777	3623	4,17	1,29	-
X2	16,965	7,445	3615	4,16	1,41	11,966
X3	17,451	8,477	4396	4,90	1,53	11,518
X4	17,749	9,524	5060	5,55	1,61	11,381

FIG 7.10o : TEST 10N2 C-12,02-17

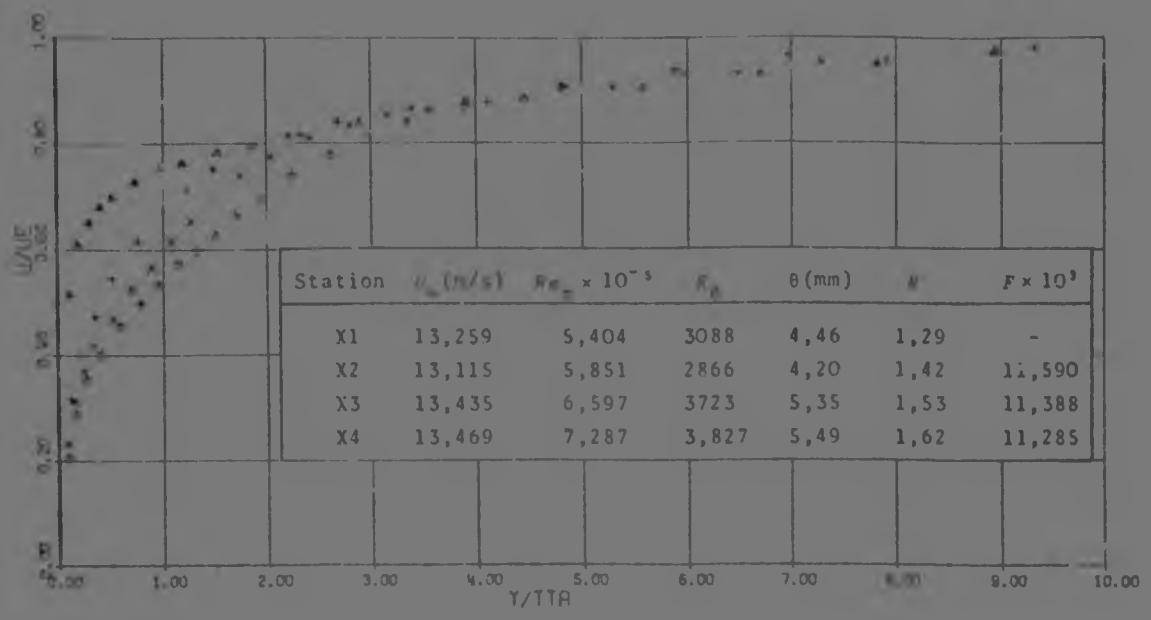
PLOT OF U/UE VS Y/TTA



Station	U_∞(m/s)	$Re_x \times 10^{-5}$	[illegible]	θ(mm)	[illegible]	$F \times 10^3$
X1	12,356	5,077	2843	4,37	1,30	-
X2	12,312	5,540	2871	4,44	1,39	8,528
X3	12,333	6,113	3318	5,13	1,46	8,514
X4	12,424	6,140	3575	5,50	1,51	8,290

FIG 7.10p : TEST 11N1 C-8,39-13

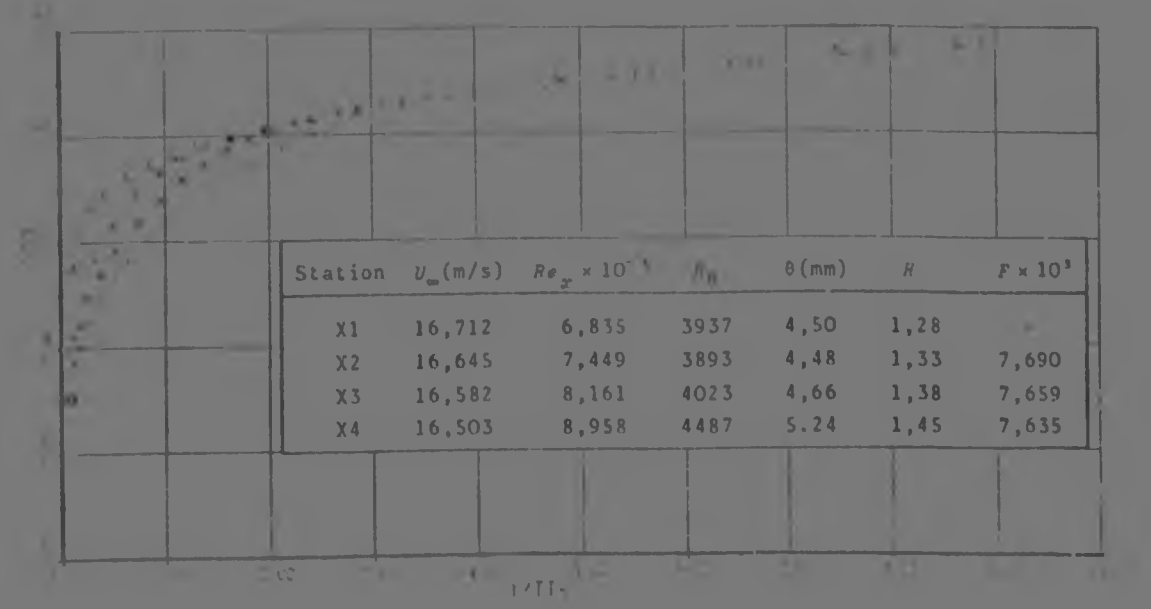
PLOT OF U/UE VS Y/TTA



Station	U_∞ (m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	13,259	5,404	3088	4,46	1,29	-
X2	13,115	5,851	2866	4,20	1,42	11,590
X3	13,435	6,597	3723	5,35	1,53	11,388
X4	13,469	7,287	3,827	5,49	1,62	11,285

FIG 7.10q : TEST 11N2 C-12,22-13

PLOT OF U/UE VS Y/TTA

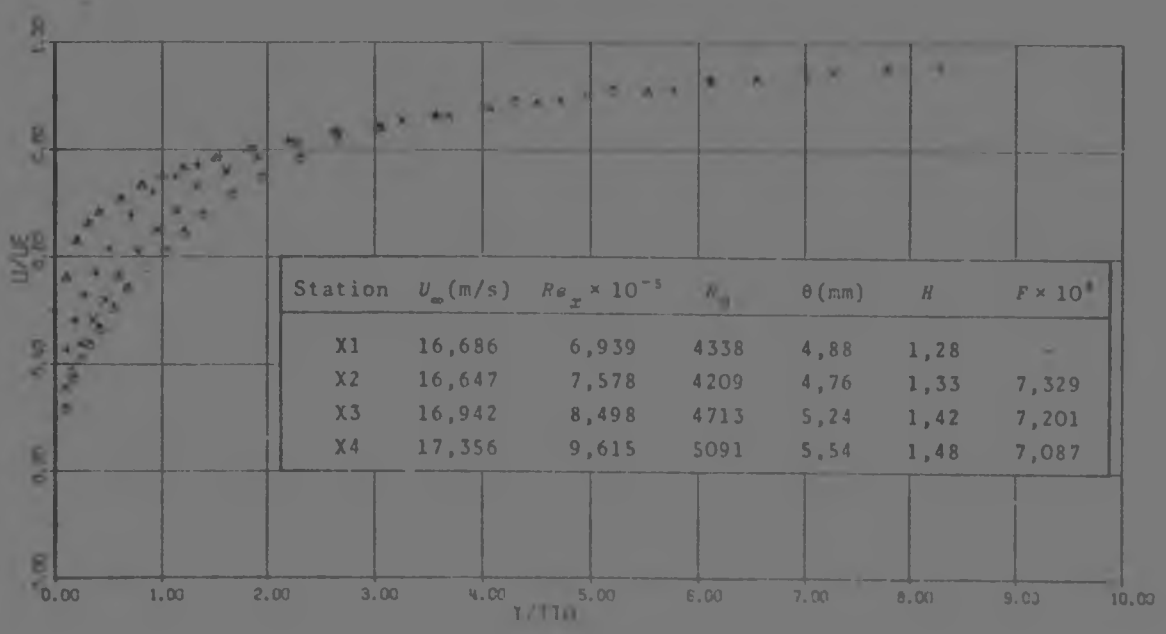


Station	U_∞ (m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	16,712	6,835	3937	4,50	1,28	-
X2	16,645	7,449	3893	4,48	1,33	7,690
X3	16,582	8,161	4023	4,66	1,38	7,659
X4	16,503	8,958	4487	5.24	1,45	7,635

FIG 7.10r : TEST 16N1 A-7,55-17

PLOT OF U/UE VS Y/TTA

RUN 23 11/1,4-8-17E

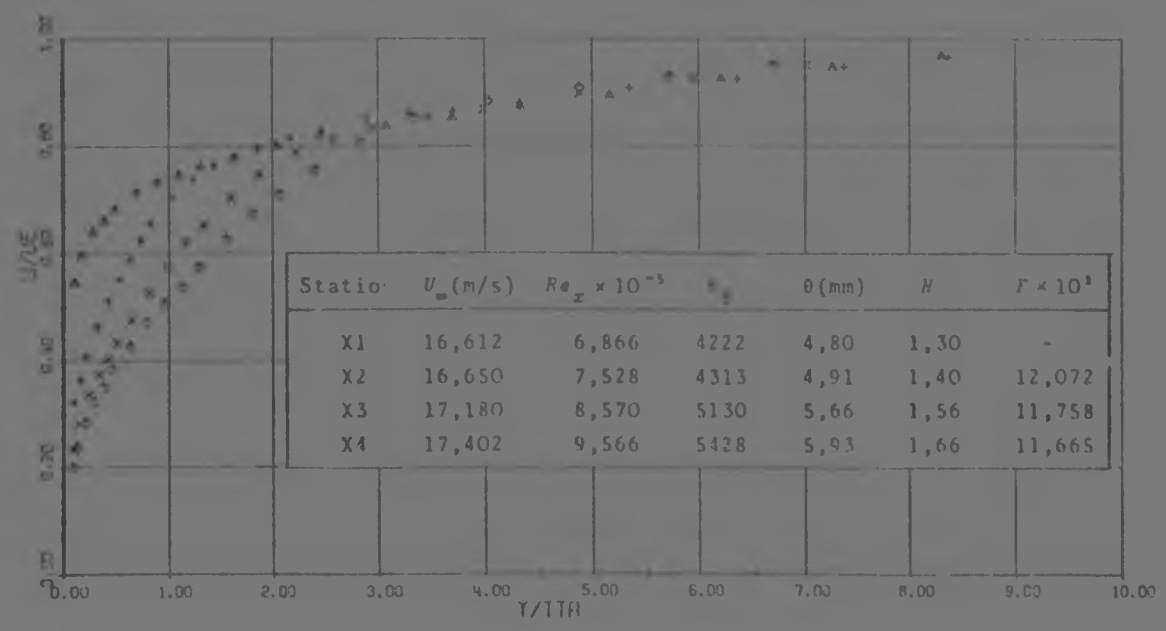


Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^4$
X1	16,686	6,939	4338	4,88	1,28	-
X2	16,647	7,578	4209	4,76	1,33	7,329
X3	16,942	8,498	4713	5,24	1,42	7,201
X4	17,356	9,615	5091	5,54	1,48	7,087

FIG 7.10s : TEST 23N1 E-7,27-17 50% BLOCKED

PLOT OF U/UE VS Y/TTA

RUN 23-11/5,8-8-17E



Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^4$
X1	16,612	6,866	4222	4,80	1,30	-
X2	16,650	7,528	4313	4,91	1,40	12,072
X3	17,180	8,570	5130	5,66	1,56	11,758
X4	17,402	9,566	5428	5,93	1,66	11,665

FIG 7.10t : TEST 23N2 E-12,0-17 50% BLOCKED

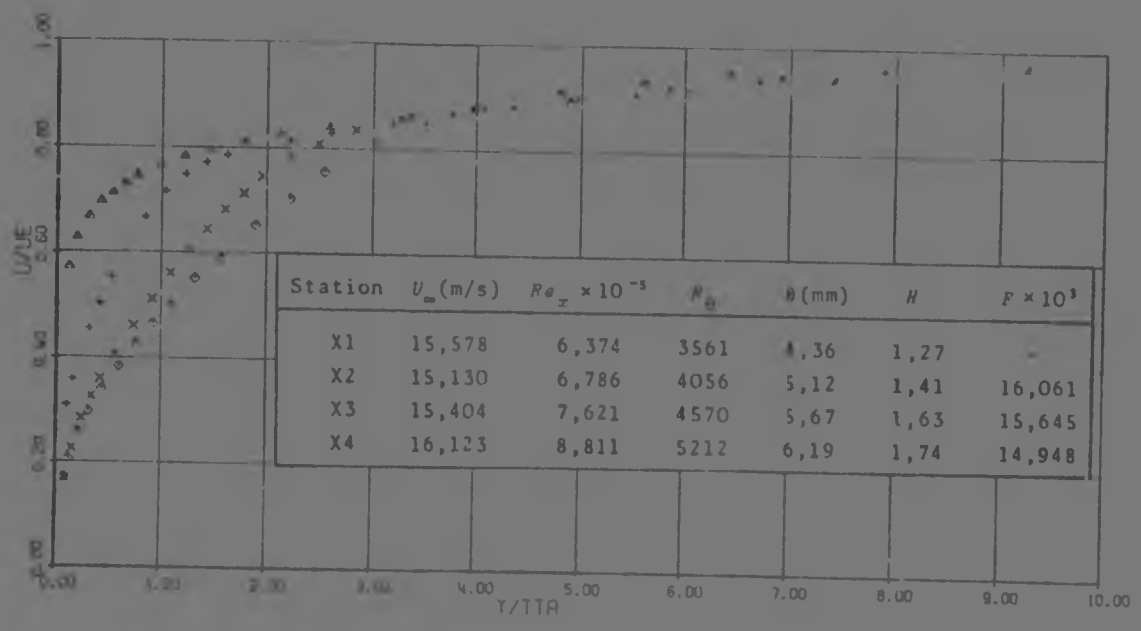


FIG 7.10u : TEST 24N1 E-14,51-17 50% BLOCKED

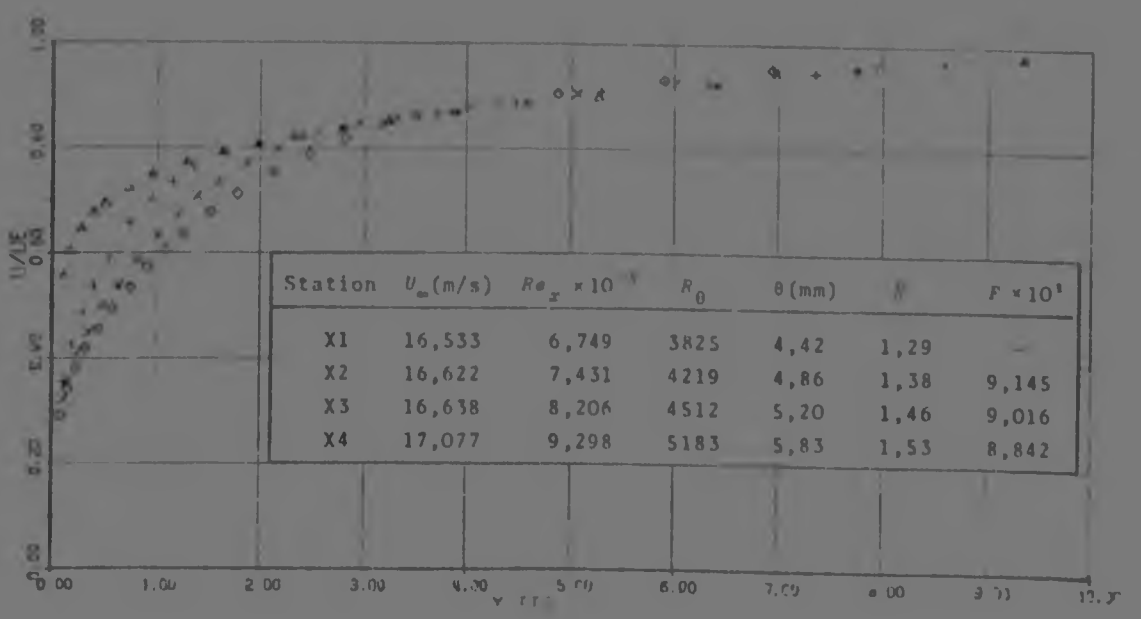
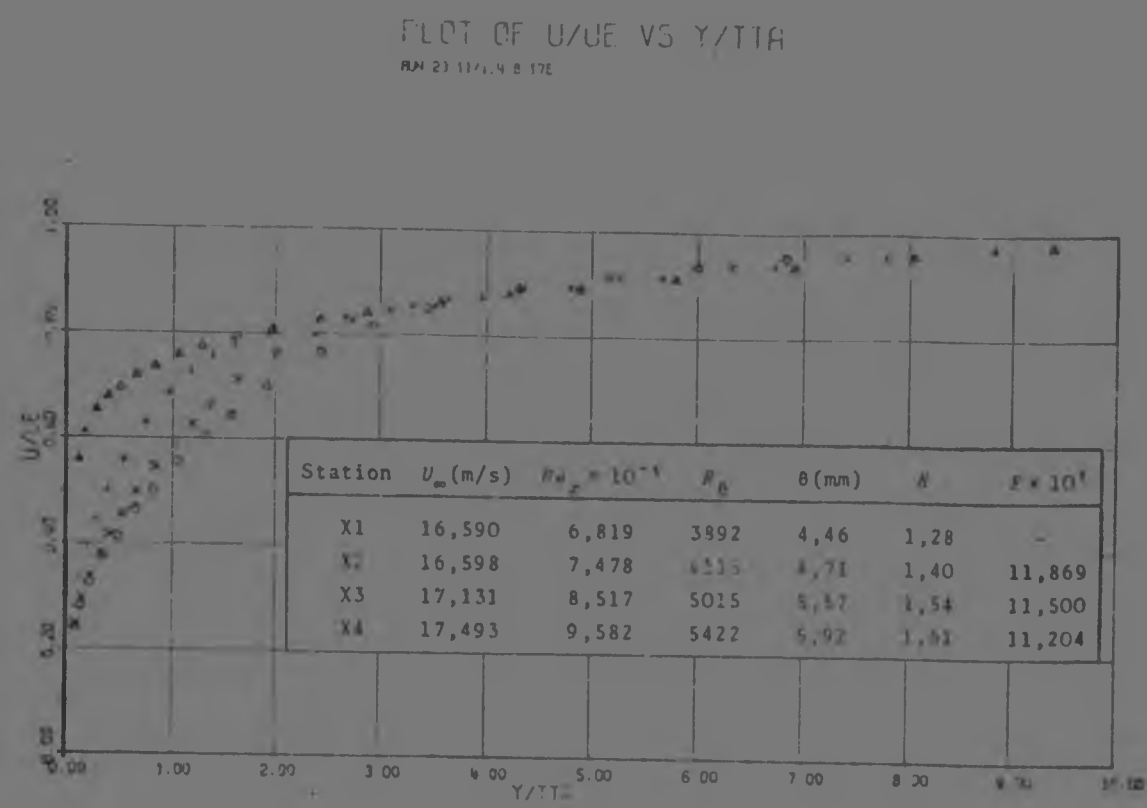
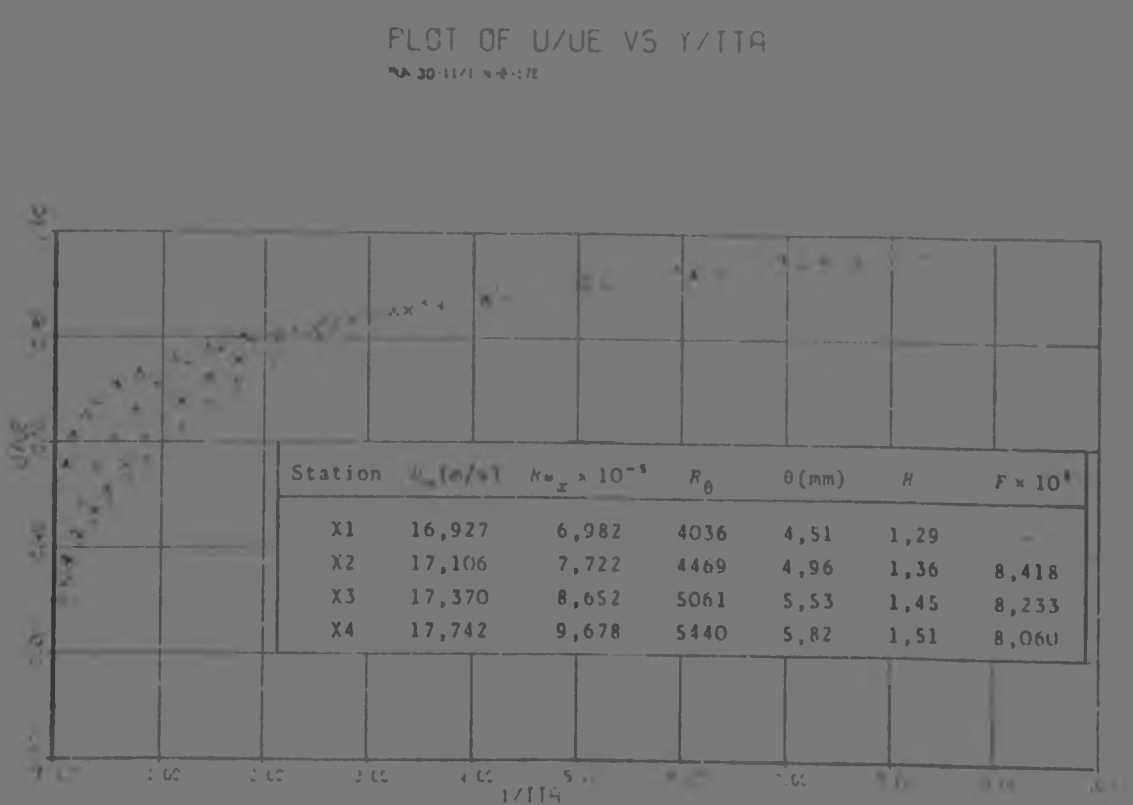


FIG 7.10v : TEST 28N1 E-9,04-17 67% BLOCKED



Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^5$
X1	16,590	6,819	3892	4,46	1,28	-
X2	16,598	7,478	[illegible]	4,71	1,40	11,869
X3	17,131	8,517	5015	5,57	1,54	11,500
X4	17,493	9,582	5422	5,92	1,61	11,204

FIG 7.10w : TEST 29N1 E-11,77-17 67% BLOCKED

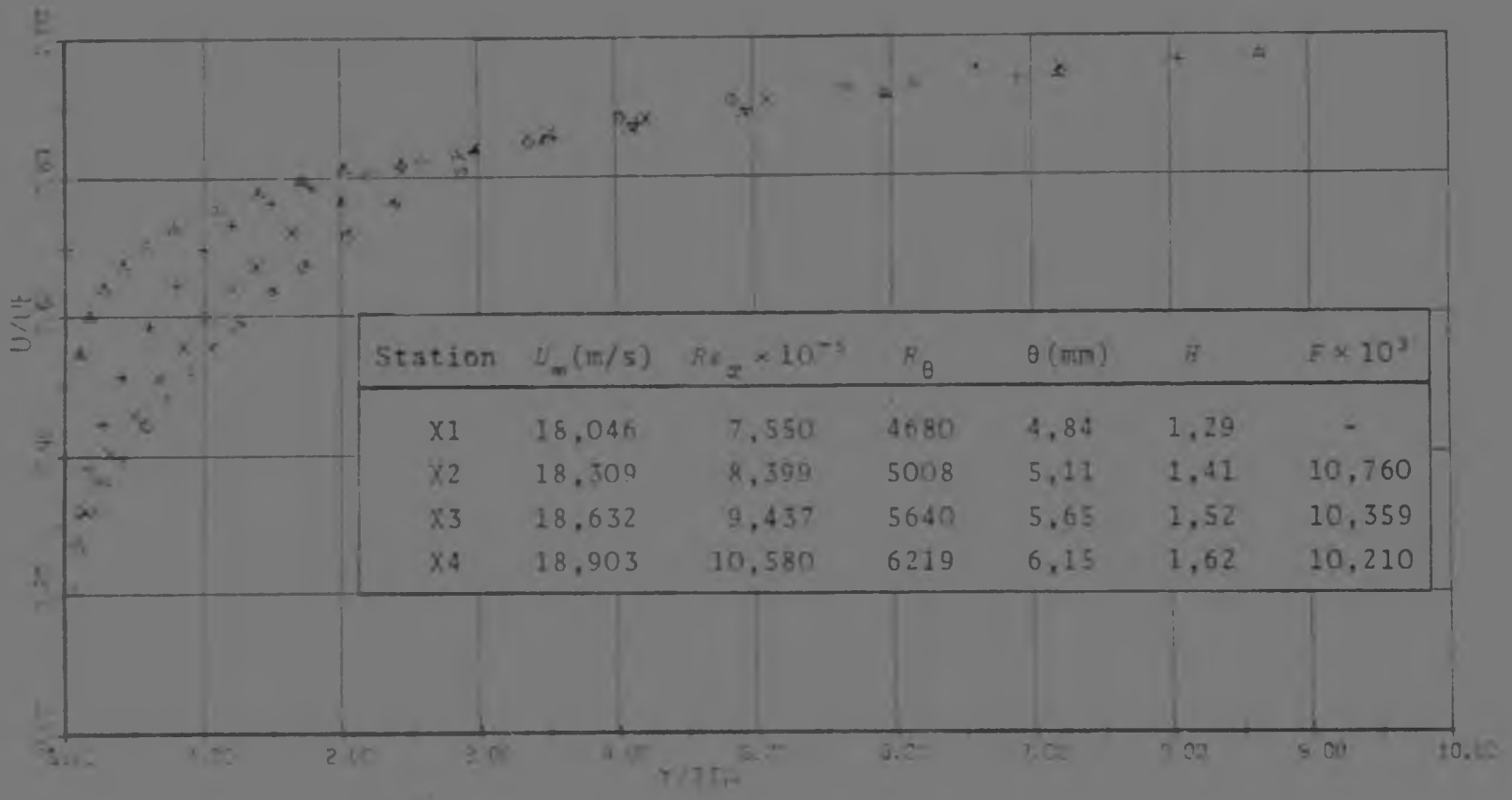


Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^5$
X1	16,927	6,982	4036	4,51	1,29	-
X2	17,106	7,722	4469	4,96	1,36	8,418
X3	17,370	8,652	5061	5,53	1,45	8,233
X4	17,742	9,678	5440	5,82	1,51	8,060

FIG 7.10x : TEST 30N1 E-8,56-17 80% BLOCKED

PLOT OF U/UE VS Y/TTA

RUN 01 12/1,4-5-17



Station	U_∞(m/s)	$Re_x \times 10^{-5}$	R_θ	θ(mm)	H	$F \times 10^3$
X1	18,046	7,550	4680	4,84	1,29	-
X2	18,309	8,399	5008	5,11	1,41	10,760
X3	18,632	9,437	5640	5,65	1,52	10,359
X4	18,903	10,580	6219	6,15	1,62	10,210

FIG 7.10y : TEST 01D1 E-11,66-17 80% BLOCKED

E and C grade plates were made by sintering spherical particles. The surface of the A grade plate was therefore much smoother, and the injection pattern was expected to be different from that experienced using grades E and C. (See Fig 7.11 and Appendix B).

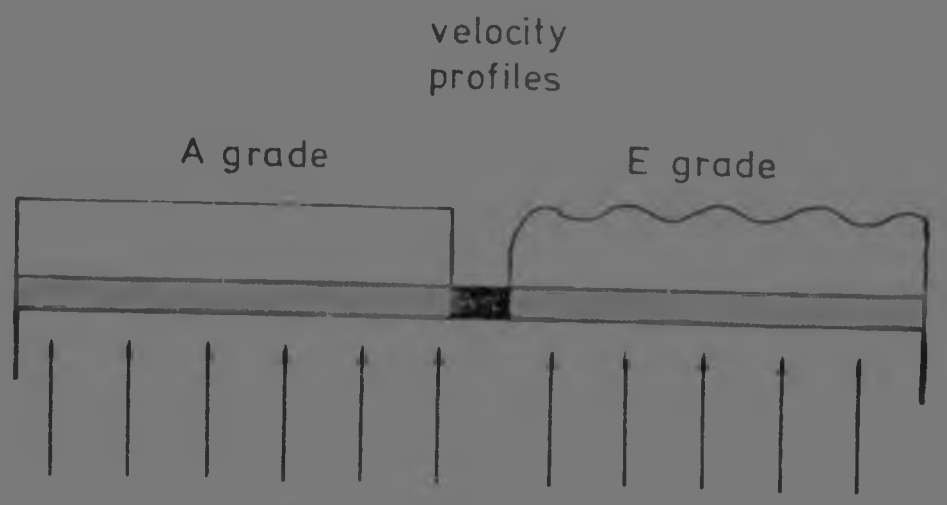


FIG 7.11 : v_w PROFILES EXPECTED FOR A AND E GRADE PLATES

Profiles obtained for the A grade plate and for test 28S1 were virtually identical. Note that for the former, F_{av} = 0,00755, for the latter F_{av} = 0,00758. The input profiles were the same as well. It was concluded that the velocity profile was mainly a function of injection ratio.

Having compiled a set of data for the unblocked porous plate, a few tests were done in which the lower porous surface was partially sealed with masking tape. The first tests were run with 50% blockage, as is shown in Fig 7.12.

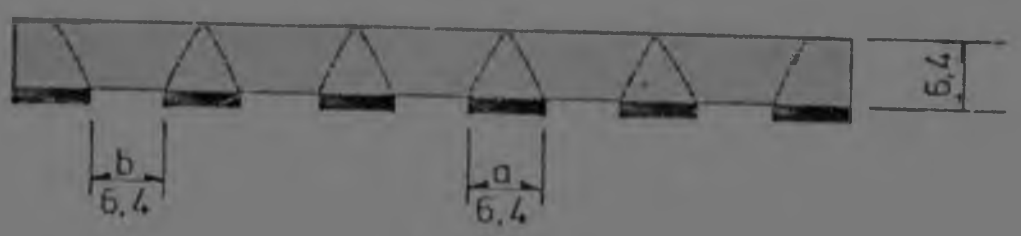


FIG 7.12 : SKETCH SHOWING THE PARTIALLY BLOCKED POROUS PLATE, 50% BLOCKED

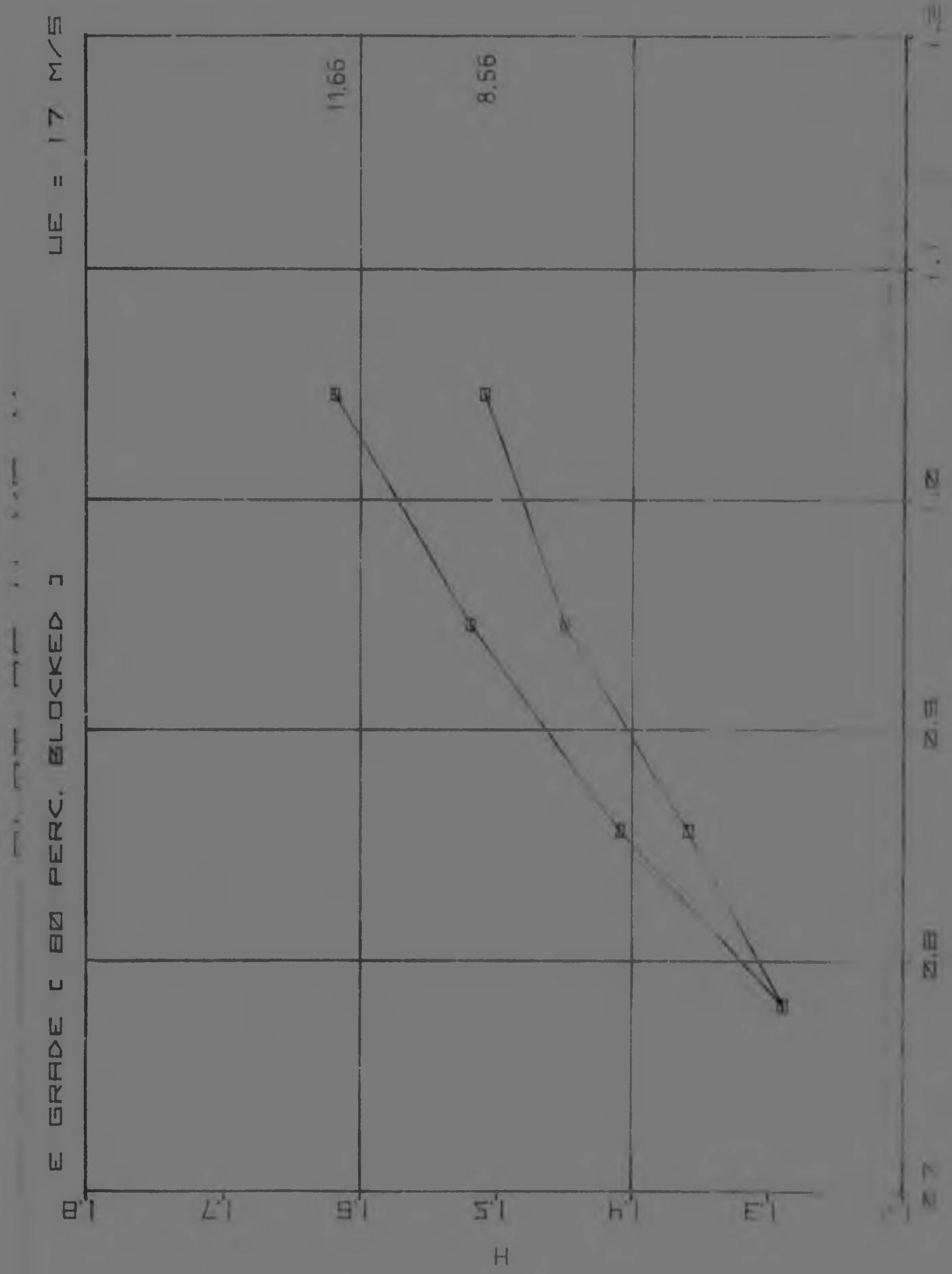


FIG 7.13d : PLOT OF — VS x FOR u_e — 17 m/s, 80% BLOCKED

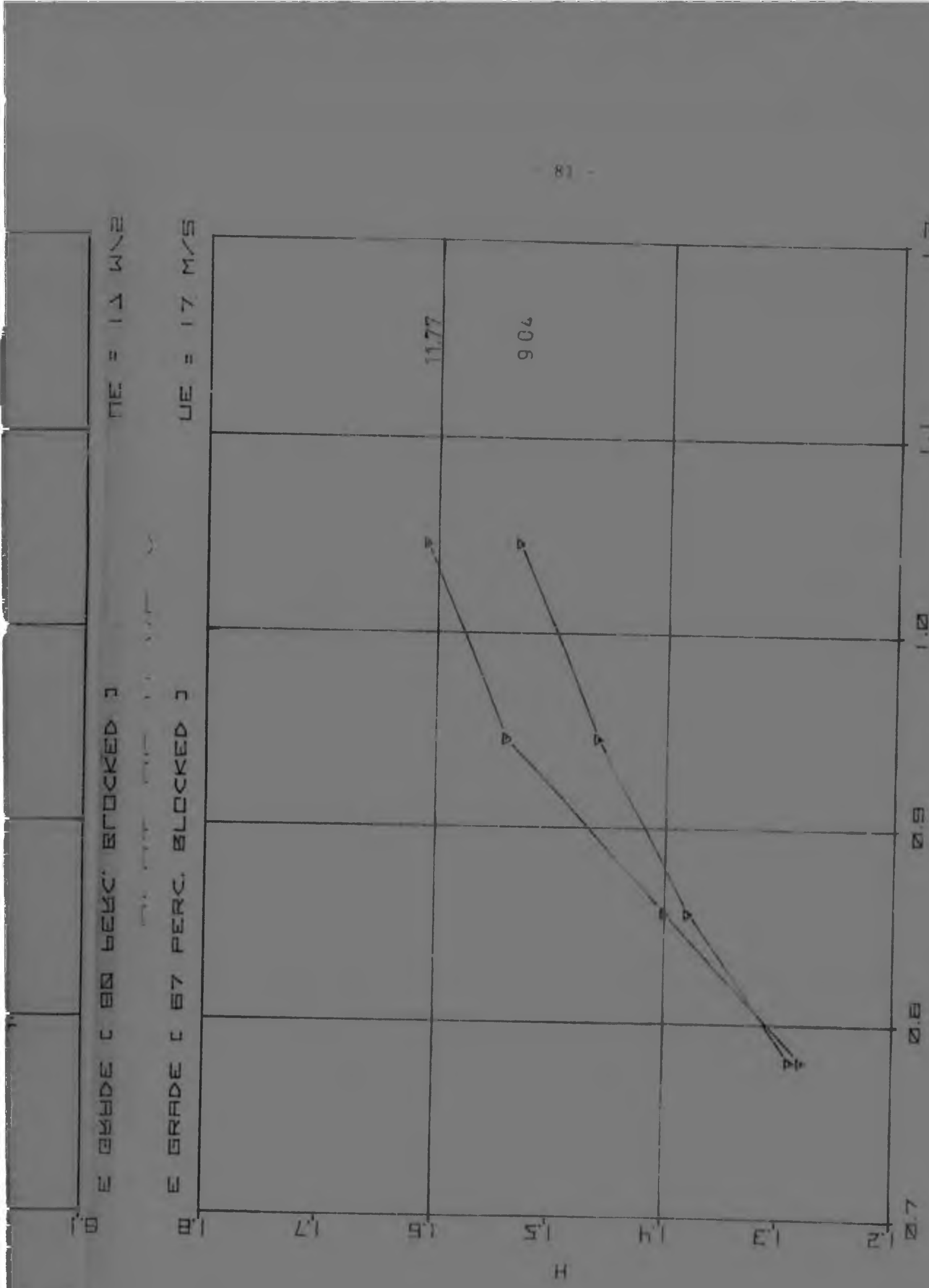


FIG 7.13c : PLOT OF H vs x FOR u_g = 17 m/s, 67% BLOCKED

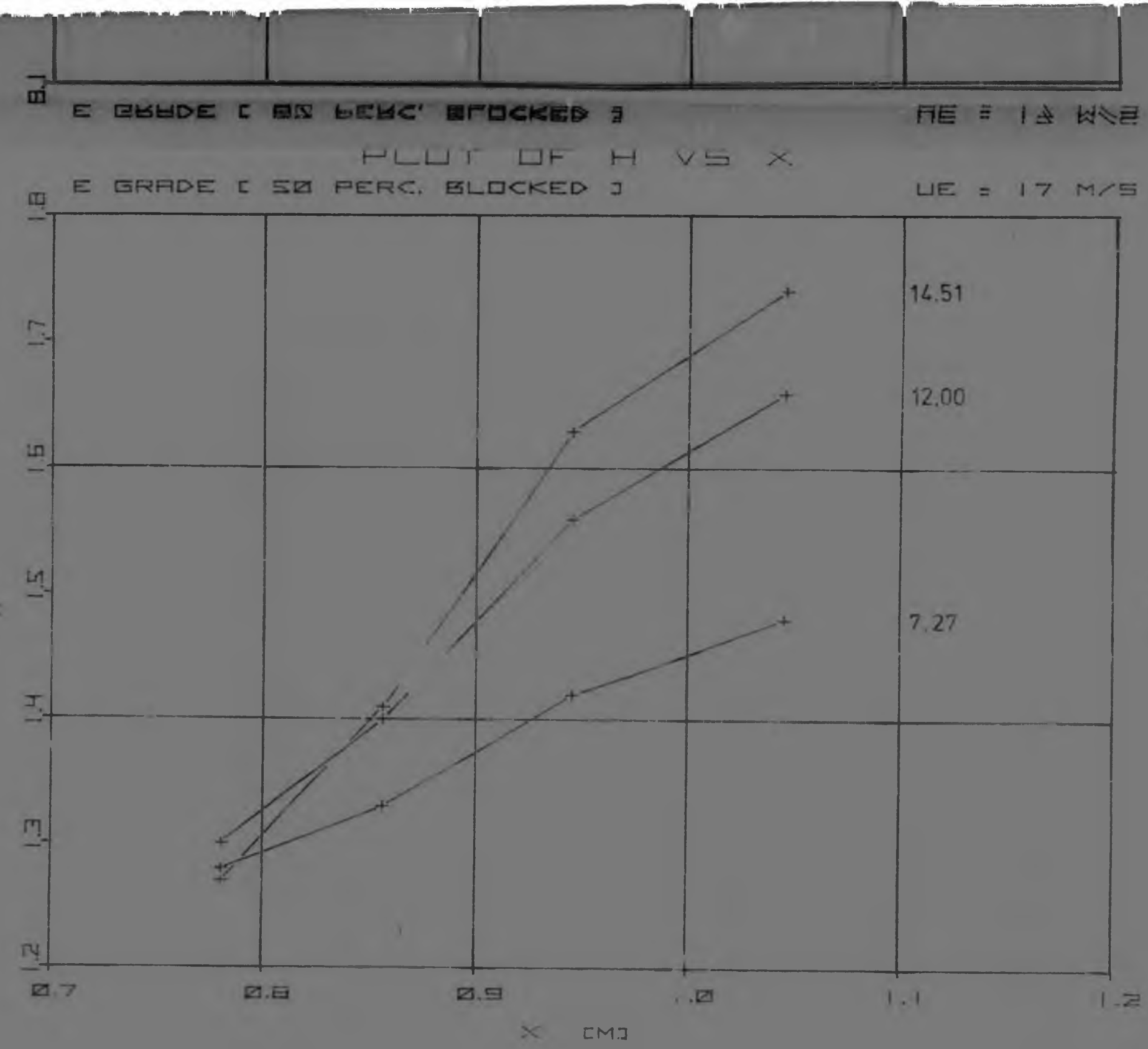


FIG 7.13b : PLOT OF H VS X FOR u_e = 17 m/s, 50% BLOCKED

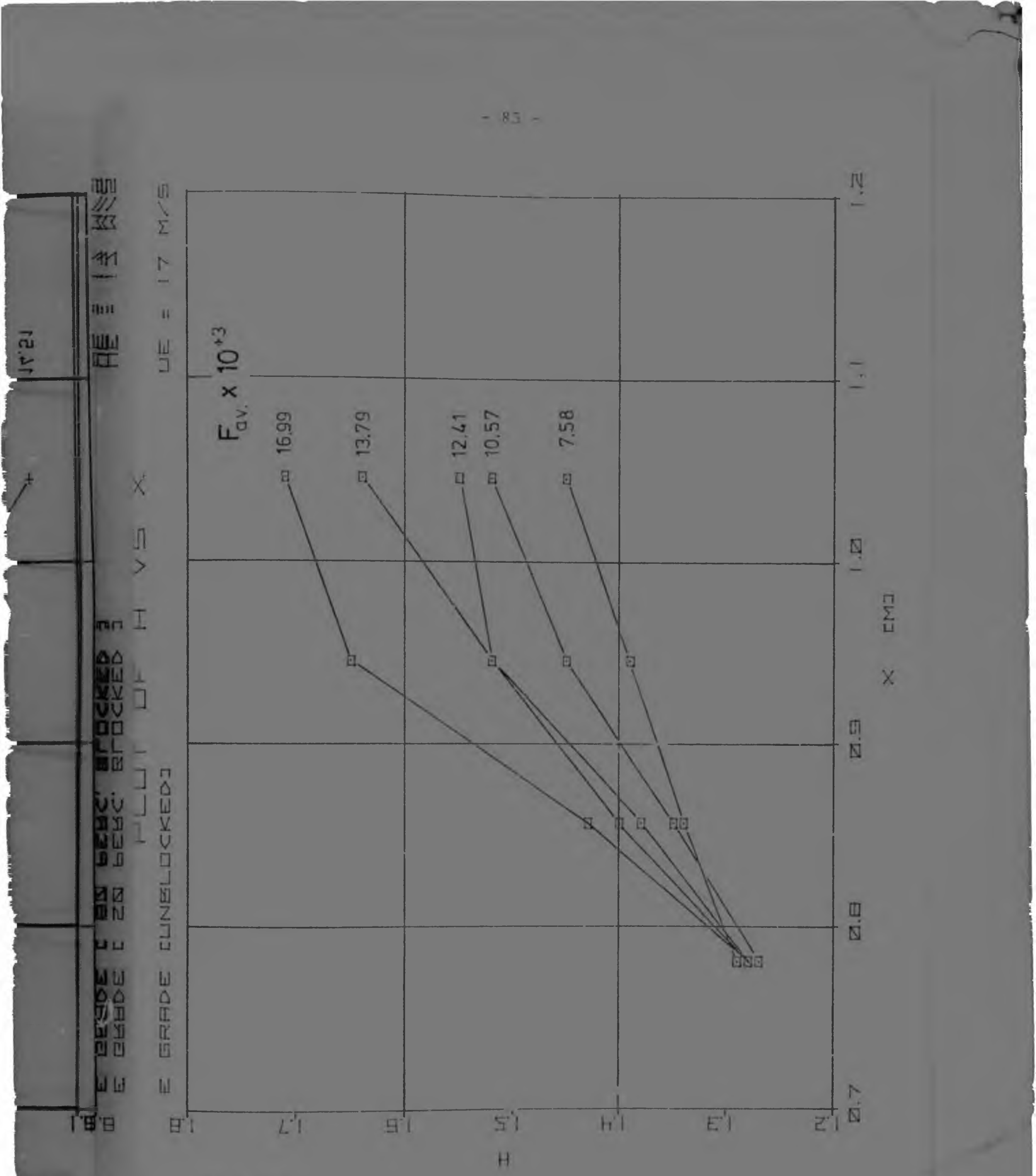


Fig 7.13a : PLOT OF H vs x FOR u_a = 17 m/s, UNBLOCKED

Tests 23N1 to 24N1 were run at U_∞ = 17 m/s, 50% blockage of the E grade plate. See Fig 7.10s to u.

With the tape covering 67% of the plate, a = 12,7 mm and b = 6,35 mm, tests 28N1 and 29N1 were performed. These profiles are presented in Fig 7.10v and w.

Two tests were run with a = 12,7 mm, b = 3,18 mm; this resulted in 80% blockage. Fig 7.10x and y are the profiles for these tests.

The effect of blockage is shown in Fig 7.13. This plot of shape factor, H vs x-station, was thought to present the change in a more succinct way than the usual velocity profile of Fig 7.10. The injection ratio, F, became a very average parameter. The definition of F now becomes :

$$F = \frac{Q_{trans}}{A_{upper} U_\infty} \qquad \text{for } \rho \text{ constant} \qquad \ldots\ldots [7.3.1]$$

Where Q_{trans} was the transpiration flow rate and A_{upper} the area of porous plate exposed to the main stream.

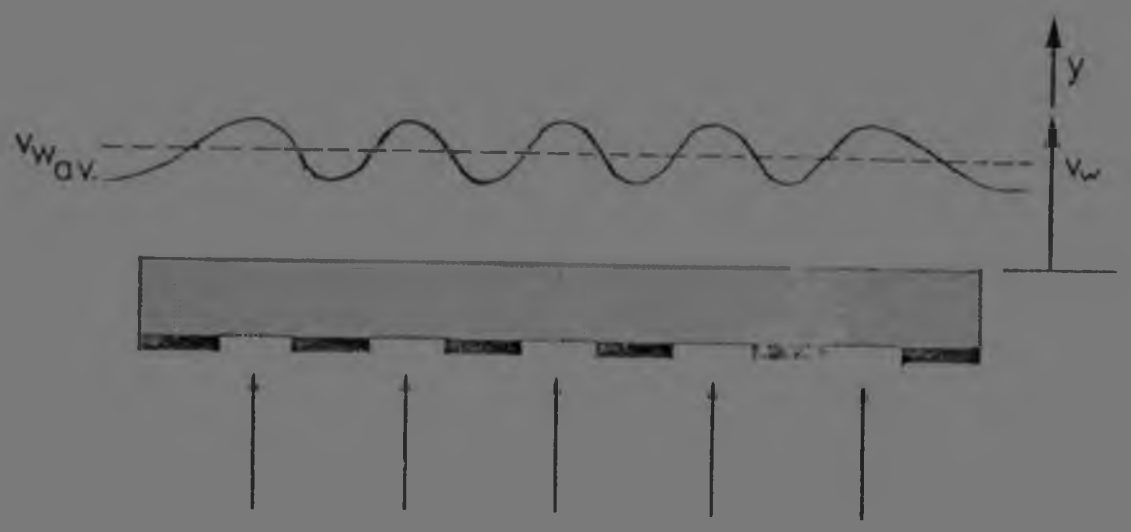


FIG 7.14 : DISTRIBUTION OF v_w WITH x FOR THE PARTIALLY BLOCKED POROUS PLATE, AND THE SPREAD OF THE FLOW IN THE POROUS MEDIUM WITH y

By considering Fig 7.13, it is seen that the curves do not increase with F as they do for the unblocked plate. The profile is developing for an apparently higher F. Clearly v_w was alternately above and below the average transpiration velocity. The average momentum in the y-direction must remain the same as for the unblocked porous plate, however, some of the injected flow penetrates deeper into the shear layer. Thus it is concluded that with the same transpiration flow rate, blockage results in an apparent increase in F and [illegible]. If the Stanton number is expected to be a function of [illegible] (see Moffat and Kays, 1968), a decreased heat transfer coeff. would become possible with blockage.* Intuitively, the opposite may be expected, however, only experiment is expected to resolve the matter.

It would therefore appear that the blockage caused by strengthening ribs below the porous surface, could result in improved performance.

7.3.2 The bilogarithmic plotting technique

This method for determining [illegible] from the velocity profile was discussed in Chapter [illegible], section 3, at some length. It was developed by Black and Sarnecki (1958), and yielded an effective imaginary shear velocity at the wall. This was merely a technique, and did not imply reverse flow, as may be encountered for flows in an adverse pressure gradient. The results are given in Fig 7.15a to c, Fig 7.16 and Fig 7.17. These graphs are presented because (i) Fig 7.15 showed the trend in the profiles for increasing F, and (ii) the graphs allowed an interesting comparison of the present results with those of Mickley and Davis (1956).

Fig 7.15a to c are graphs of $u/u_e - Y_2^2$ vs Y for the basic data of Mickley and Davis (1956), and the present work. Fig 7.15a is for U_∞ = 17 m/s, E grade. This graph also shows the limiting curves, ie. for $u/u_e = 0$ and $u/u_e = 1$, ie. the edge of the boundary layer. Plots shown in

* see Addendum for further explanation.

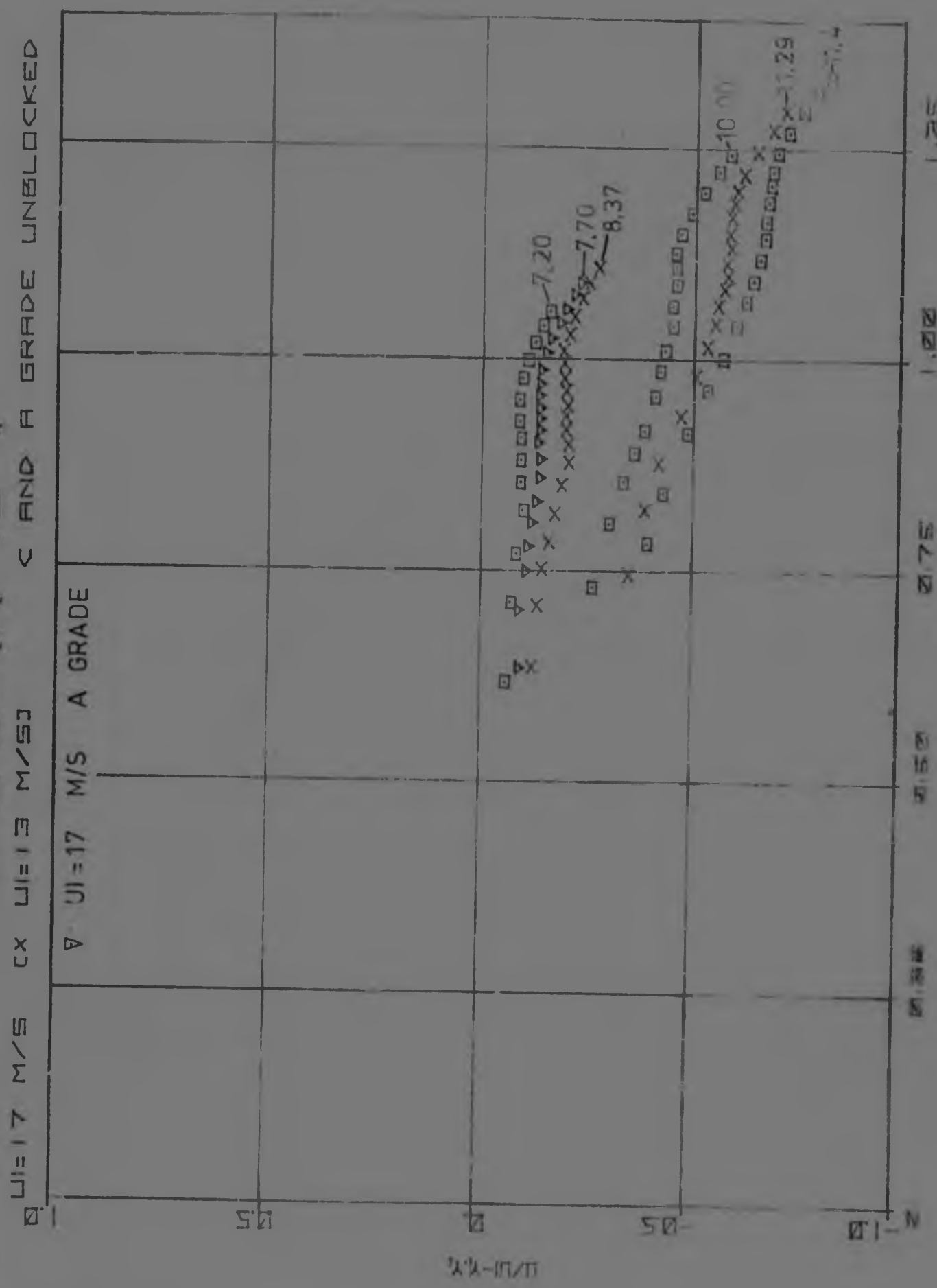


FIG 7.15c : SOME EXPERIMENTAL RESULTS PLOTTED ON THE RILOG CO-ORDINATES

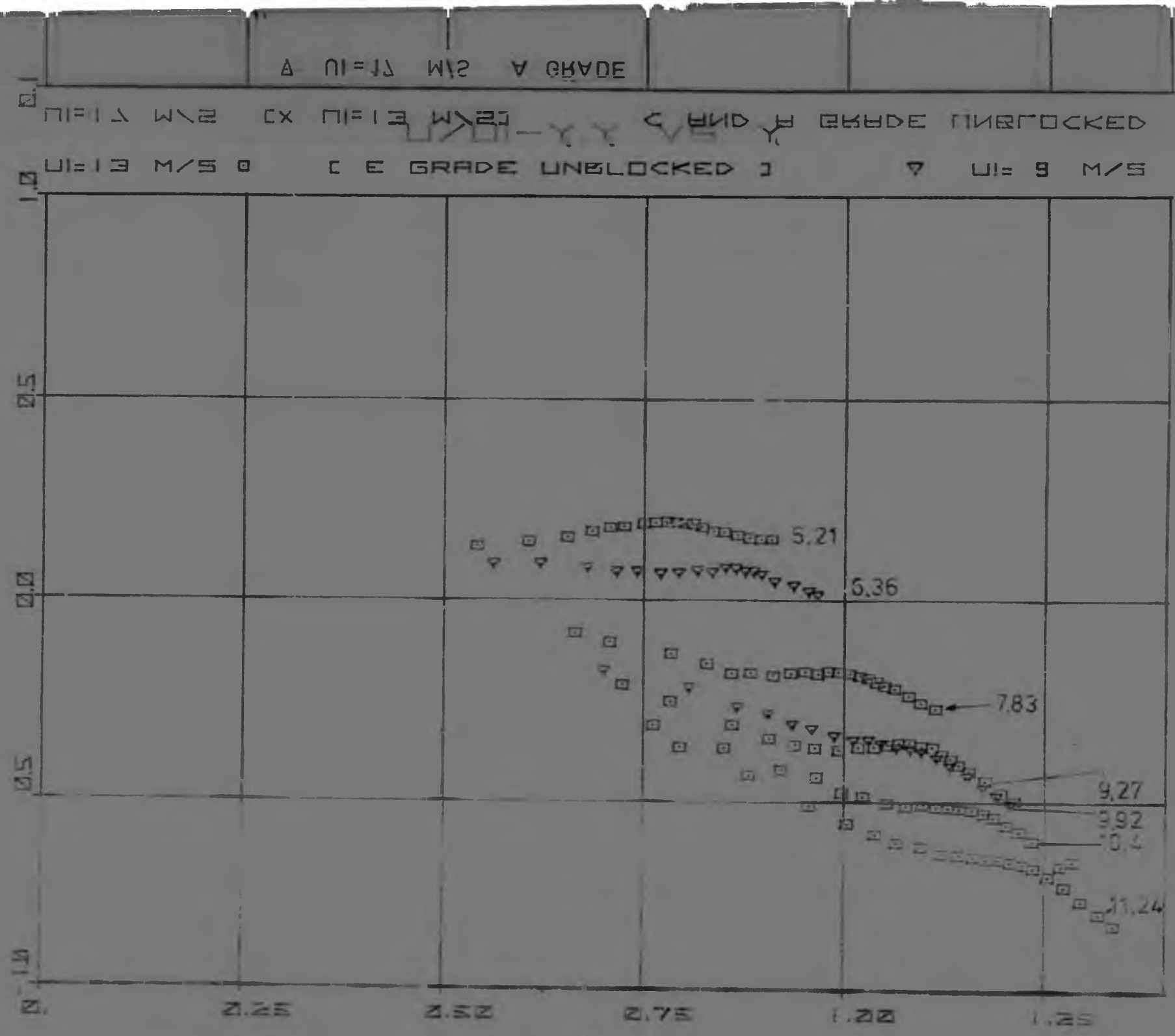


FIG 7.15B : SOME EXPERIMENTAL RESULTS PLOTTED ON THE BILOG CO-ORDINATES

X - M/S

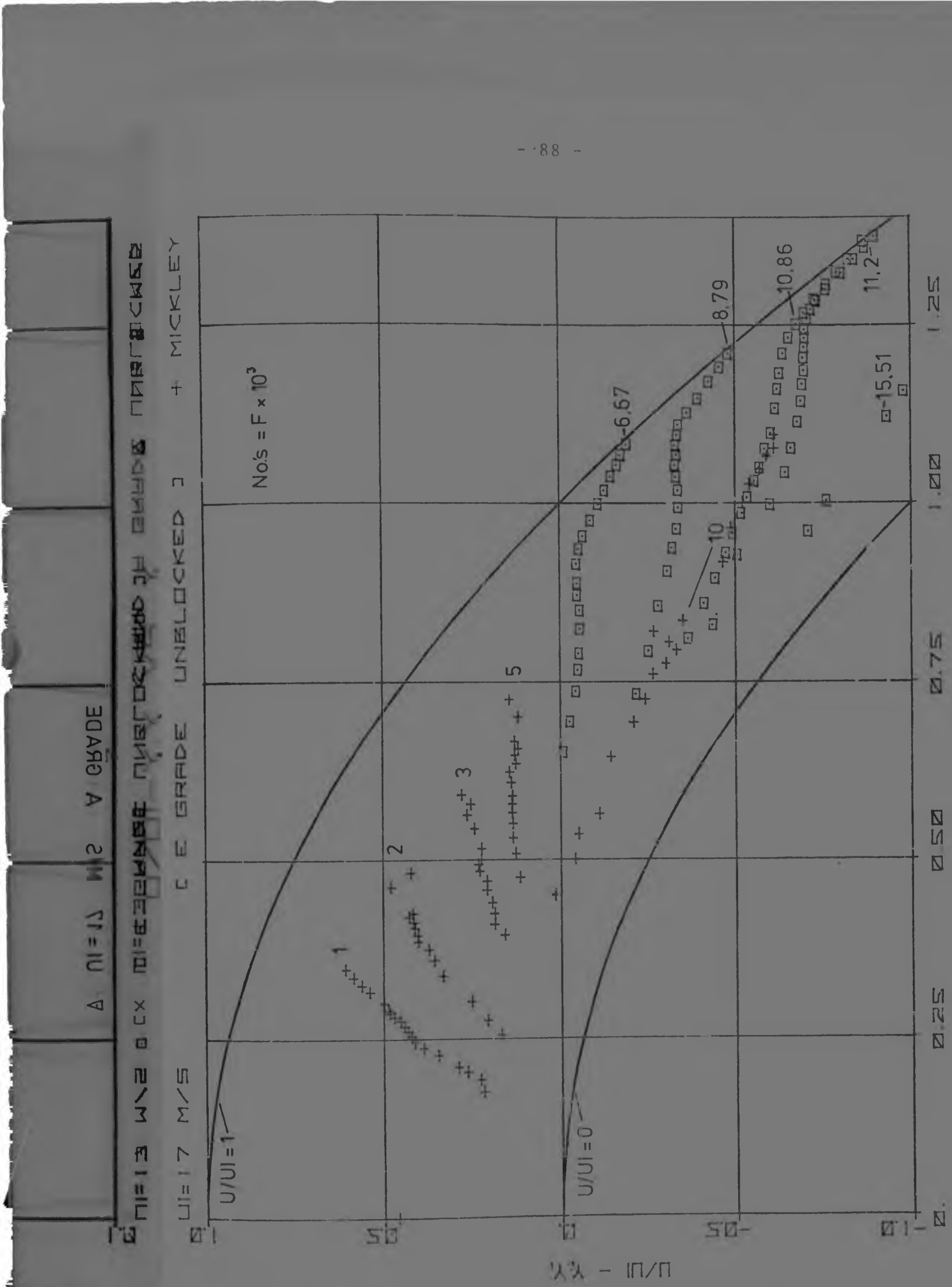


FIG 7.15A : PRESENT DATA AND THAT OF MICKLEY AND DAVIS (1956) PLOTTED ACCORDING TO THE BILOG LAW TECHNIQUE

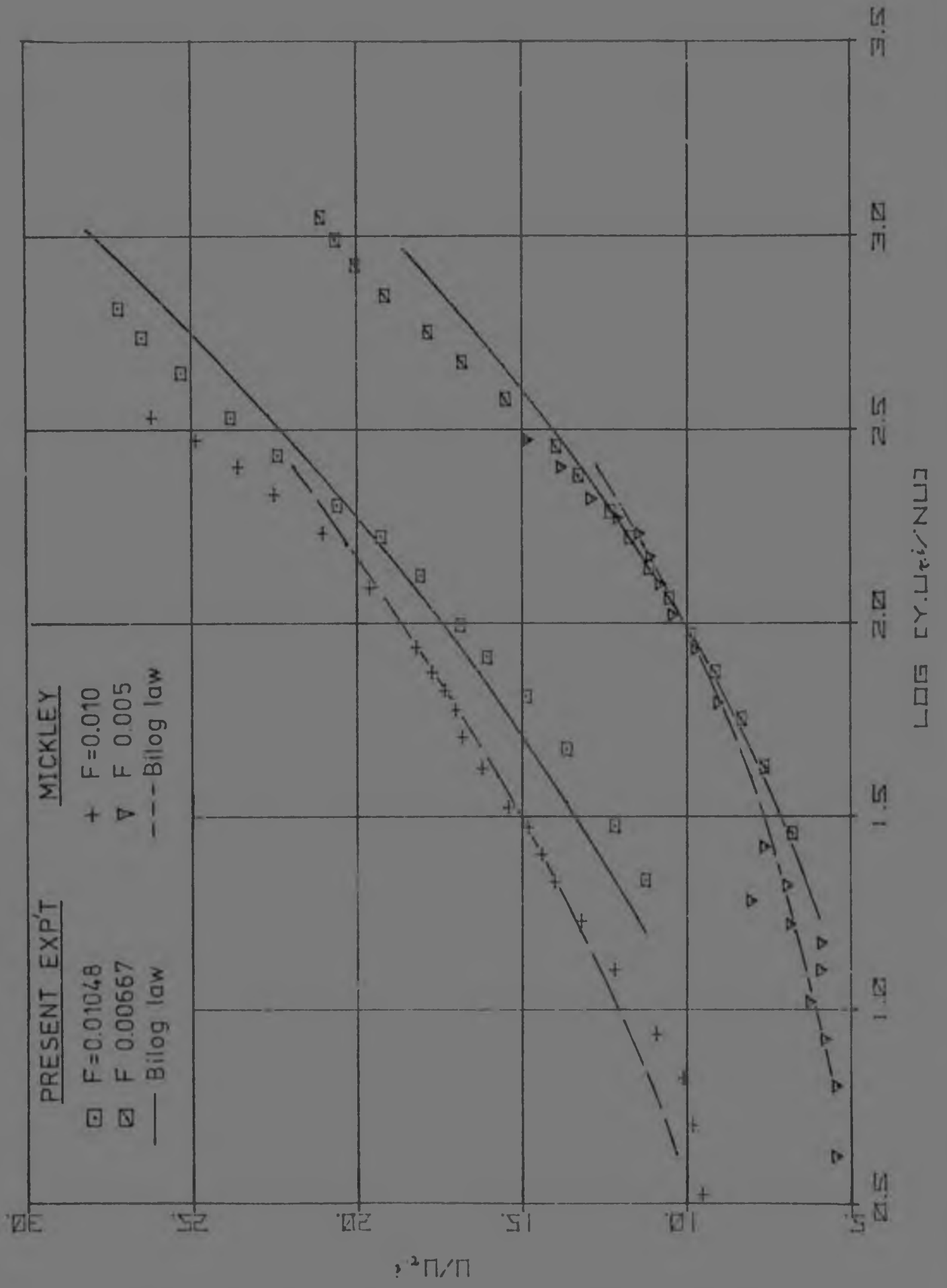


FIG 7.16 : EXPERIMENTAL DATA AND BILOG PREDICTED PROFILE

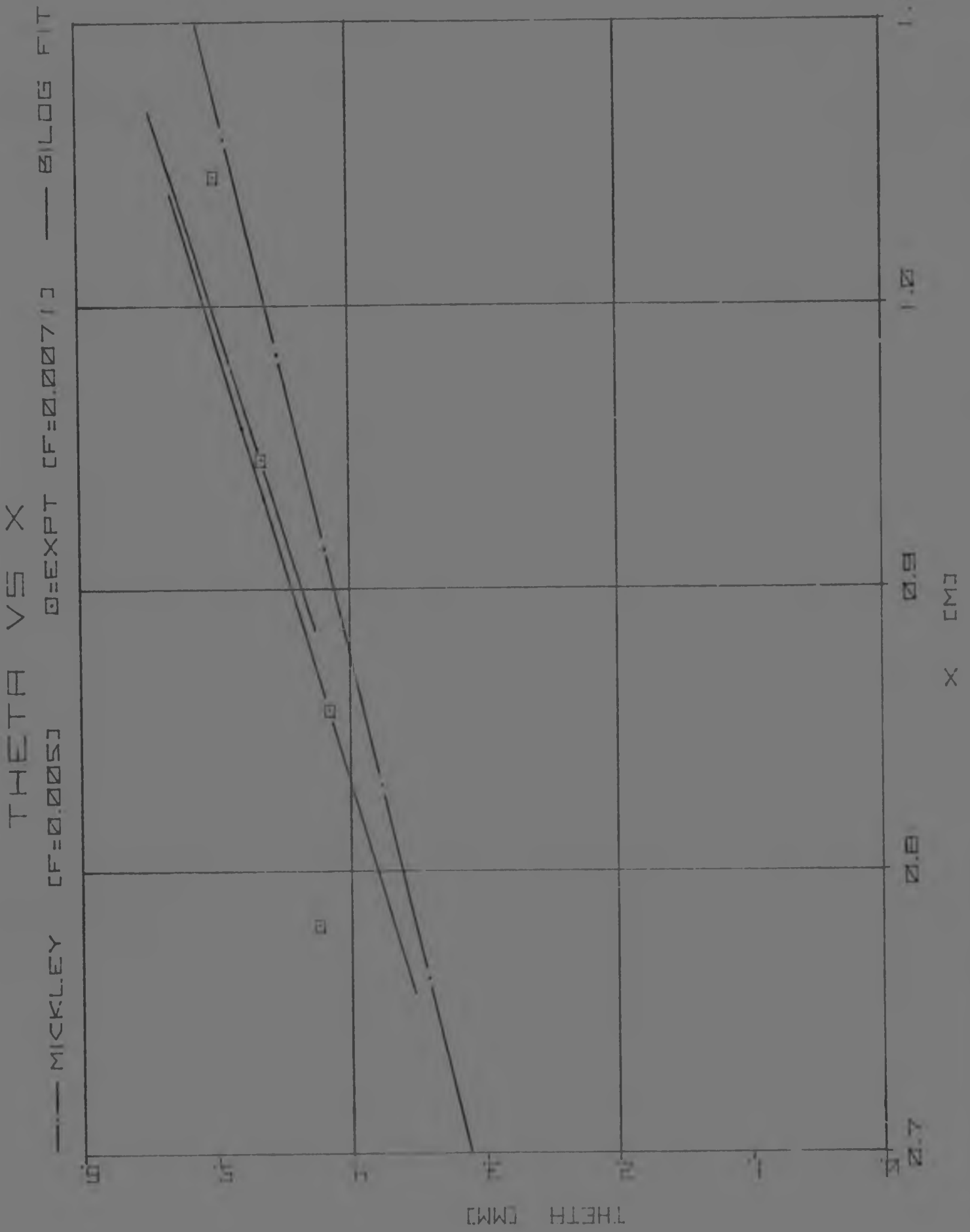


FIG 7.17 : GRAPH OF θ vs x - EXPERIMENTAL AND BILOG PREDICTED SLOPE

Fig 7.15b are for U_∞ = 13 m/s (⊡) and U_∞ = 9 m/s (∇), both sets on the E grade plate. Results obtained for U_∞ = 17 m/s (⊡), U_∞ = 13 m/s (×) on the C grade plate, and for the single run using the A grade plate (U_∞ = 17 m/s (∇)) are plotted on Fig 7.15c.

By fitting a straight line to the experimental points of a run (in the bilog region), u_τ could be calculated from the slope and ordinate intercept of that line (see equations 3.3.21 to 3.3.23). If this line did not pass through the limiting line of u/u_e = 0, u_τ would be imaginary. This was the case for all values of $F \geq 5$. The uncertainty in fitting the straight line can be seen from the scatter of the points. Two examples are shown in the non-dimensional plot of u/u_τ vs log $y.u_\tau/\nu$ in Fig 7.16. Again comparable results of Mickley and Davis (1956) are included. The lines represent the profiles predicted by the bilog law.

Because it was of importance to know $d\theta/dx$, it was thought useful to show that the bilog technique could predict this derivative, but gave no indication of the origin of the boundary layer. Fig 7.17 shows a typical example for F = 0,0071. The slope was calculated at a point, and a straight line with that gradient drawn through the [illegible]. Good agreement was again obtained with the result of Mickley and Davis (1956).

It is felt that as this method yielded imaginary shear, it is only useful as a plotting technique, and is inadequate for estimating c_f. The graphs did allow comparison of the present work with that of other researchers.

7.3.3 A two-parameter family of curves

The two-parameter family of curves of Thompson (1965) was used to construct the mean velocity profile ahead of the porous wall. McQuaid (1967) suggested a family of curves for the transpired boundary layer. This set of curves

predicted the velocity profile and the skin friction. Intermittency was included in the formulation (by the term δ_g, see eqn.[3.3.30]). This author showed that u/U_∞ was a function of y/δ_g, c_f, $R\delta_\theta$, v_w/U_∞, which was transformed to eqn.[3.3.29]. This was a function of y/θ, H, R_θ, v_w/U_∞.

A cross-plot of the present results was attempted, and is shown in Fig 7.18. These values were obtained from the velocity profiles (Fig 7.10) by keeping u/U_∞ constant, and reading y/θ for the various x stations (effectively Re_x, or Re_θ). It was thought that for constructing mean velocity profiles, it would be more useful to have u/u_e as one of the axes. Thus y/θ was kept constant, and the value of u/u_e read from Fig 7.10. These values were plotted, and a number of points from the experimental work of Mickley and Davis (1956) and McQuaid (1967) added. A series of curves were obtained, apparently independent of v_w/U_∞, and are presented as Fig 7.19 a to d.

This result may be stated :

$$H = H(R_\theta, v_w/U_\infty) \qquad \ldots\ldots\ldots [7.3.2]$$

$$u/U_\infty = f(y/\theta, H) \qquad \ldots\ldots\ldots [7.3.3]$$

A limitation of this family is that c_f is not accounted for. McQuaid (1967) presented a skin friction law, for v_w/U_∞ up to 0,010 :

$$c_f = c_f(H, R_\theta, v_w/U_\infty) \qquad \ldots\ldots\ldots [7.3.4]$$

These curves were assumed to hold for a porous wall, continuous from $x = 0$. It was thought that the values of c_f would be very different for discontinuous injection. However, it must again be emphasised that only direct measurement of τ_w would give reliable values of c_f. This would be necessary in each individual test, for its particular input profile, porous plate configuration, surface roughness, pressure gradient, etc.

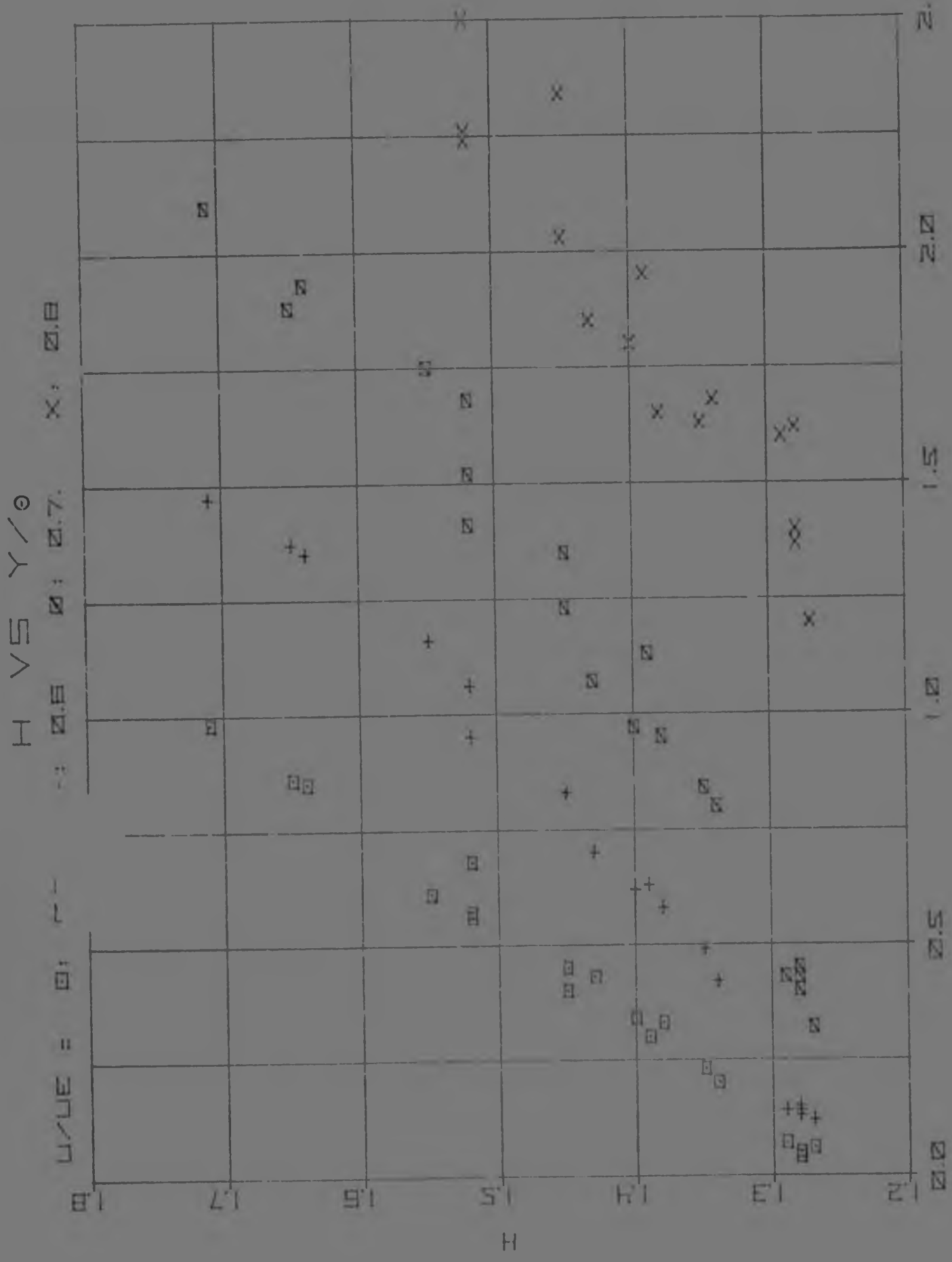


FIG 7.18 : CROSS PLOT OF PRESENT RESULTS, u/u_e CONSTANT

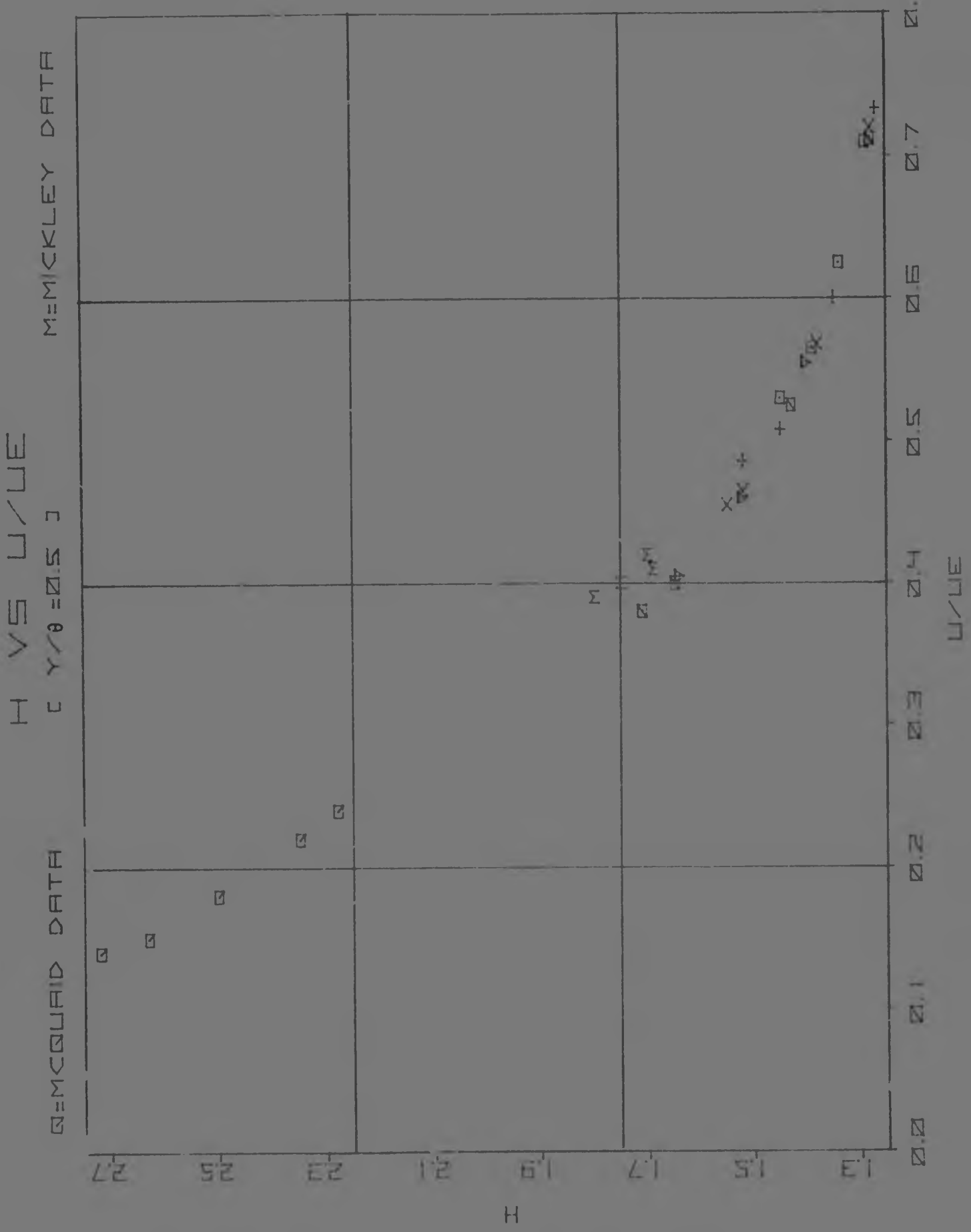


FIG 7.19A : CROSS PLOT OF EXPERIMENTAL DATA, FOR y/θ CONSTANT

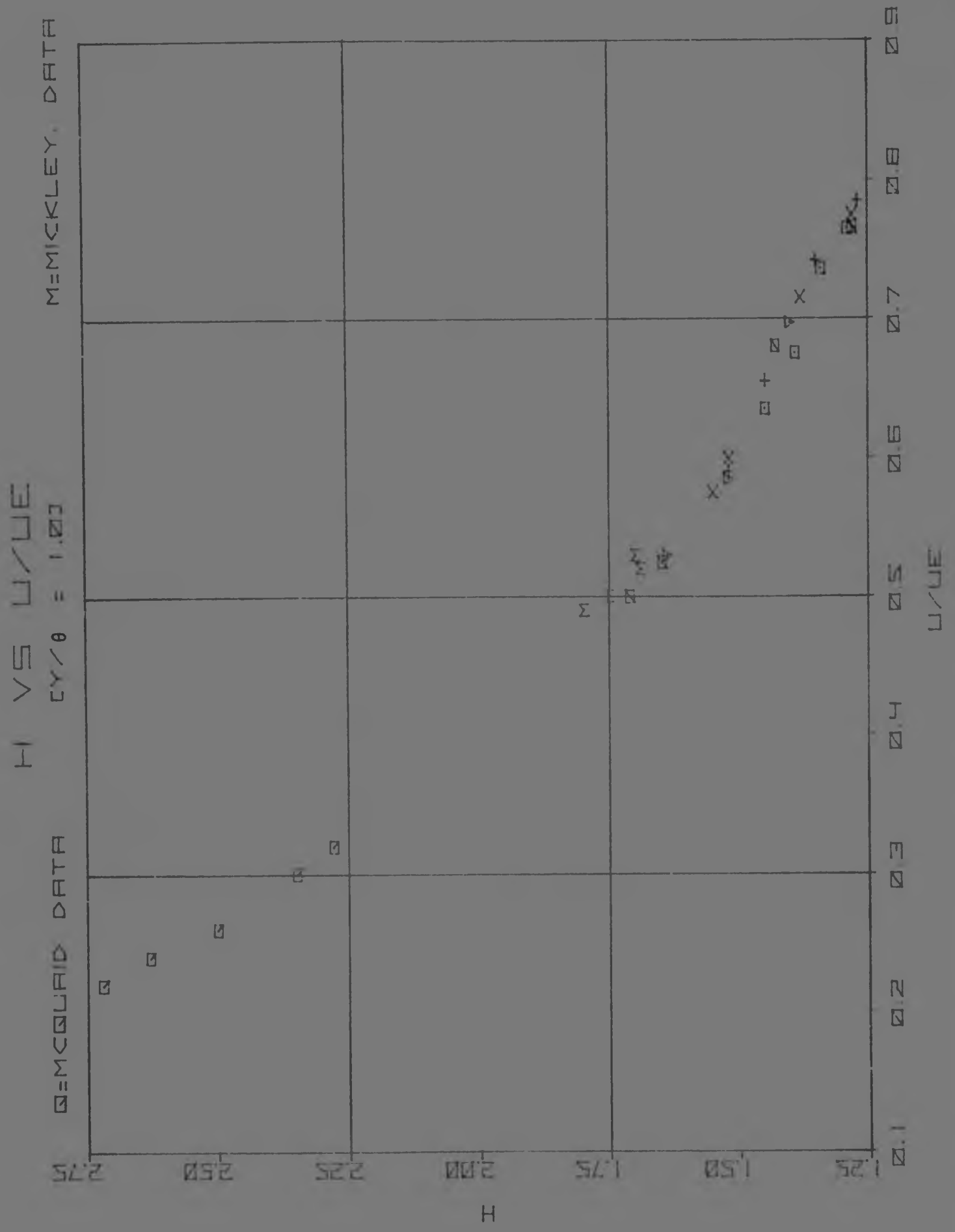


FIG 7.10B : CROSS PLOT OF EXPERIMENTAL DATA, FOR y/θ CONSTANT

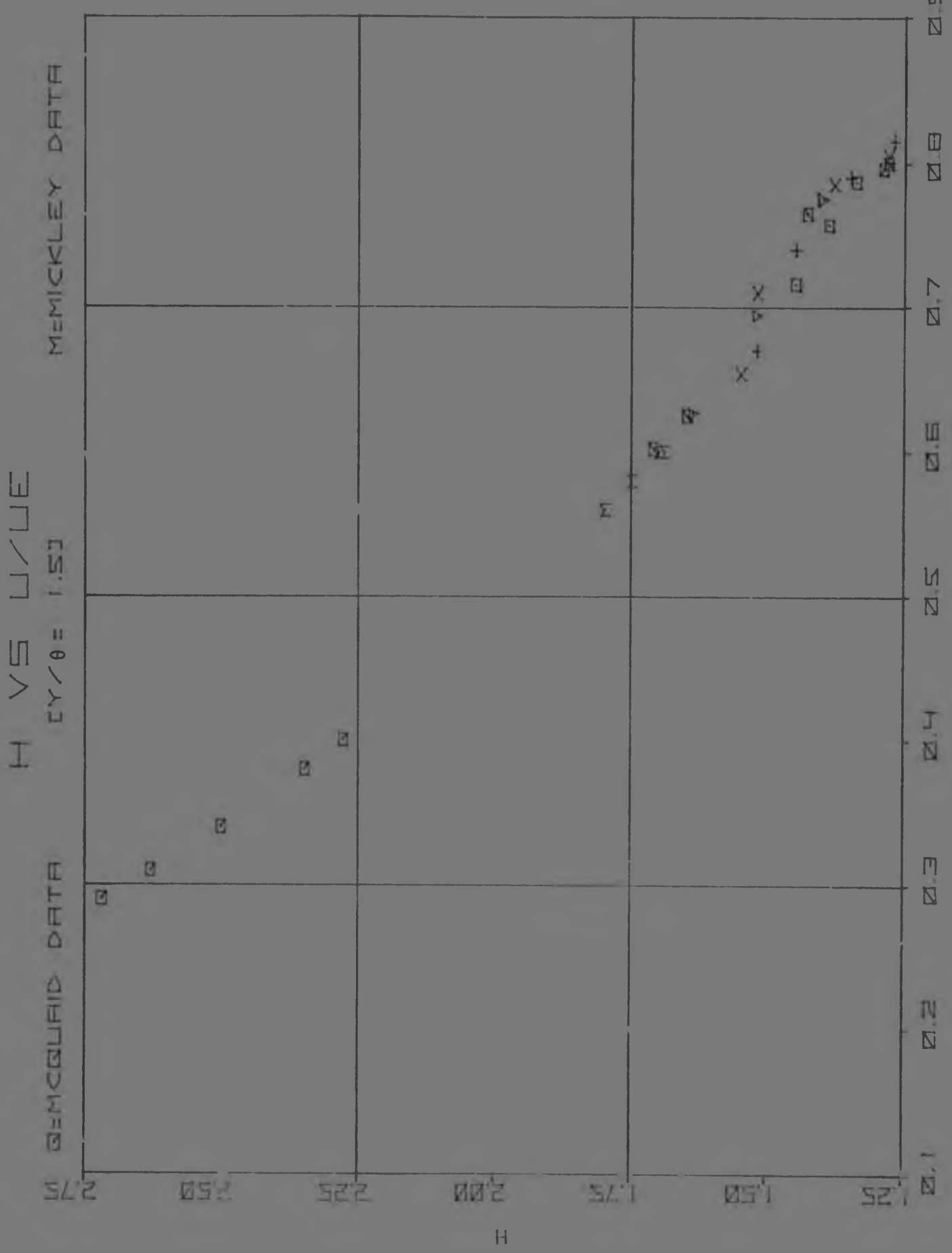


FIG 7.19C : CROSS PLOT OF EXPERIMENTAL DATA, FOR y/θ CONSTANT

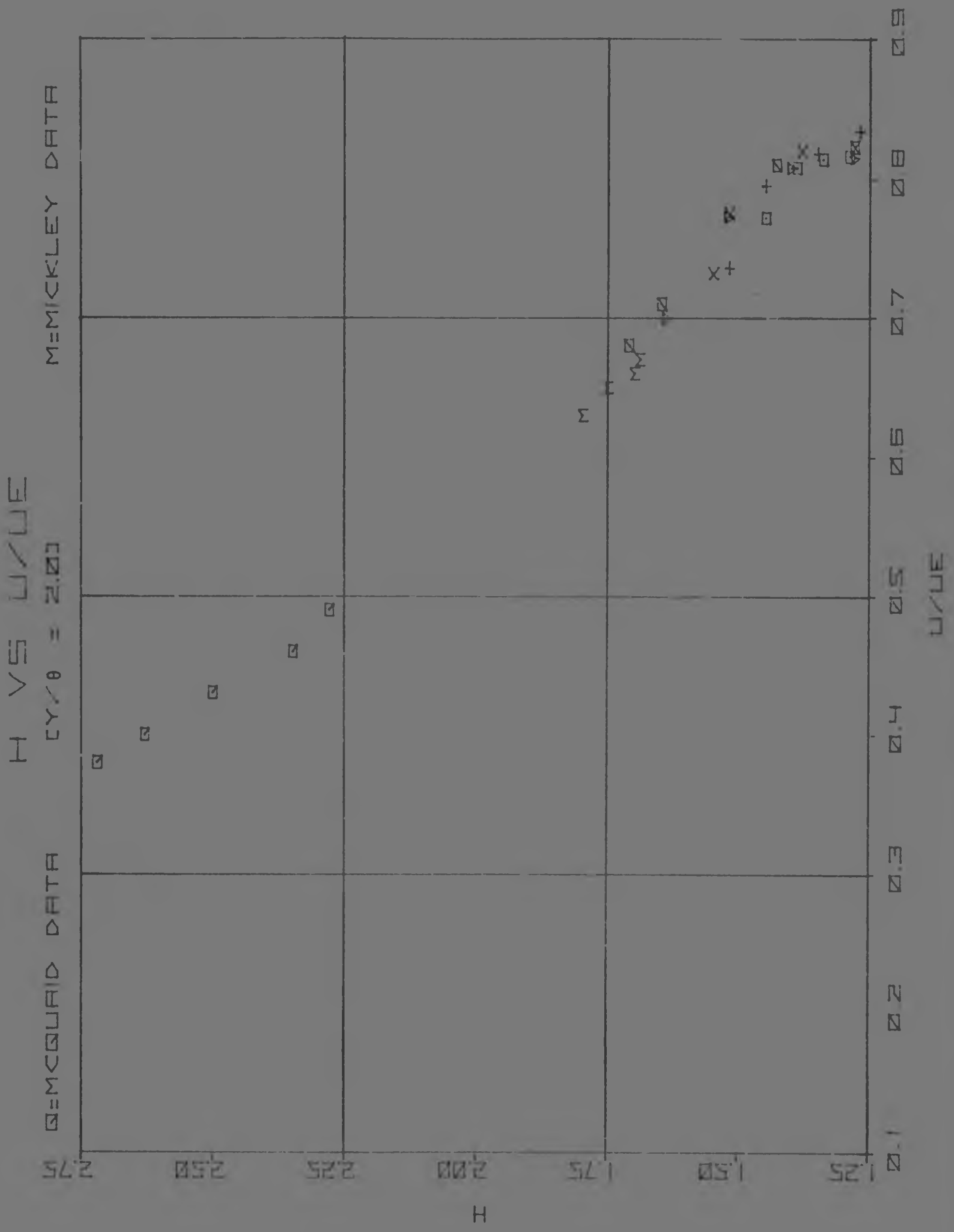


FIG 7.19D : CROSS PLOT OF EXPERIMENTAL DATA, FOR y/θ CONSTANT

7.4 Computer Programme Results

As discussed previously, the programme required two initial profiles to start the solution. These could be either laminar or turbulent, but with $v_w = 0$. Starting the solution with transpiration from the boundary layer origin was therefore not possible. By installing a trip wire, it is possible to obtain a turbulent profile for very low values of Re_x experimentally. However, the equation used to generate the turbulent profile was valid for $Re_x > 5 \times 10^4$. Thus it was not possible to simulate experimental conditions very effectively.

The boundary layer thickness was over-estimated because the equation used was valid only to $y^+ = 10^4$ (depending on Reynolds number). This is illustrated below in Fig 7.20.

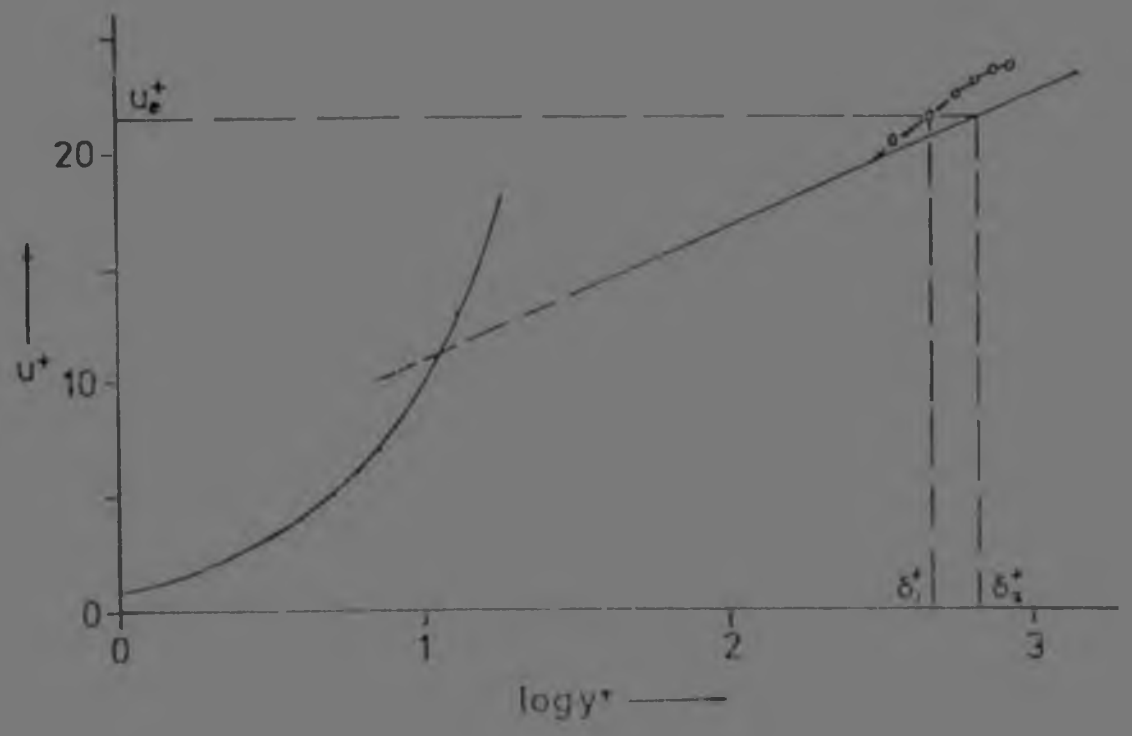


FIG 7.20 : DETAIL OF SEMI-LOG PLOT OF TURBULENT PROFILE, SHOWING ERRONEOUS VALUE OF δ

Clearly, if the straight line was used, $\delta^+ = \delta_2^+$, instead of δ_1^+, obtained from experimental points. If a wake law was not used in this region, a power law would probably be the easiest method of generating u^+ near the edge of the layer.

7.4.1 Main computer runs

The results of the main computer runs are shown graphically in Fig 7.21 a to j. See also Appendix F3 for tabulated values of Re_θ, H, etc.

By generating the input profiles on a flat plate, the programme was a close simulation of the experimental work. It was, however, not possible to obtain the identical input profile that was measured experimentally without extensive reprogramming - the Van Driest profile was used instead. Furthermore, the programme as written is for the 'flat plate in an infinite stream', whereas almost channel flow was obtained in the tunnel, ie. the boundary layer growth in the tunnel was limited to the centre line of the tunnel.

Examination of Fig 7.21 shows that the profiles generated are very similar to those depicted in Fig 7.10. The trends with x and F were identical, ie. increased 'laminarisation' with x and F.

The values of c_f appear to be highly erroneous. On the other hand, there is no experimental data for the step change in transpiration and surface roughness with which these values could be compared. If ϕ_0'' is obtained from ϕ, negative c_f results, and hence imaginary u_τ^+, p^+ and v_τ^+. Although this is predicted by the bilog law, this is not of much use, as the programme cannot solve the equations for imaginary shear velocity. ϕ_0'' was therefore obtained from ϕ', and it is expected that the error in ϕ_0'' does not affect the solution significantly (Note:- ϕ_0'' affects the inner eddy-viscosity equation). Clearly the finite difference equation which yields satisfactory values of c_f for the unblown layer was inadequate for the blown boundary layer. By decreasing the step size more accurate results would be obtained, but this would increase the cost of running the programme significantly. In this work, H=0,065 was common, whereas other investigators have reported H=0,001, with 300 steps.

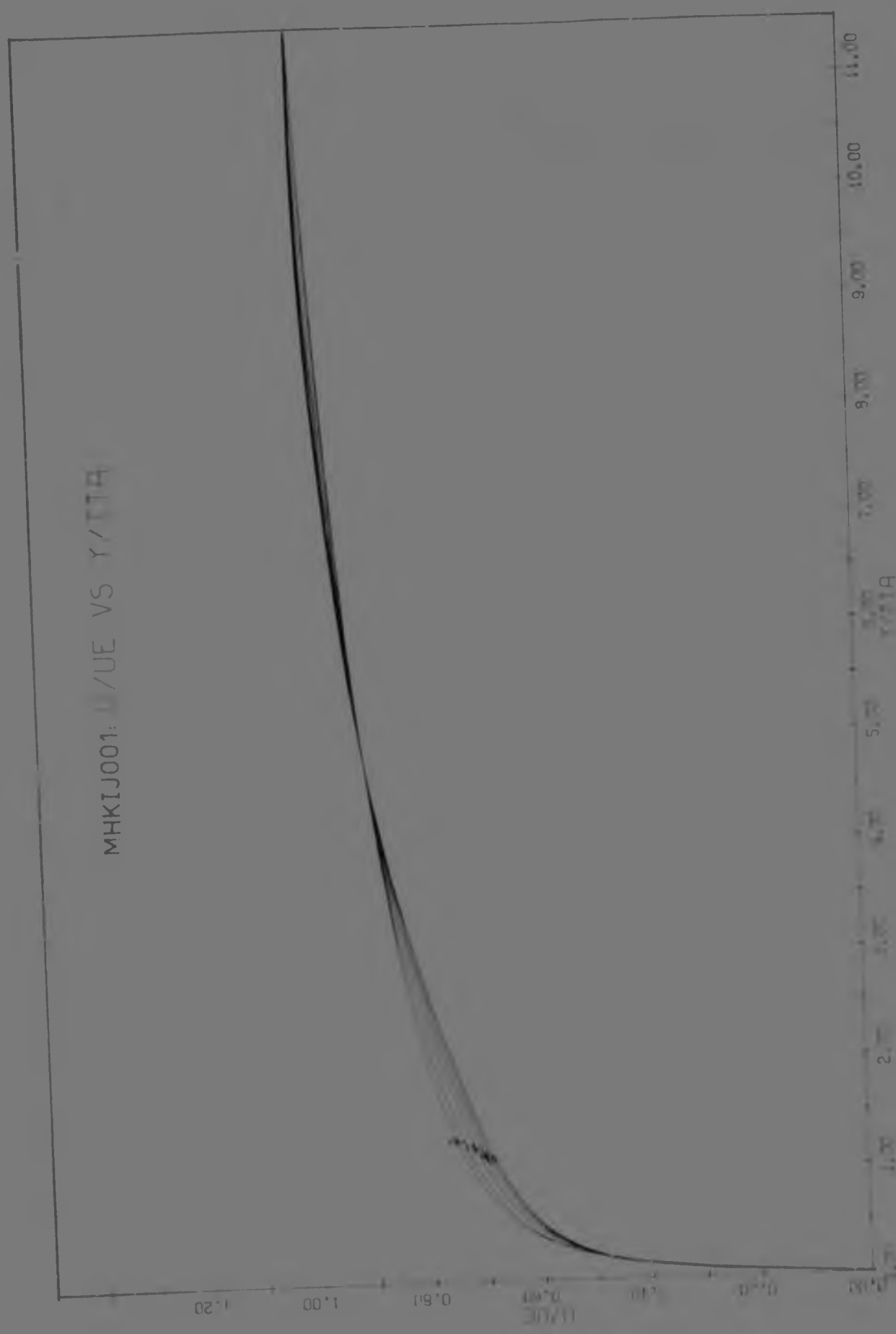


FIG 7.21A : TURBULENT PROFILES WITH INCREASING INJECTION, U_∞ = 17 m/s, F = 0,001

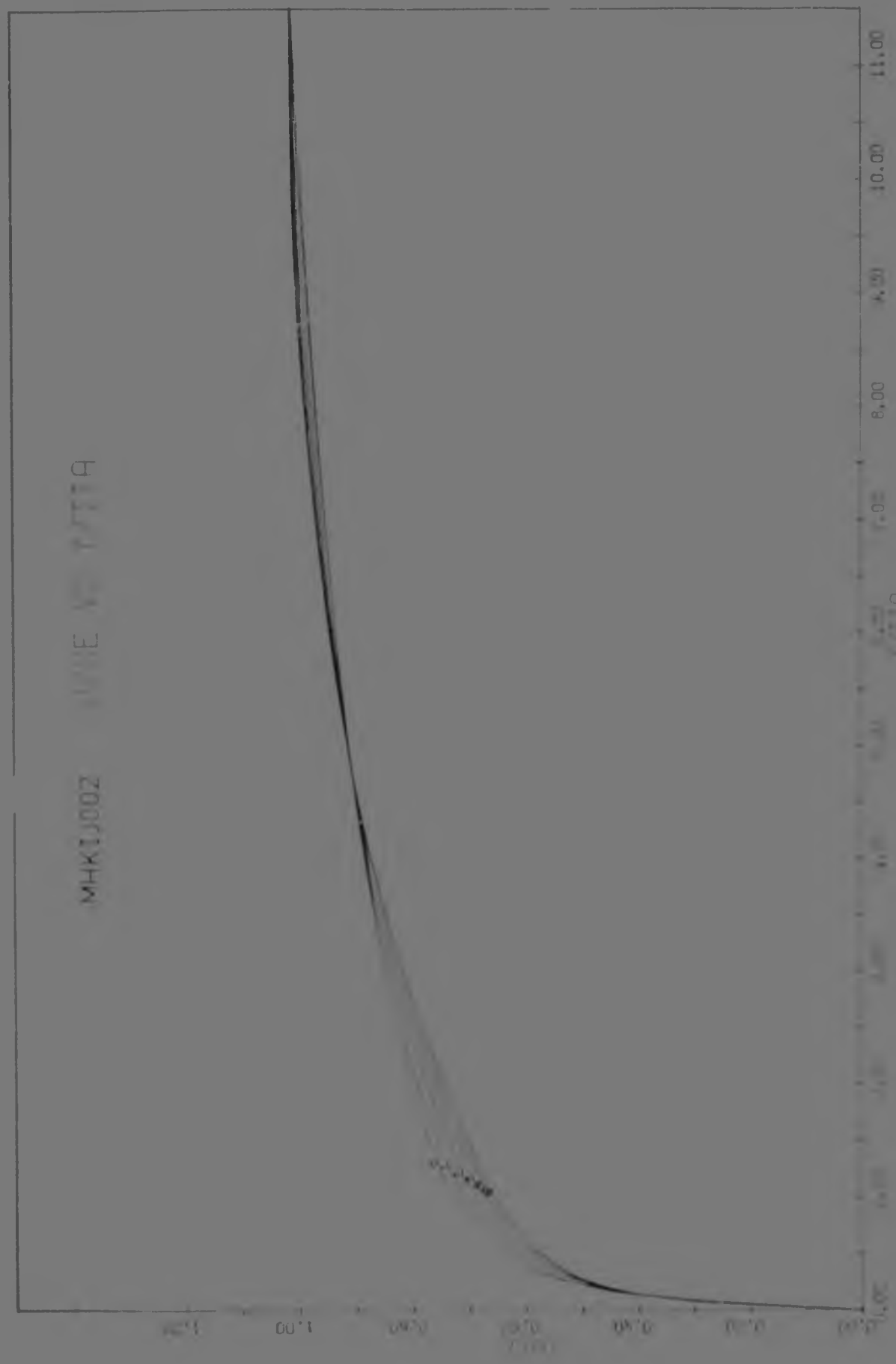


FIG 7.21B : INJECTED TURBULENT PROFILES FOR
U_∞ = 17 m/s, F = 0,002

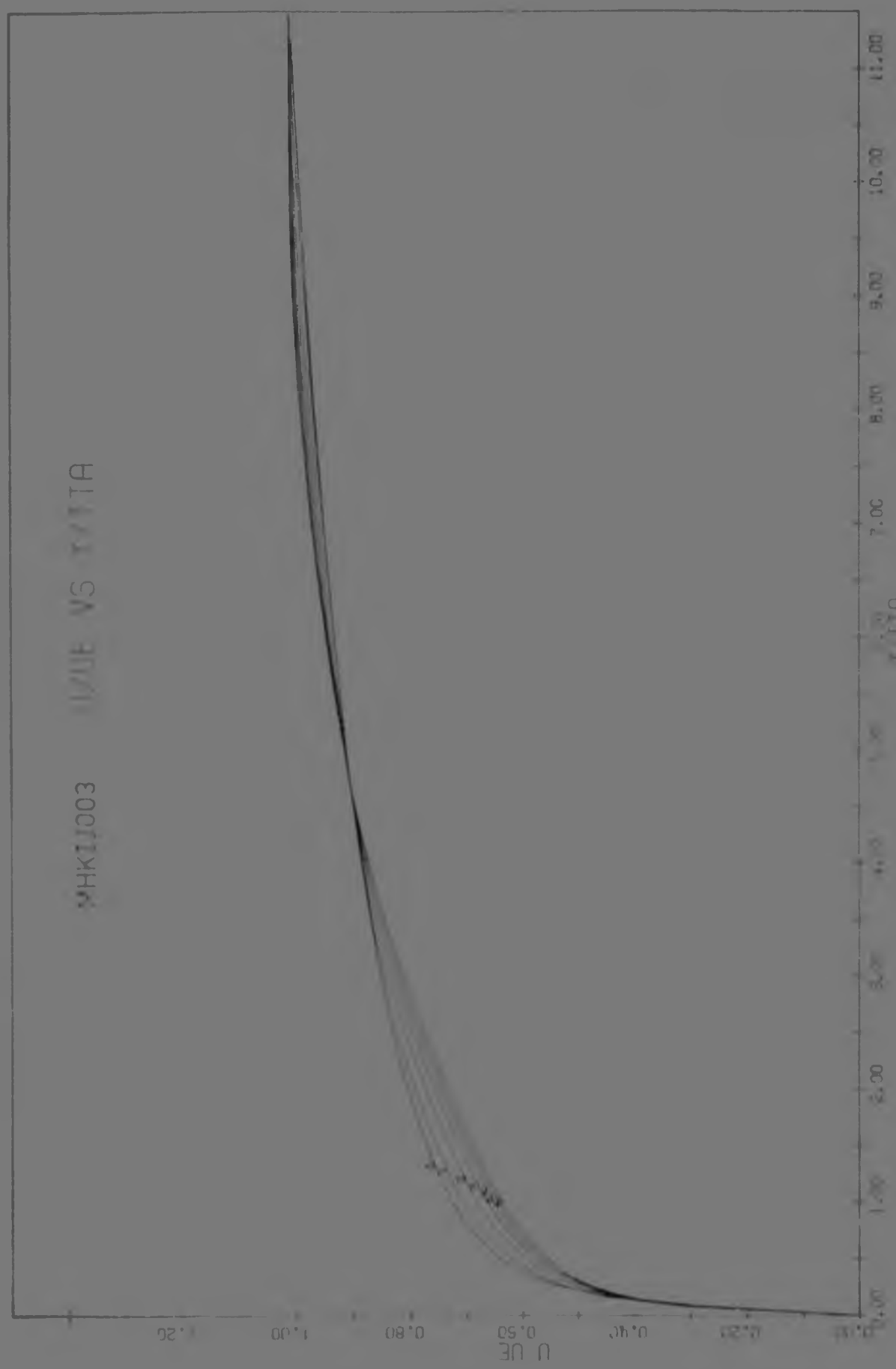


FIG 7.21c : INJECTED TURBULENT PROFILES FOR
U_∞ = 17 m/s, F = 0,003

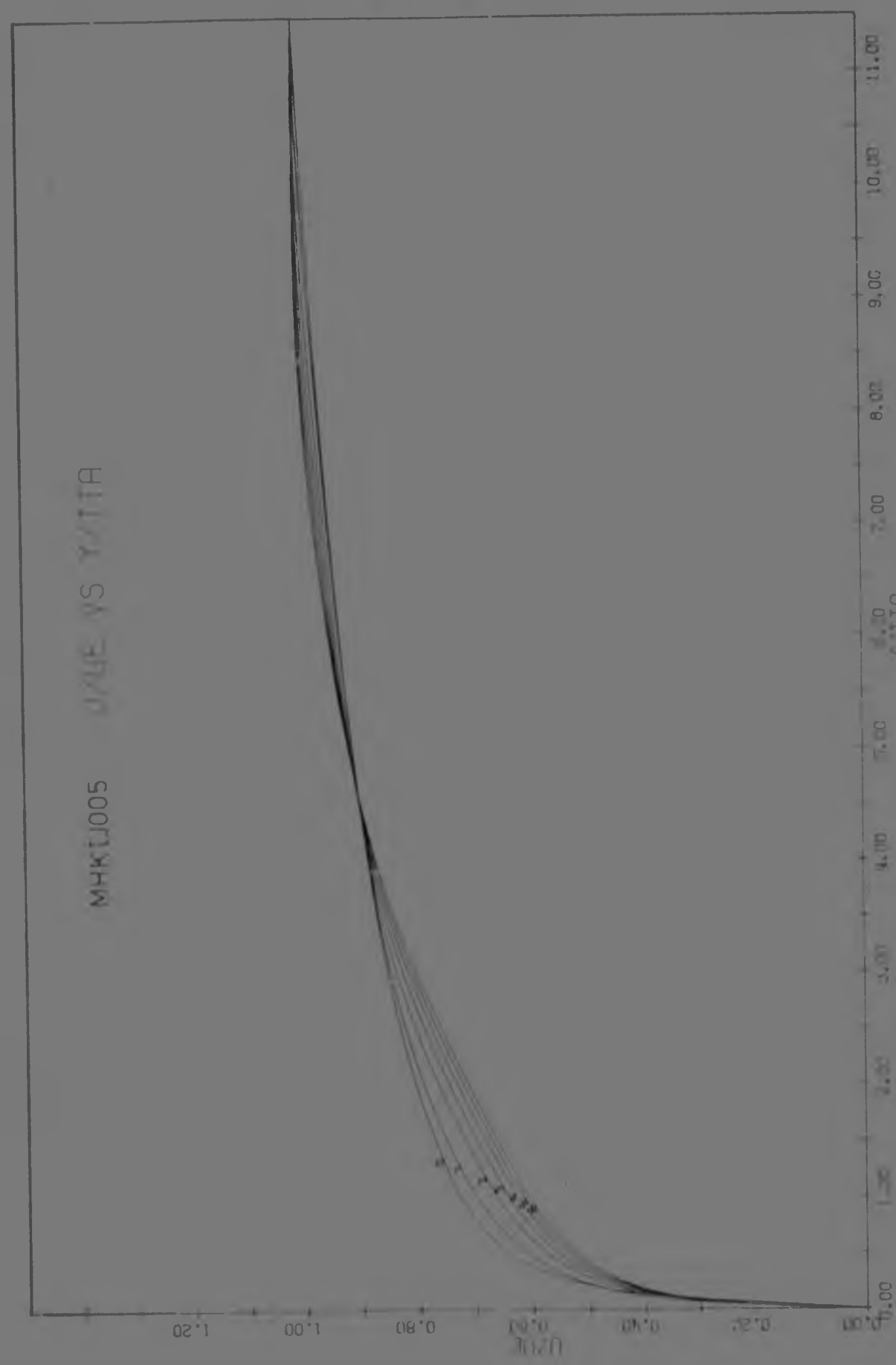


FIG 7.21D : INJECTED TURBULENT PROFILES FOR
U_∞ = 17 m/s, F = 0,005

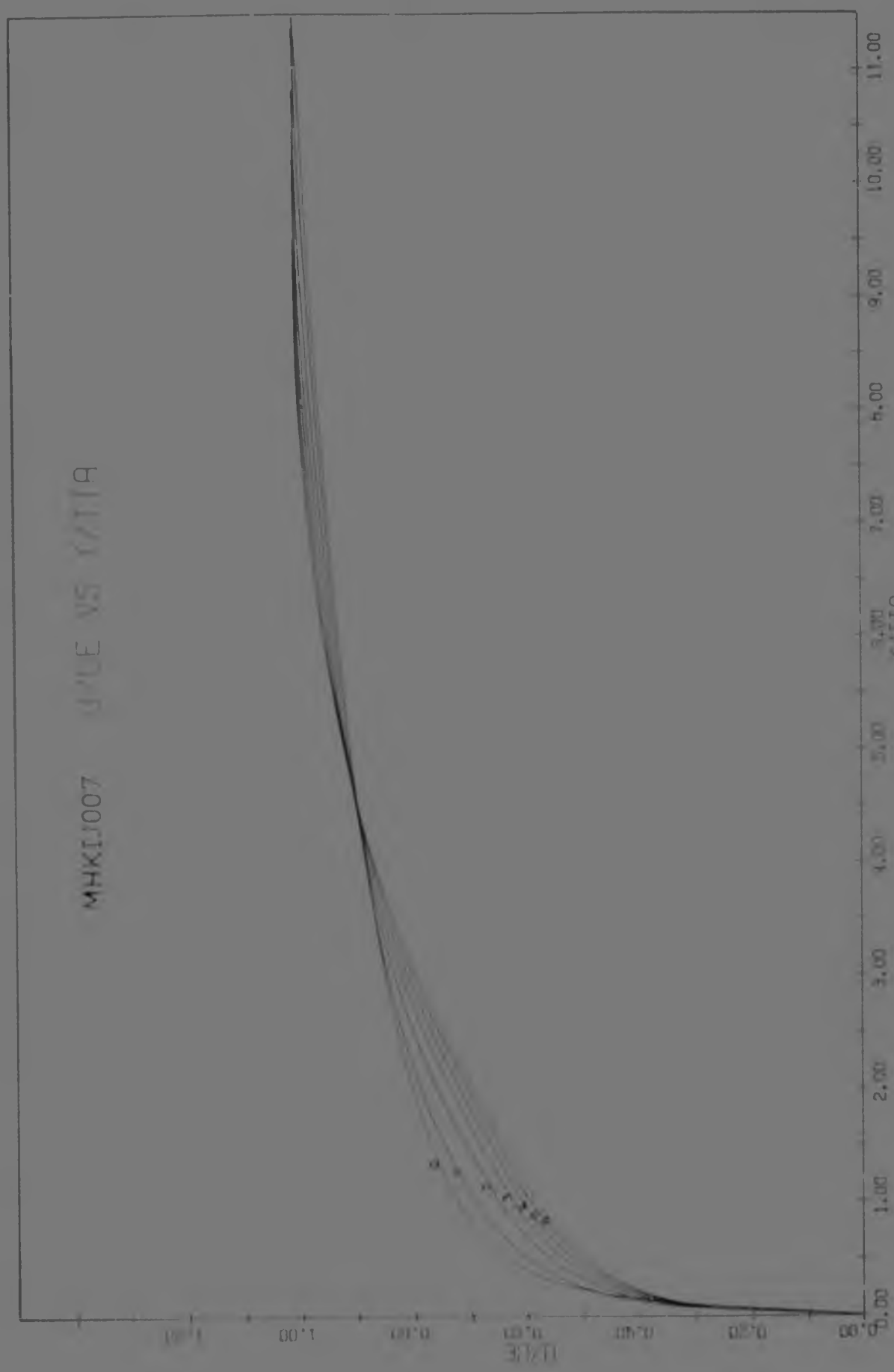


FIG 7.21E : INJECTED TURBULENT PROFILES FOR
U_∞ = 17 m/s, F = 0,007

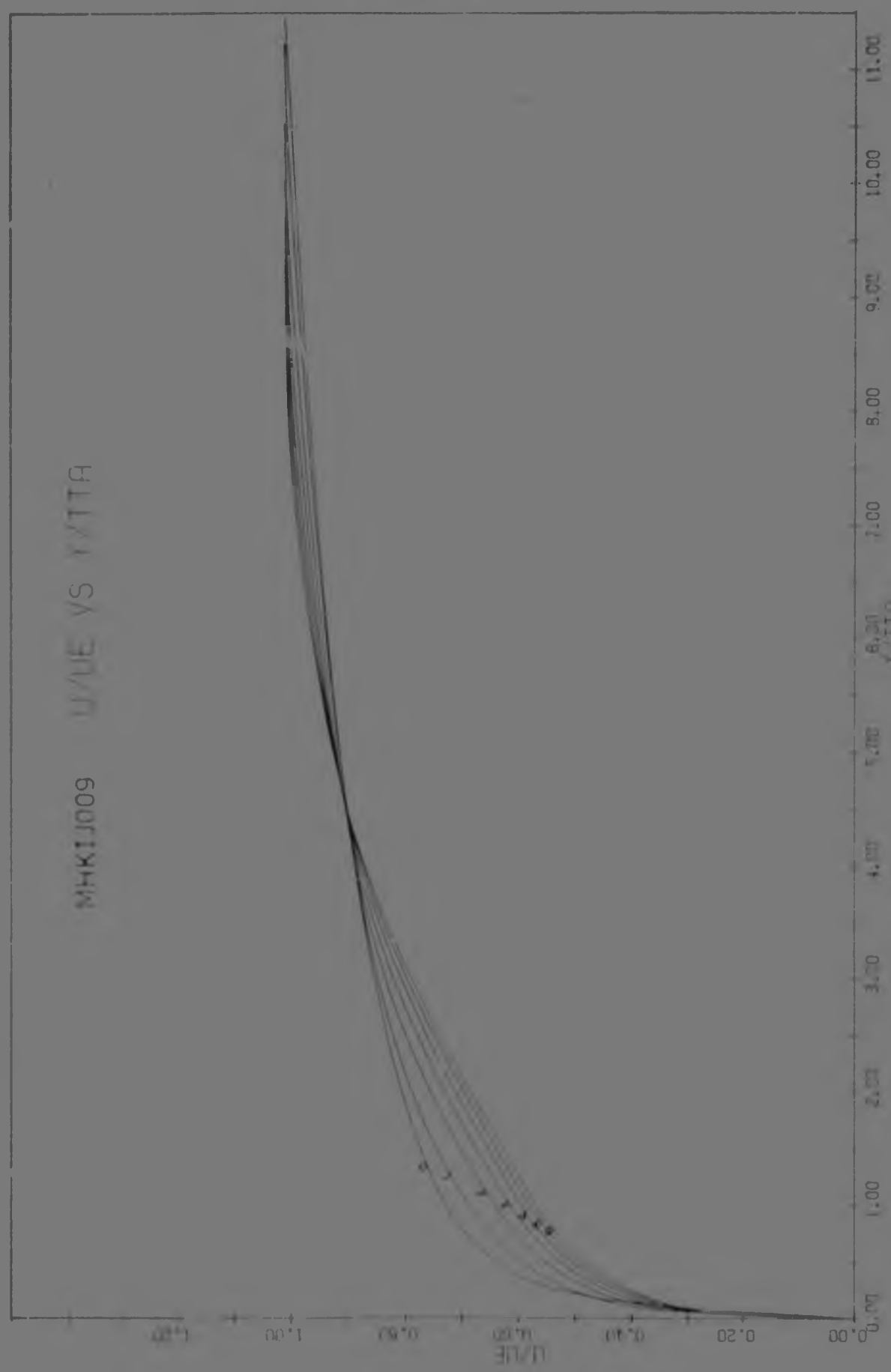


FIG 7.21F : INJECTED TURBULENT PROFILES FOR
U_∞ = 17 m/s, F = 0,00%

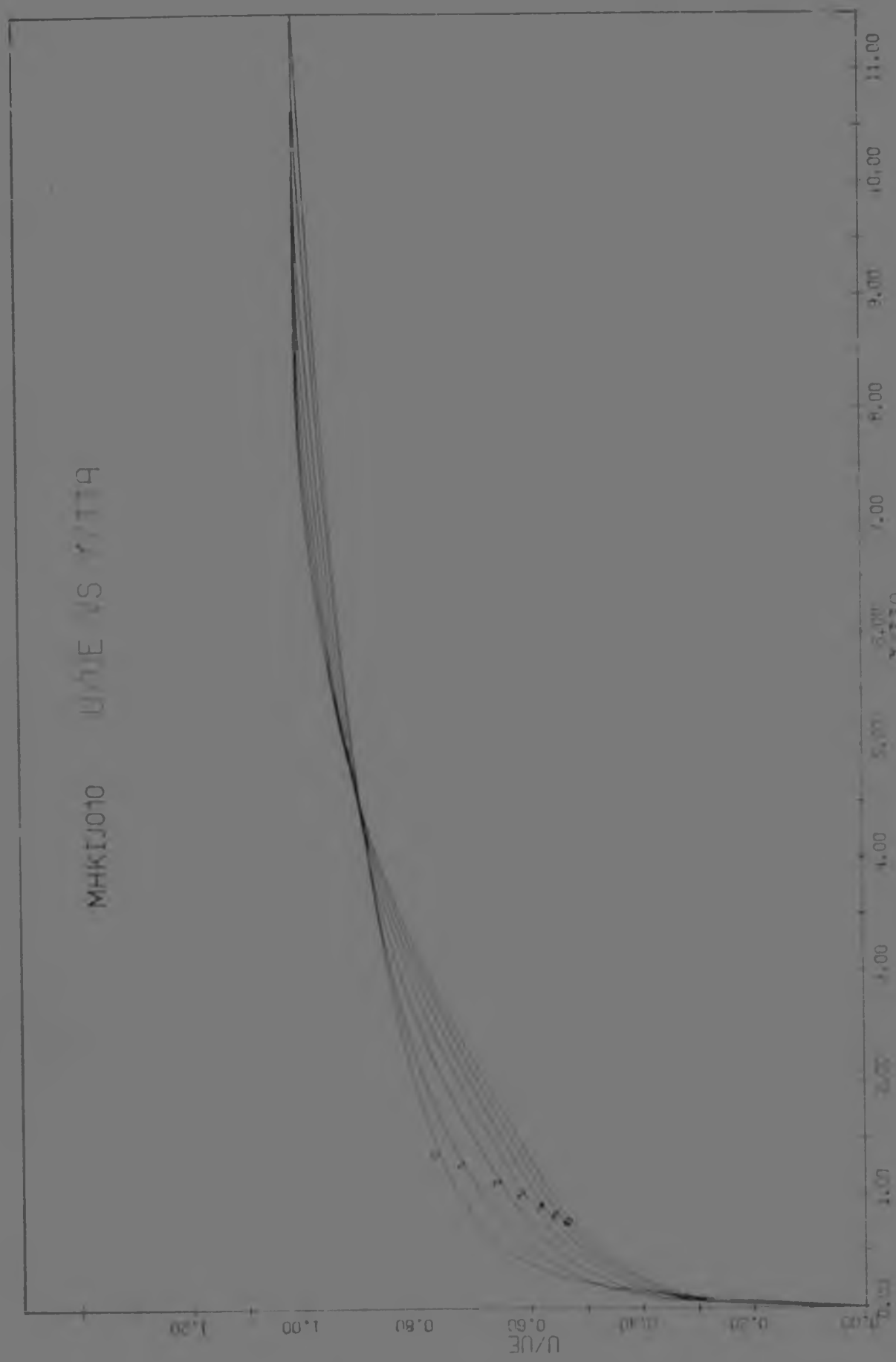


FIG 7.21G : INJECTED TURBULENT PROFILES FOR
U_∞ = 17 m/s, F = 0,010

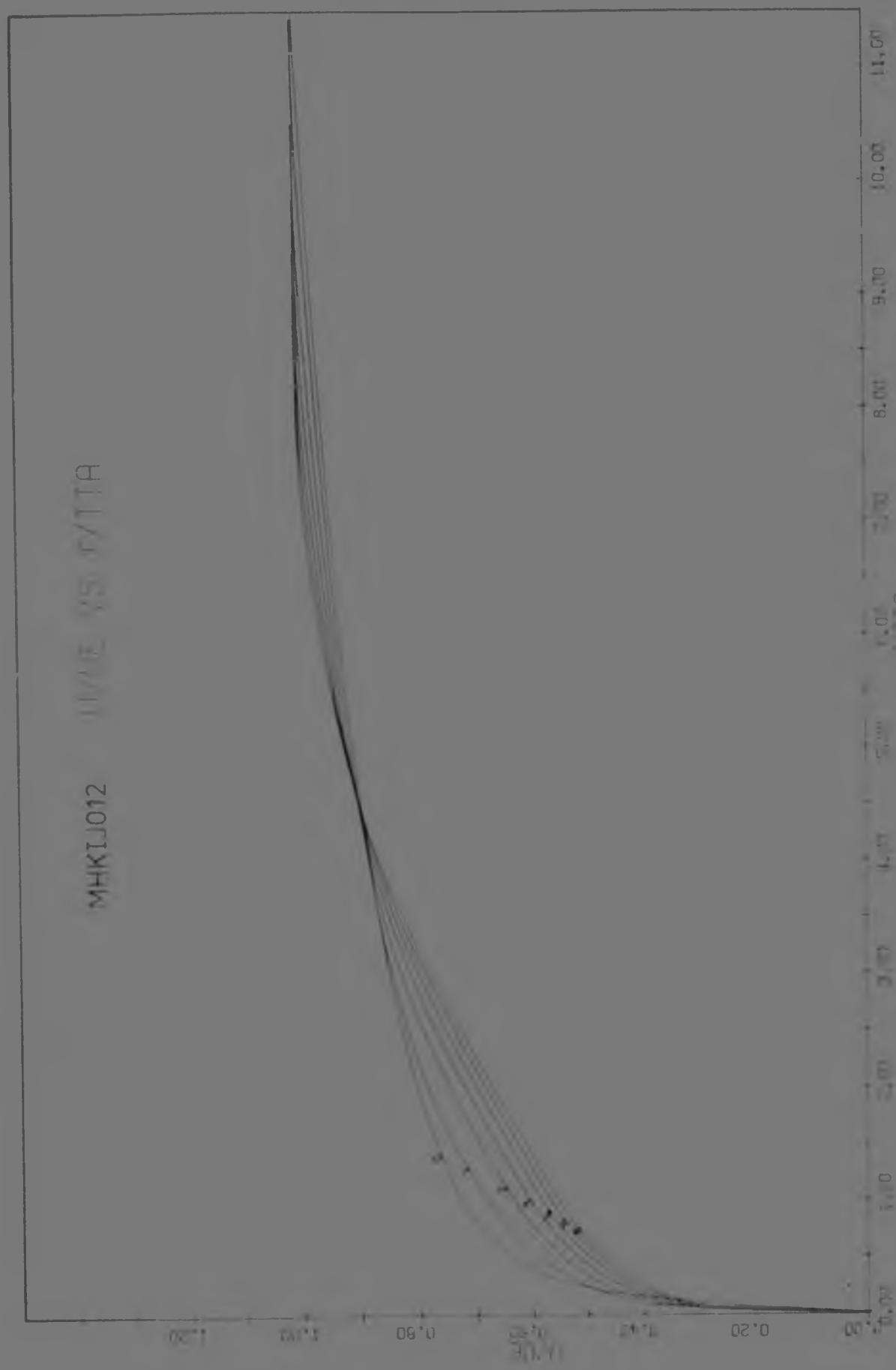


FIG 7.21H : INJECTED TURBULENT PROFILES FOR
U_∞ = 17 m/s, k = 0,012

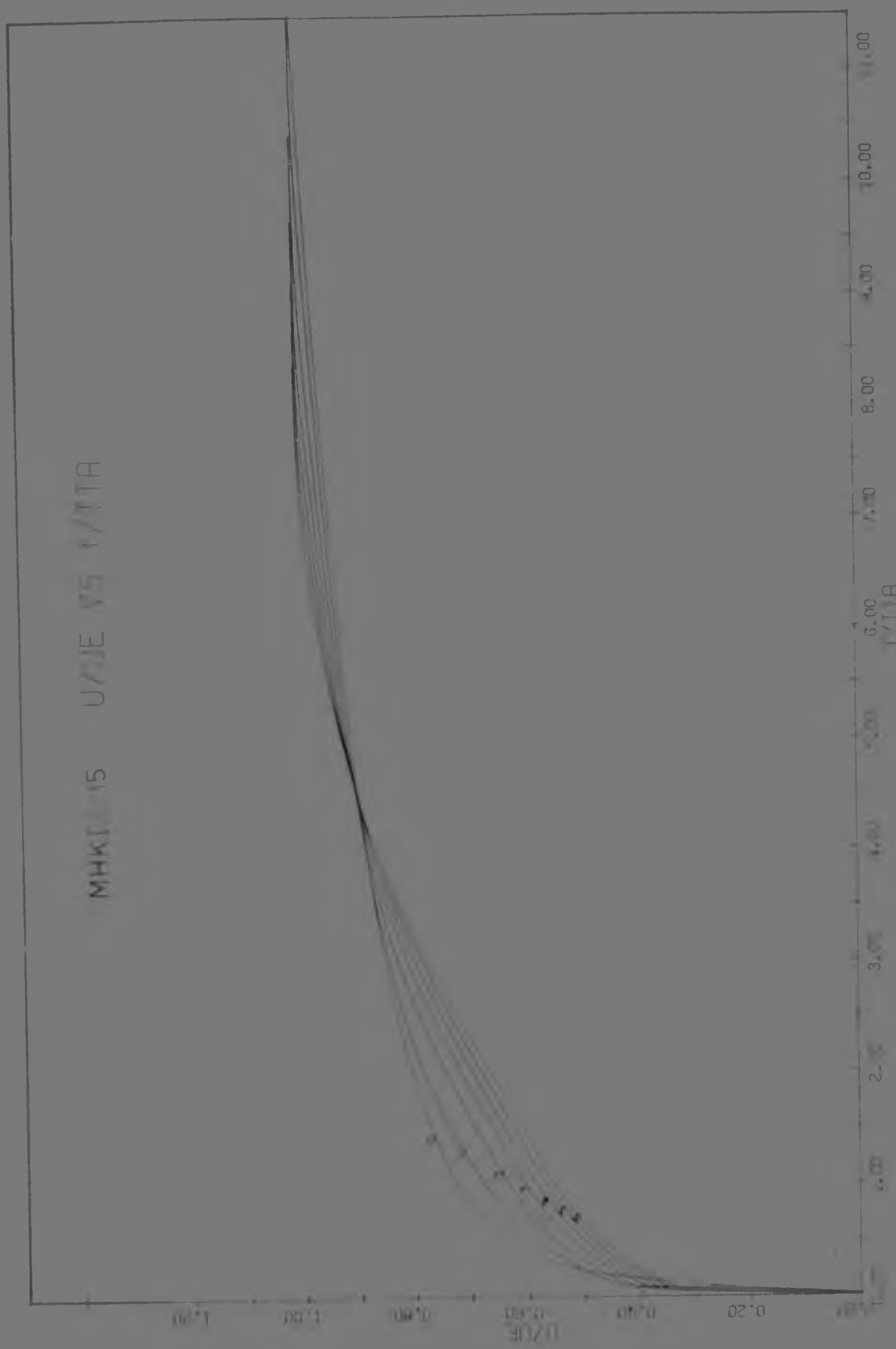


FIG 7.21 : INJECTED TURBULENT PROFILES FOR
U_{∞} = 17 m/s, F = 0,015

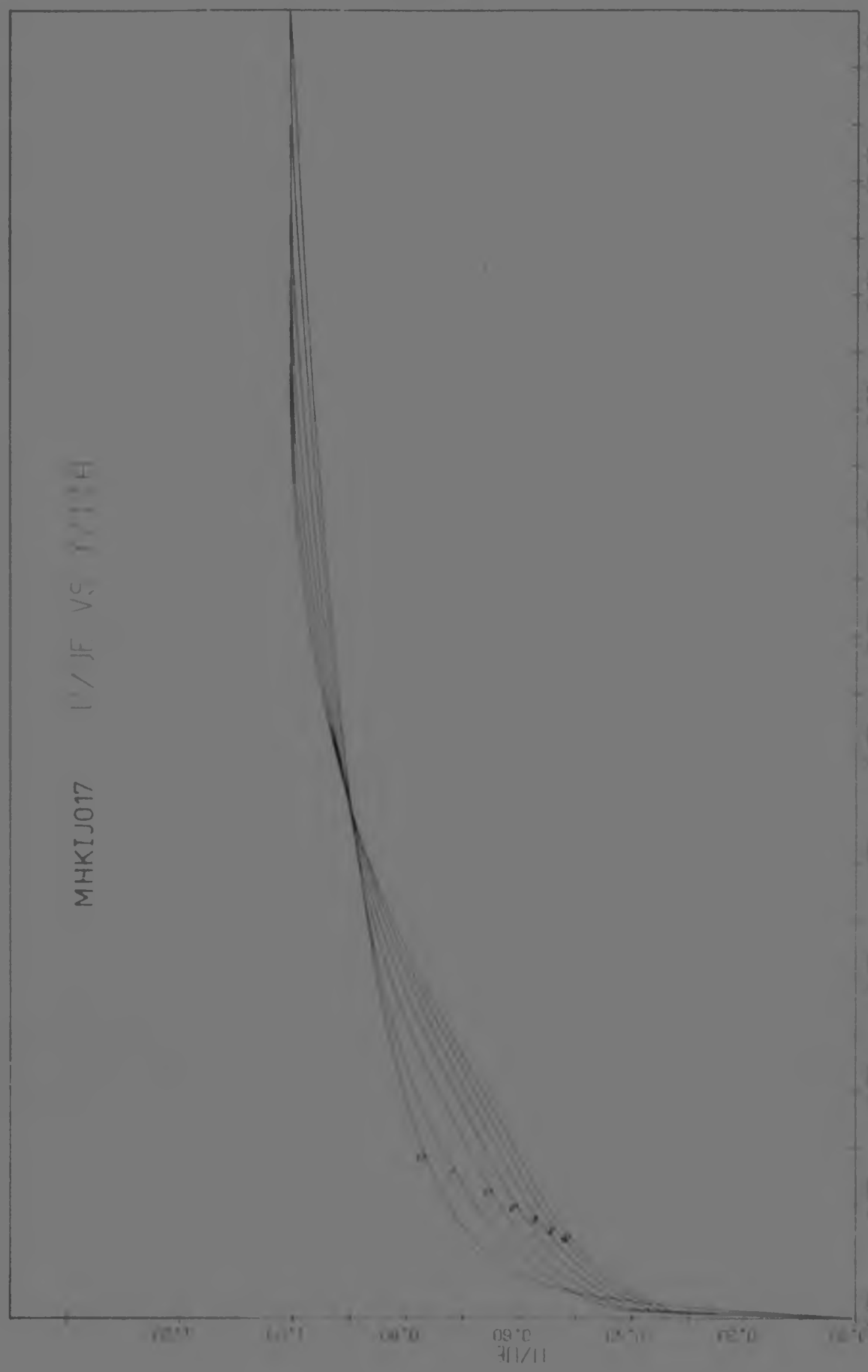


FIG 7.21J : INJECTED TURBULENT PROFILES FOR
U_∞ = 17 m/s, F = 0,017

By using the approximat[illegible] ϕ'' as described, the programme was remarkedly s[illegible], solving for injection ratios up to $F = 0{,}017$. These high injection ratios have not been reported in the literature, and are approaching, if not exceeding, the limit of the boundary layer analysis.

The configuration and condition of the fluid for the main computer runs are reported in Table 7.2. Fig 7.22 shows the eddy viscosity distribution across the boundary layer.

TABLE 7.2 : Key to x-Stations used in Main Runs

Station	x(m)	$\xi \times 10^4$	$Re_x \times 10^5$	Plot symbol
3	0,790	2,416	7,274	0
10	0,825	2,523	7,596	1
20	0,875	2,676	8,056	2
30	0,925	2,829	8,516	3
40	0,975	2,982	8,977	4
50	1,025	3,135	9,437	5
60	1,075	3,288	9,898	6

U = 17 m/s
du/dx = 0 $^1/_s$
ρ = 0,9971 kg/m^3
μ = 1,825 kg/ms
XTR = 0,8 m
IY = 100
K = 1,025
H = 0,065
DX = 0,005

7.4.2 Some additional runs

A run with injection and pressure gradient was performed - the results presented in Fig 7.23. MHKIJ003 was the comparable run with du_e/dx = 0 $^1/_s$, and considering the shape factors at the same x stations show the difference very clearly, e.g. Station 60 : H_o = 1,45. $H_{du/dx=10}$ = 1,36. δ grew at a much slower rate (32,4 mm and 25,2 mm respectively), which is as expected.

MHKLONG3 and MHKLONG5 were runs in which an uninterrupted porous plate was simulated. The porous plate started at x = 0,312 m. This was improved in MHKTEST3, which is compared with the Mickley and Davis results for their run C-3-50. See Fig 7.26.

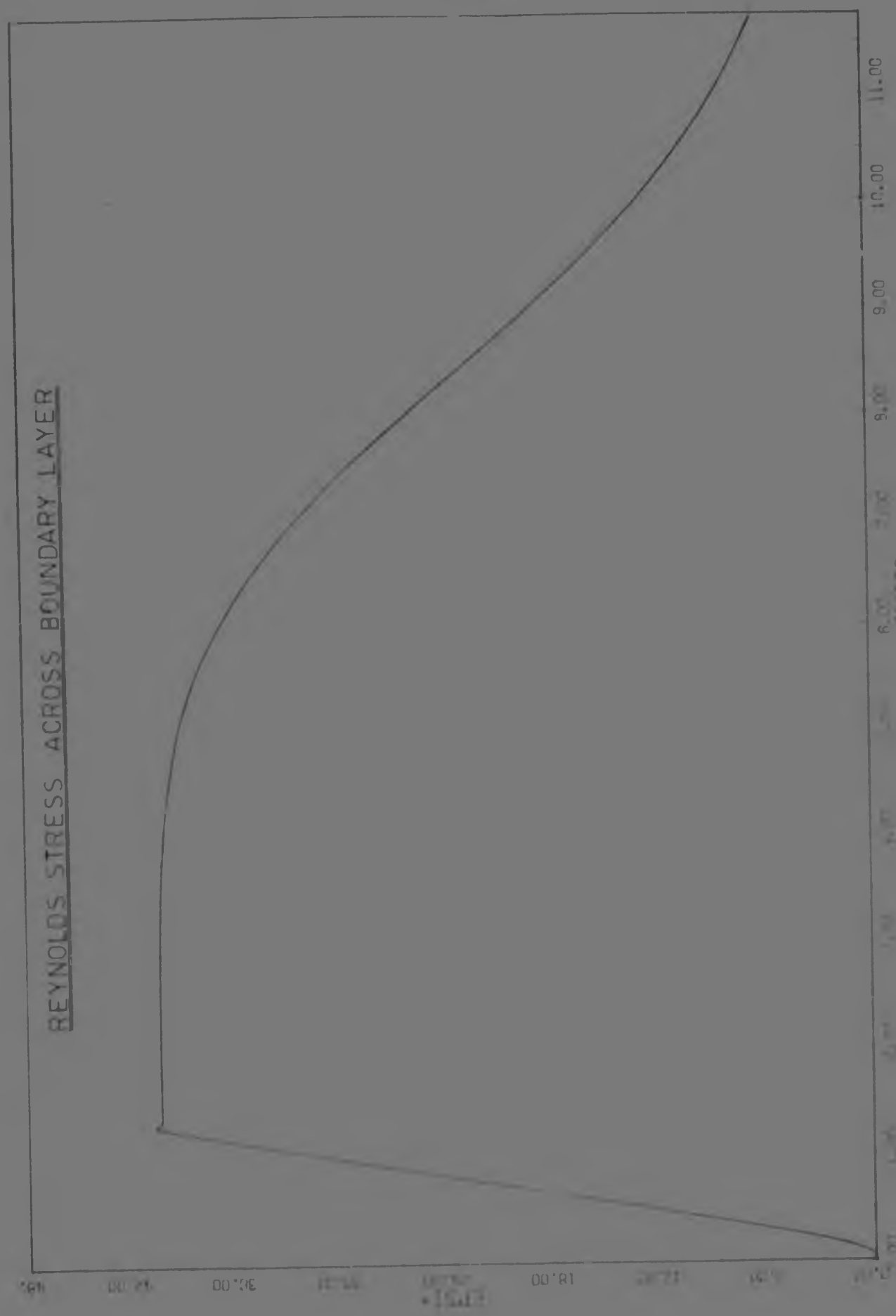


FIG 7.22 : EDDY-VISCOSITY ACROSS THE BOUNDARY LAYER
AT x = 0,790 m, U_∞ = 17 m/s

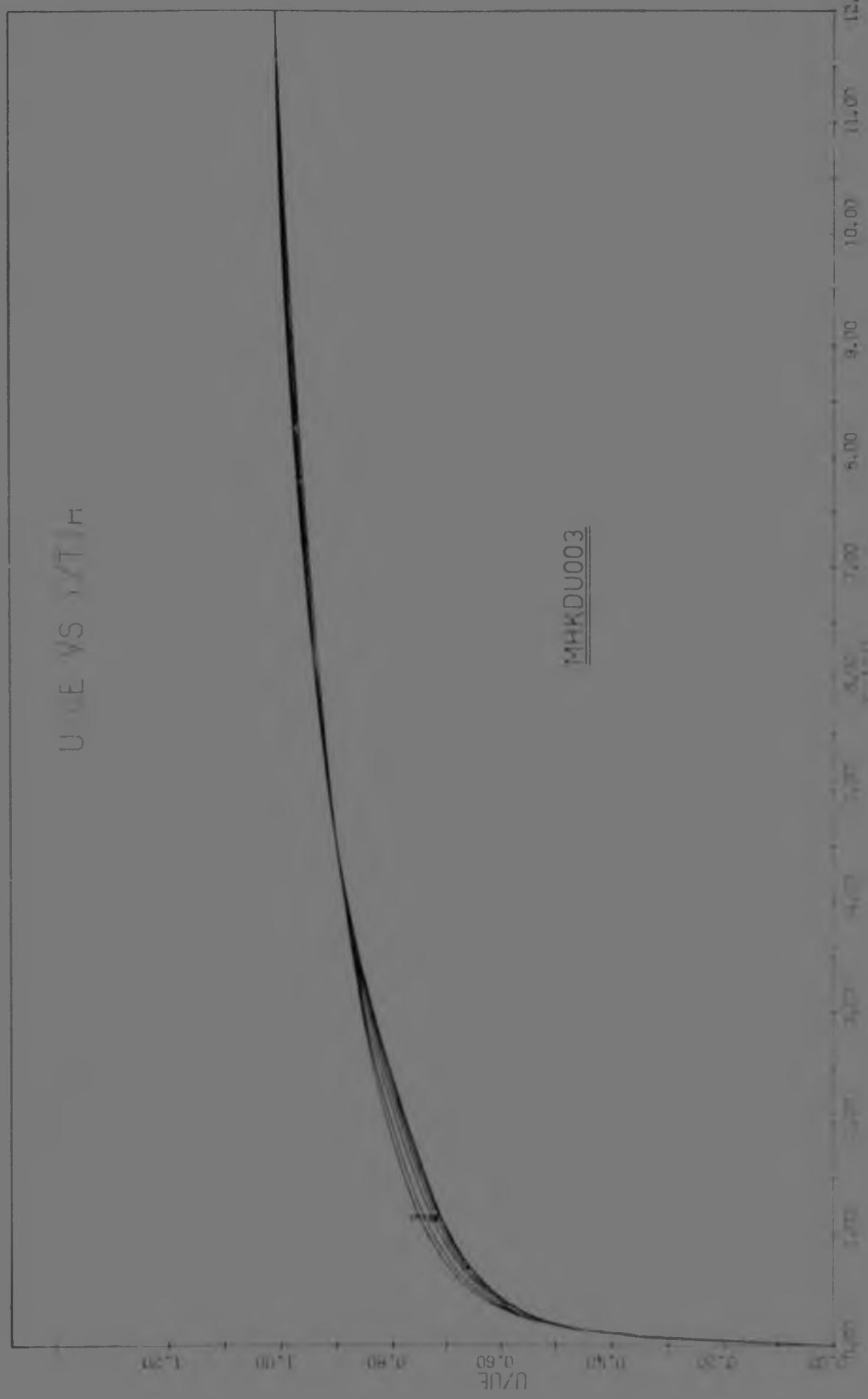


FIG 7.23 : VELOCITY PROFILE WITH INJECTION AND PRESSURE GRADIENT

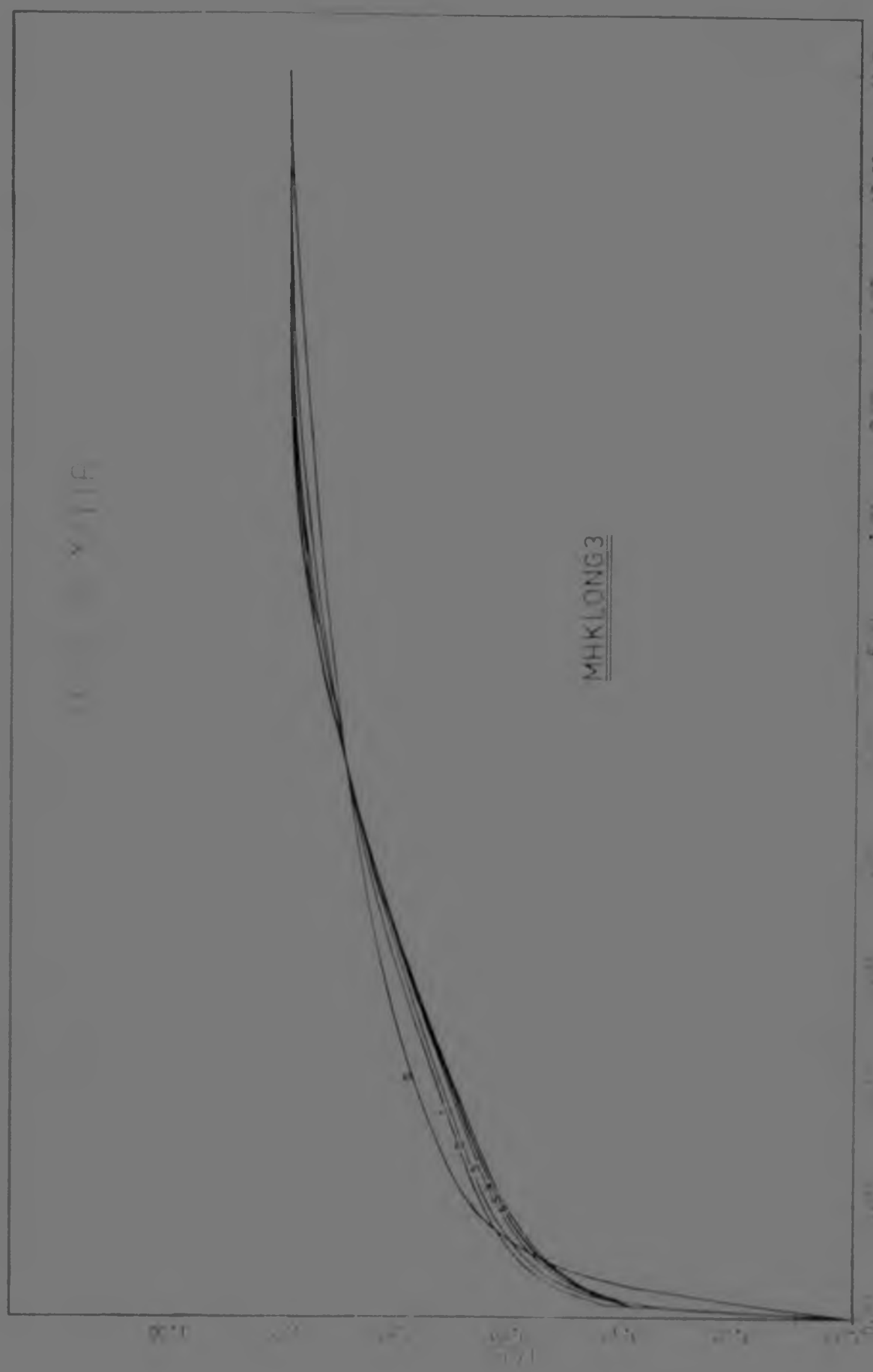


FIG 7.24 : VELOCITY PROFILE WITH INJECTION
STARTING AT x = 0,312 m

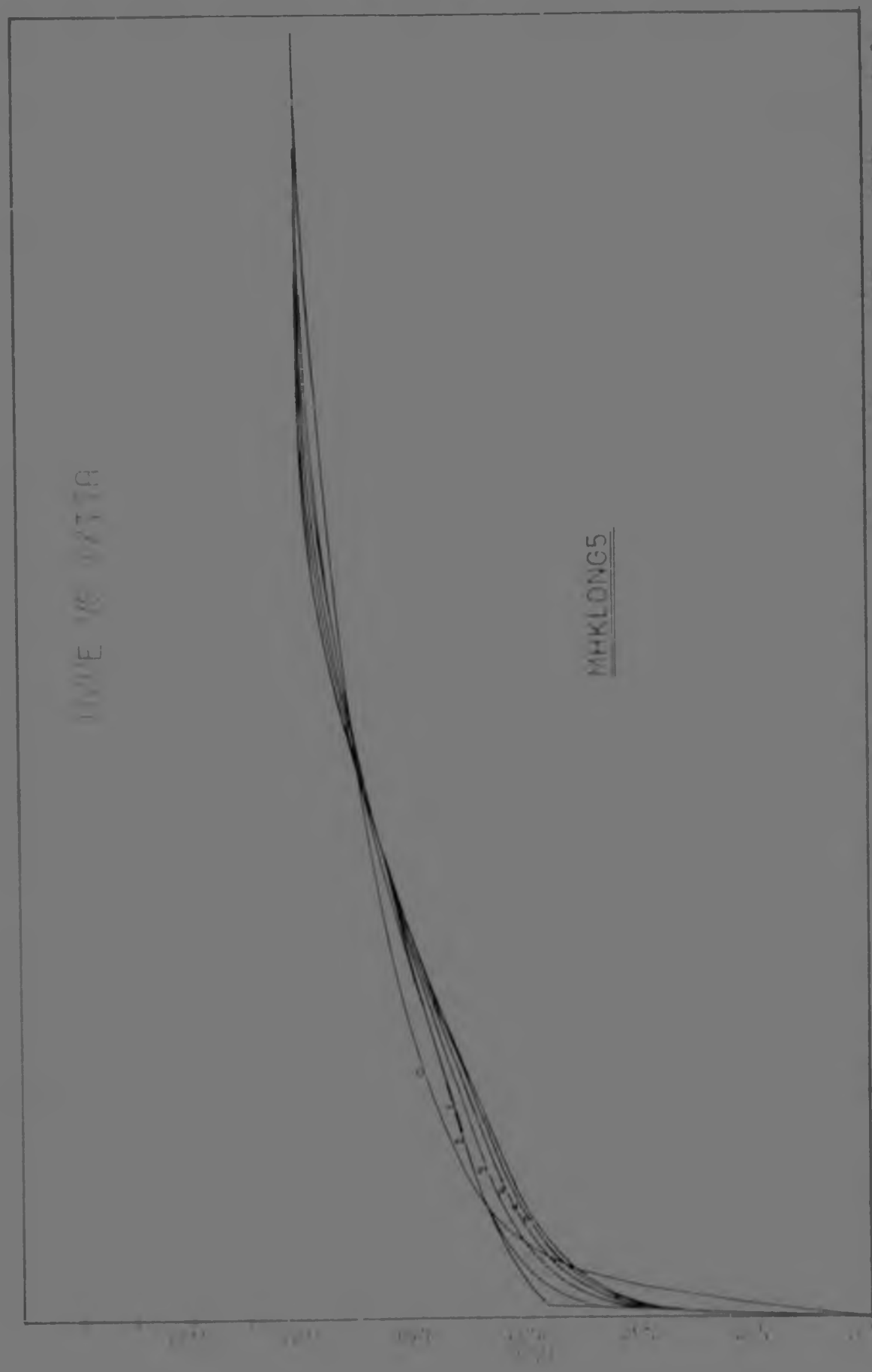


FIG 7.25 : VELOCITY PROFILE WITH INJECTION STARTING AT x = 0,312 m

TABLE 7.3 : Comparison Table

MHKTEST 3 STATION 60				MICKLEY AND DAVIS C-3-50 STATION H			
Re_θ	δ(mm)	θ(mm)	H	Re_θ	δ	θ(mm)	H
2687	25,87	2,94	1,50	2830	22,86	2,85	1,46

This is for the final station of run MHKTEST3, and Re_θ was still somewhat below that of the Mickley and Davis experiment. δ was again high, and hence also θ. The profiles compare well, and it is expected that if Re_θ were more accurately matched, the correspondence would be even better.

The programme was thus shown to produce results which compared well with experiment. Qualifying the programme more extensively would require many more runs, changing the free stream conditions and injection ratio, and finding similar experimental profiles. Note that the computer was using local (Johannesburg) density for air, which was why Re_θ was lower than that of Mickley and Davis given in Table 7.3, for similar values of θ and H.

To allow smaller step lengths to be used, a thinner boundary layer was necessary. For this reason the main runs were performed from x=0,790 m, ie. fully turbulent flow, but δ≈23 mm, whereas the experiment produced δ-45mm. The latter would require a much coarser grid, and hence loss of accuracy. It was therefore not possible to compare the main runs with the experimental results. However, the trend of the 'transition' region from impermeable wall to injected flow obtained experimentally was clearly reflected by the computer results.

Skin friction results were thought to be in error by orders of magnitude. As presented, the programme calculated ϕ_w'' from a second order fit, which was very satisfactory for the unblown profile. If Fig 5.9 is a correct representation of u, then a linear fit with very small step length at the wall would produce better results.

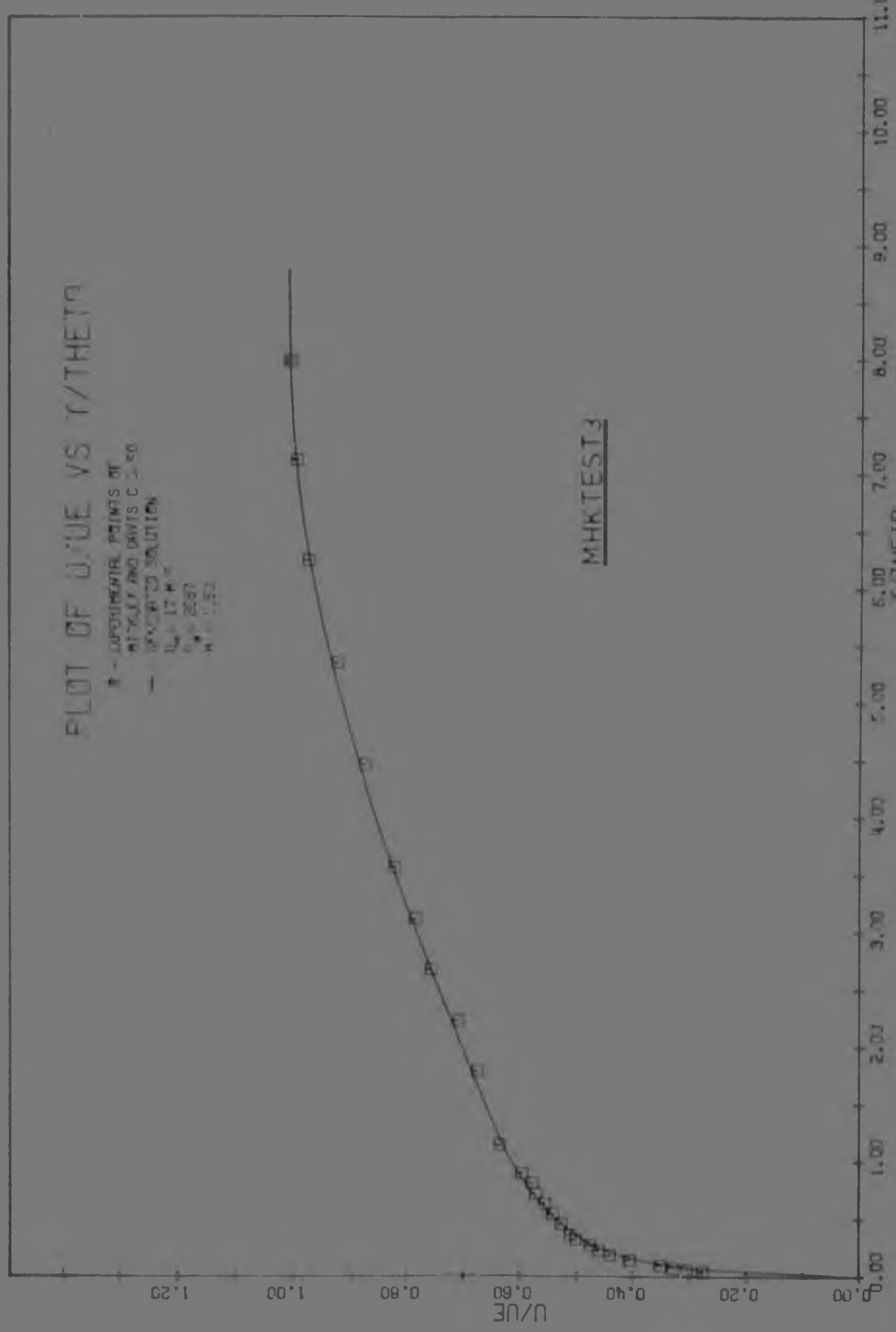


FIG 7.2F : COMPUTER GENERATED PROFILE COMPARED TO EXPERIMENTAL RESULTS OF MICKLEY AND DAVIS (1956)

CHAPTER 8

CONCLUSIONS

8.1 Experimental Features

A two dimensional, open circuit wind tunnel was designed, built and commissioned. A free stream velocity of 21 m/s could be obtained in the working section. To simulate the conditions described on page 7, a turbulent boundary layer was produced on a flat plate, which was interspersed with a porous plate. The boundary layer thus encountered injection, which was introduced through the porous plate.

Using the hot wire anemometer, a transverse velocity profile was obtained, and showed that the flow was two dimensional. The turbulence intensity was better than 0.5%, which is less than the expected level for this type of tunnel (ref. Schlichting, 1968). Measured energy spectra at a number of free stream velocities compared favourably with accepted theoretical predictions and experimental data.

Velocity profiles on the smooth flat plate were ascertained and shown to follow the profiles predicted by the Thompson two parameter family of curves.

To further qualify the performance of the tunnel, profiles with injection were plotted on the Bilog axes suggested by Black and Sarnecki, together with experimental data of Mickley and Davis (1956). This allowed direct comparison with other authors work, and also showed the development of the profile with increasing injection. Furthermore, the need for accurate skin friction information was highlighted.

8.2 Velocity Profiles and General Experimental Results

Velocity profiles were measured for a range of free stream velocities and injection ratios. By using different grades of porous plate, the roughness of the wall was also varied. A set of data for the turbulent boundary layer with uniform injection was established. By partially blocking the lower surface of the porous plate, velocity profiles with non-uniform injection were ascertained, and compared with the initial set of results.

The experimental results gathered in the region in which the flow encountered the abrupt change in injection and roughness showed that the average velocity in the shear layer decreased with increasing x. The shape parameter H can be used to quantify this change in momentum. Plotting H vs x showed that H increased rapidly with x, with a decrease in slope for larger x. It also showed that H increased with injection ratio. Consideration of the results of Mickley and Davis confirms this result, and indicates that H may asymptote to a constant value for a fixed injection ratio.

When the results for the partially blocked porous plate were compared with the initial set of data, it was found that H was higher for a particular x station at the same average injection ratio. As is explained in the Addendum this result could indicate a lower wall temperature in the case of a heated stream and cold air injection (assuming constant heat transfer). This would be a very desirable result for the applications discussed on page 1, however, this can only be confirmed with extensive additional experimentation.

To the author's knowledge, these tests constituted original work for the following reasons :-

i) The turbulent boundary layer encountered a step change in surface roughness and injection ratio, an intended feature of the test rig. Previous investigators had considered the fully developed turbulent boundary layer with uniform injection.

ii) Partial blockage of the porous plate, thus altering the injection profile, constituted a further controlled parameter. This feature simulated the attachment of the porous matrix to a rigid base, which would thus enable these materials to be used for effusion cooling in highly stressed materials.

A technique for predicting the turbulent boundary layer velocity profile with injection was developed. A two parameter family of curves was presented, which was independent of injection ratio. The results of Mickley and Davis as well as McQuaid were added to these plots, and indicate the existence of a correlation equation over a significant range of injection ratios. It was thought that more experimental data was required before a correlation equation could confidently be deduced.

The lowest point is $H = 1,3$, which is the value for the uninjected turbulent boundary layer. As the layer encountered injection, the value of the shape parameter increased, while u/u_∞ decreased for a fixed value of y/θ. This trend continued until the value at X1 was reached which was very close to the results of Mickley and Davis, whose tests were done in the 'fully developed turbulent boundary layer'.

8.3 Features Pertinent to the Numerically Obtained Results

The momentum equations were solved numerically, and the velocity profiles thus generated were plotted, reflecting the trends determined experimentally, ie. the decrease of velocity in the shear layer with increased injection ratio and distance along the plate. To qualify the programme, various test runs were performed. Firstly, the laminar profile generated was compared with analytical results given in Schlichting. Then a turbulent profile was plotted on semi log axes and compared with established experimental and empirical data. Various test cases were investigated, in which Re_x was varied with and without pressure gradient, and also one in which the computer solution was allowed to march into the transition region.

Finally, runs with injection were performed. One of these was compared with the experimental results of Mickley and Davis. In all these comparisons, correlation was excellent, and the programme was considered to yield accurate velocity profiles.

The programme was run for a range of injection ratios of F = 0,017. This was the highest ratio investigated experimentally, and was thought to be at the limit of the assumption of the analysis. It should be noted that F = 0,017 is significantly higher than any injection ratio encountered in the literature survey, both in experimental or numerical work. The programme remained exceptionally stable, even at high values of F.

CHAPTER 9

SUGGESTIONS FOR FURTHER WORK

1. Modifications to the wind tunnel, which would result in a thin boundary layer arriving in the entry section, allowing greater control.

2. Measurement of the local skin friction by direct means, so that this matter may be cleared up satisfactorily. Initially, the effect of surface roughness with transpiration would have to be determined. If a floating element balance was used, the element must be made of porous material with the same roughness as the plate; and with injection at its surface.

3. To establish the heat transfer characteristics of step change, distributed injection, with and without blockage, tests must be done with a heated mainstream. This latter provision is intended to obviate the inverted temperature profile which results from heating the transpiration flow. The inverted temperature profile acts as a turbulence inhibiter, thus affecting the heat transfer mechanism.

4. The computer programme requires an improved finite difference technique for obtaining the second derivative, especially at the wall. From this, more realistic values of c_f may be expected. A more sophisticated turbulence transport equation will be necessary to account for surface roughness.

5. Alterations to the programme could be designed to allow for enclosed flow, and for more complicated pressure gradient situations.

6. By including the Energy Equation, the heat transfer to the plate could be calculated.

7. A deeper understanding of the flow in the porous matrix should be obtained, mainly from experiment. The spread of the jet, and the exit velocity of the air at the exposed surface should be studied.

8. Turbine blades in cascade with porous inserts should be manufactured and tests on heat transfer characteristics done. These could be compared with tests for blades with discrete hole injection.

APPENDIX A

A1 Transformation of the Momentum Equation

For convenience, the continuity and momentum equations of section 4.2 are restated here :-

Continuity : $$\frac{\delta u}{\delta x} + \frac{\delta v}{\delta y} = 0 \qquad \ldots\ldots\ldots [A1.1]$$

Momentum : $$u\frac{\delta u}{\delta x} + v\frac{\delta u}{\delta y} = u_e\frac{\delta u}{\delta x}e + \frac{\delta}{\delta y}(\nu\frac{\delta u}{\delta y} - \overline{u'v'}) \qquad [A1.2]$$

Numerous transformations exist for equation A1.2. a popular one is the transformation to the Von Mises plane. The equation takes on the form of an unsteady heat-conduction equation. The disadvantage in solving an equation which is pseudo-elliptic (ie. the entire flow-field has to be solved simultaneously), is the excessive computer time used. A transformation similar to the Falkner-Skan solution could be used in a finite difference scheme that marches in the direction of predominant flow. In this way, conditions at each successive step could be set as required, e.g. surface roughness, injection (steady or varying with x), and also step length.

Following the treatment of Cebeci and Smith (1970a), the Levy-Lees transformation was used. This resulted in combining two independent variables, u and , shortened the abscissa and lengthened the ordinate.

The Levy-Lees transformation for flat-plate, incompressible flow is :-

$$d\xi = \rho\mu u_e dx; \quad d\eta = \frac{\rho u_e}{(2\xi)^{\frac{1}{2}}}dy \qquad \ldots\ldots\ldots [A1.3]$$

Define a dimensionless stream function, f

$$\psi(x,y) = (2\xi)^{\frac{1}{2}} f(\xi,\eta) \qquad \ldots\ldots\ldots [A1.4]$$

ψ is the stream function which satisfies the continuity equation :-

$$\frac{\delta\psi}{\delta y} = \rho u \; ; \quad \frac{\delta\psi}{\delta x} = -\rho v \qquad \ldots\ldots\ldots [A1.5]$$

Substituting A1.5 into A1.2, for μ and ρ constant :

$$\frac{1}{\rho^2}\frac{\delta\psi}{\delta y}\cdot\frac{\delta^2\psi}{\delta x\delta y} - \frac{1}{\rho^2}\frac{\delta\psi}{\delta x}\cdot\frac{\delta^2\psi}{\delta y^2} = \nu_e\frac{du_e}{dx} + \frac{\nu}{\rho}\cdot\frac{\delta}{\delta y}\left[(1 + \varepsilon^+)\frac{\delta^2\psi}{\delta y^2}\right] \quad [A1.6]$$

With $\varepsilon^+ = \varepsilon/\nu$

Hence :-

$$\frac{\delta\psi}{\delta y}\cdot\frac{\delta^2\psi}{\delta x\delta y} - \frac{\delta\psi}{\delta x}\cdot\frac{\delta^2\psi}{\delta y^2} = \rho^2\nu_e\frac{du_e}{dx} + \mu\frac{\delta}{\delta y}\left[(1 + \varepsilon^+)\frac{\delta^2\psi}{\delta y^2}\right] \quad \ldots [A1.7]$$

From A1.5 (see Cebeci and Smith, 1970a) :-

$$\left.\begin{aligned}\frac{\delta}{\delta x} &= \rho\mu u_e\left(\frac{\delta}{\delta\xi} + \frac{\delta\eta}{\delta\xi}\cdot\frac{\delta}{\delta\eta}\right)\\ \frac{\delta}{\delta y} &= \frac{\rho u_e}{(2\xi)^{\frac{1}{2}}}\frac{\delta}{\delta\eta}\end{aligned}\right\} \qquad \ldots\ldots\ldots [A1.8]$$

From A1.4 :-

$$\left.\begin{aligned}\frac{\delta\psi}{\delta\xi} &= (2\xi)^{\frac{1}{2}}\left(\frac{f}{2\xi} + \frac{\delta f}{\delta\xi}\right)\\ \frac{\delta\psi}{\delta\eta} &= (2\xi)^{\frac{1}{2}}f'\end{aligned}\right\} \qquad \ldots\ldots\ldots [A1.9]$$

Using [A1.9] and $\beta = (2\xi).(du_e/d\xi)/u_e$, eqn.[A1.7] becomes :

$$\left[(1 + \varepsilon^+)f''\right]' + ff'' + \beta(1 - f'^2) = (2\xi)\left[f'\frac{\delta f'}{\delta\xi} - f''\frac{\delta f}{\delta\xi}\right]$$

$$\ldots\ldots\ldots [A1.10]$$

where the prime denotes $\partial/\delta\eta$, and $f' = \delta f/\delta\eta = u/u_e$.

The left hand side of [A1.10] will be recognised as the solution obtained by Falkner and Skan (1931) for the laminar boundary layer with $u_e(x) \propto x^m$ (ie. the potential flow was

proportional to a power of the length measured from the stagnation point).

Now introduce a translated stream function, ϕ. (This was done to improve the numerical computation.)

$$\left.\begin{aligned} f &= \phi + \eta \\ f' &= \phi' + 1 \\ f'' &= \phi'' \end{aligned}\right\} \qquad \ldots\ldots\ldots [A1.11]$$

Substitute [A1.11] into [A1.10]:-

$$[(1 + \varepsilon^{+})\phi'']' + (\phi + \eta)\phi - \beta.\phi'(\phi' + 2) = 2\xi[(\phi' + 1)\delta\phi'/\delta\xi - \phi''\delta\phi/d\xi] \qquad \ldots\ldots\ldots [A1.12]$$

This equation was also given as [4.6.1], and is an o.d.e. in η at $\xi = \xi_n$.

A2 The Finite Difference Approximations

Consider a function f at grid points i-2, i-1, i, ... etc., and let the distance between these points be h_1, h_2, h_3 and h_4 :-

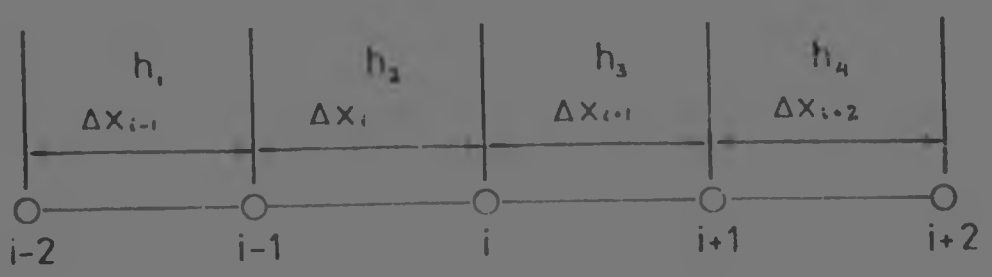


FIG A2.1 : SKETCH OF GRID POINTS, SHOWING NOMENCLATURE

Using Taylor's series to express :-

$$f(x_{i+1}) = f(x_i) + h_3 f'(x_i) + \frac{h_3^2 f''(x_i)}{2!} + O(h_3^3) \qquad [A2.1]$$

$$f(x_{i-1}) = f(x_i) - h_2 f'(x_i) + \frac{h_2^2}{2!} f''(x_i) + O(h_2^3) \ldots [A2.2]$$

By doing the following manipulation : [A2.1] x h_2^2 - [A2.2] x h_3^2 obtain :

$$f'(x_i) = \frac{-h_3 f(x_{i-1})}{h_2(h_2 + h_3)} - \frac{(h_2 - h_3)}{h_2 h_3} f(x_i) + \frac{h_2 f(x_{i+1})}{h_3(h_2 + h_3)} + O(h^2)$$

..... [A.2.3]

This equation was written for $h_2 \neq h_3$, which creates some difficulty in expressing the order of error. In [A2.3] it is approximately $O(h_2.h_3)$, and if $h_3 = h_2 = h$, $O(h^2)$.

Eliminating f' from [A2.1] and [A2.2] :

$$f''(x_i) = \frac{2f(x_{i-1})}{h_3(h_2+h_3)} - \frac{2f(x_i)}{h_2 h_3} + \frac{2f(x_{i+1})}{h_3(h_2+h_3)} \quad \ldots\ldots [A2.4]$$

This equation has an error $O(h_2)$ or $O(h_3)$, ie. much less accurate than [A2.3].

Equations derived in a similar manner are :-

$$f''(x_{i+1}) = \frac{2f(x_i)}{h_3(h_3+h_4)} - \frac{2f(x_{i+1})}{h_3 h_4} + \frac{2f(x_{i+2})}{h_4(h_3+h_4)} \quad \ldots\ldots [A2.5]$$

$$f''(x_{i-1}) = \frac{2f(x_{i-2})}{h_1(h_1+h_2)} - \frac{2f(x_{i-1})}{h_1 h_2} + \frac{2f(x_i)}{h_2(h_1+h_2)} \quad \ldots\ldots [A2.6]$$

Considering Fig A2.1 again, and using eqn.[5.3.3]

$$\left.\begin{aligned} h_1 &= \Delta x_{i-1} = h.K^{i-3} \\ h_2 &= \Delta x_i = h.K^{i-2} \\ h_3 &= \Delta x_{i+1} = h.K^{i-1} \\ h_4 &= \Delta x_{i+2} = h.K^{i} \end{aligned}\right\} \quad \ldots\ldots [A2.7]$$

Where h is the first step of the η grid.

Substituting [A2.7] into [A2.3] and [A2.4] :-

$$f'(x_i) = \frac{-f(x_i-1)}{hK^{i-3}(1+K)} - \frac{(1-K)f(x_i)}{hK^{i-1}} + \frac{f(x_i+1)}{hK^{i-1}(1+K)} \quad \ldots\ldots [A2.8]$$

$$f''(x_i) = \frac{2f(x_i-1)}{h^2K^{2i-4}(1+K)} - \frac{2f(x_i)}{h^2K^{2i-3}} + \frac{2f(x_i+1)}{h^2K^{2i-3}(1+K)} \quad [A2.9]$$

Each term in the last two equations could be divided into three parts, namely f, a constant in K and h, and a co efficient in i. This fact was used to simplify the equations. The first term of equation [A2.8] thus becomes :

$$\frac{-f(x_i-1)}{hK^{i-3}(1+K)} = -f(x_{i-1}).A = -f(x_{i-1}).\frac{A1}{K^i} \quad \ldots\ldots [A2.10]$$

So $A1 = -K^3/h(1+K)$, and all other coefficients dependent on h and K were calculated only once, ie. in subroutine MK002.

Because the x-stations were not restrained as the η points were, coefficients required for derivatives in the ξ-direction were calculated at each new station.

The coefficients that appeared in equation [5.4.2], are listed below :-

$$\left.\begin{aligned} A &= \frac{-K^3}{h(1+K)}.\frac{1}{K}i = \frac{A1}{K^i} \\ B &= \frac{-(1-K)K}{h}.\frac{1}{K}i = \frac{B1}{K^i} \\ C &= \frac{K}{h(1+K)}.\frac{1}{K}i = \frac{C1}{K^i} \\ D &= \frac{2K^4}{h^2(1+K)}.\frac{1}{K^2}i = \frac{D1}{K^2i} \\ E &= \frac{-2K^3}{h^2}.\frac{1}{K^2}i = \frac{E1}{K^2i} \\ F &= \frac{2K^3}{h^2(1+K)}.\frac{1}{K^2}i = \frac{F1}{K^2i} \end{aligned}\right\} \quad \ldots\ldots [A2.11]$$

$$X1 = \frac{2K^6}{h^2(1+K)} \cdot \frac{1}{K^2} i$$

$$X2 = \frac{-2K^5}{h^2} \cdot \frac{1}{K^2} i$$

$$X3 = \frac{2K^5}{h^2(1+K)} \cdot \frac{1}{K^2} i$$

$$X4 = \frac{2K^2}{h^2(1+K)} \cdot \frac{1}{K^2} i$$

$$X5 = \frac{-2K}{h^2} \cdot \frac{1}{K^2} i$$

$$X6 = \frac{2K}{h^2(1+K)} \cdot \frac{1}{K^2} i$$

..... [A2.11]

Coefficients starting with *X* were not split up into two parts. This had been done initially, in a different form, and is the reason for real G1, H1, I1, J1, K1 being defined in subroutine MK002.

The streamwise derivatives were calculated as follows :-

$$\left.\frac{\delta \phi_i}{\delta \xi}\right|_n = L\phi_{n-2,i} + M\phi_{n-1,i} + N\phi_{n,i} \qquad \text{..... [A2.12]}$$

$$\left.\frac{\delta \phi'_i}{\delta \xi}\right|_n = L\phi'_{n-2,i} + M\phi'_{n-1,i} + N\phi'_{n,i} \qquad \text{..... [A2.13]}$$

These equations were obtained in a manner very similar to the derivation of [A2.3]. They were backward difference equations, and the step length remained variable.

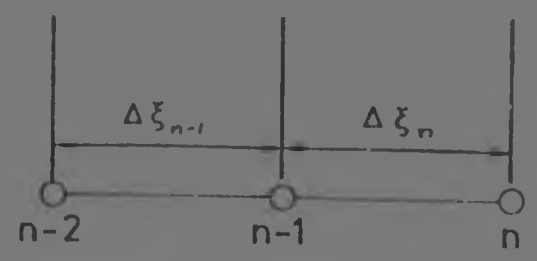


FIG A2.2 : SKETCH OF ξ GRID POINTS

$$\frac{\delta f(\xi_n)}{\delta \xi} = \frac{\Delta\xi_n f(\xi_{n-2})}{\Delta\xi_{n-1}(\Delta\xi_n + \Delta\xi_{n-1})} - \frac{(\Delta\xi_{n-1} + \Delta\xi_n) f(\xi_{n-1})}{\Delta\xi_{n-1}.\Delta\xi_n}$$

$$+ \frac{(\Delta\xi_{n-1} + 2\Delta\xi_n) f(\xi_n)}{\Delta\xi_n(\Delta\xi_{n-1} + \xi_n)} \qquad \ldots\ldots\ldots [A2.14]$$

Thus :-

$$L = \frac{\Delta\xi_n}{\Delta\xi_{n-1}(\Delta\xi_n + \Delta\xi_{n-1})}$$

$$M = \frac{-(\Delta\xi_{n-1} + \Delta\xi_n)}{\Delta\xi_{n-1}.\Delta\xi_n} \qquad \ldots\ldots\ldots [A2.15]$$

$$N = \frac{(\Delta\xi_{n-1} + 2\Delta\xi_n)}{\Delta\xi_n(\Delta\xi_{n-1} + \Delta\xi_n)}$$

To calculate ϕ_1'', Newton's Divided Difference method was used. The following equation was derived (see Milne-Thomson, 1933), from a second order fit :-

$$\phi_1'' \quad \frac{\phi_1' - \phi_2'}{\eta_1 - \eta_2} + (\eta_1 - \eta_2 \quad \frac{\phi_2' - \frac{\phi_2' - \phi_3'}{\eta_2 - \eta_3}}{\eta_1 - \eta_3} \qquad \ldots\ldots [A2.16]$$

From Chapter 5, ϕ_1 and ϕ_2 were to be determined from boundary conditions. An equation was given for ϕ_1, but ϕ_2 still remained to be calculated. From eqn.[4.6.3], one of the boundary conditions is -

$$\phi'(\xi,0) = \phi_1' = -1 \qquad \ldots\ldots\ldots [A2.17]$$

Using a very simple finite difference equation -

$$\phi_1' = \frac{\phi_2 - \phi_1}{\eta_2 - \eta_1} = -1 \qquad \ldots\ldots\ldots [A2.18]$$

$$\therefore \phi_2 = \phi_1 - 1(\eta_2 - \eta_1)$$

[A2.18] did not give very satisfactory results, but by using the divided difference technique, the following relationship was derived :-

$$\phi_2 = \frac{\phi_1 \times K \times (K+2) + \phi_3 - K \times \Pi \times (K+1)}{(K+1)^2} \qquad \ldots\ldots [A2.19]$$

The unblown profile was checked, and [A2.19] was found to agree to 6 figures. After the experience gained with calculating ϕ_1'' from a second order fit, it was felt that the plot of ϕ vs η should be reconsidered when injected, and a better fit developed for this curve. Although not tested, it was thought that a 4th order fit would be an improvement.

Except at the boundaries, central difference equations were used throughout. Note that these equations were derived to allow calculation of a function at i, and not mid-way between $i-1$ and $i+1$, which would have occurred had the function been calculated from a standard central difference equation for equal step length.

The equations derived were relatively simple, but produced a banded matrix with 5 columns. More complex equations, which become possible for equal step length, would have resulted in more columns in the banded matrix. This would require more core storage and more calculations, with related round-off errors, when solving $[A]\{\phi\} = \{B\}$. For generating the initial turbulent profile, it was found that the unequal step length improved the accuracy significantly. Because $\delta u/\delta y$ was much lower for laminar profiles, equal steps were more suitable for these calculations. This could be obtained by setting $K = 1$.

A3 Flow in Porous Media

One of the important aspects of using porous materials in transpiration cooling, is the need for strengthening the structure. As already suggested, this could be done by attaching the porous matrix to a rigid base with metering holes or slots.

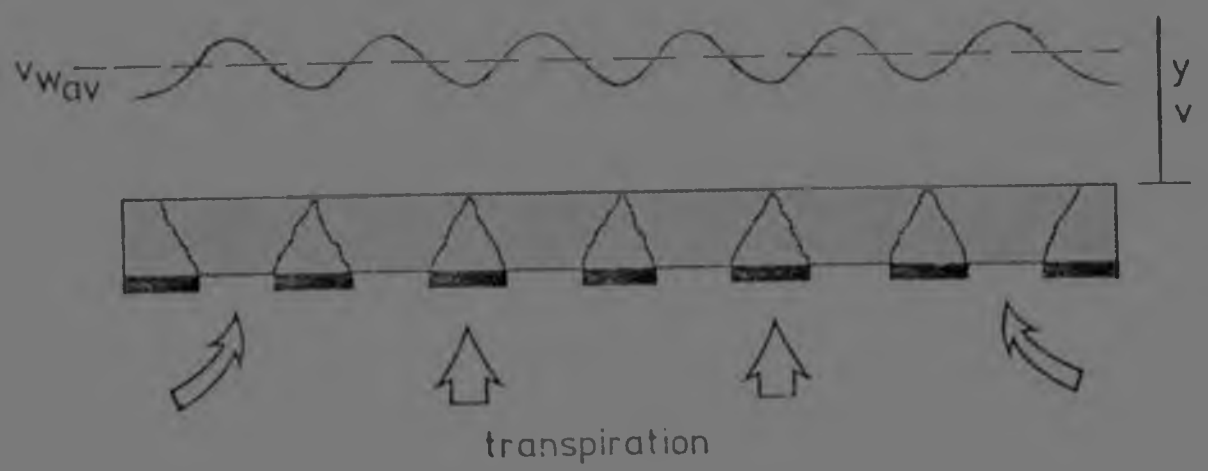


FIG A3.1 : THE POROUS MATRIX (▭) ATTACHED TO A RIGID BASE (▬) WITH METERING SLOTS

In the past, all results for pressure drop through the matrix have been obtained for the unrestricted case, ie, a one-dimensional flow situation. The average velocity at any y value in the porous material was constant. The pressure drop was found to be proportional to the superficial velocity, V_∞, for the so-called laminar region, and to V_∞^2 for the 'turbulent' region. This was found experimentally, and is useful if V_∞ is constant.

The configuration shown in Fig A3.1 was expected to behave very differently. Because the jet is spreading in the matrix, the velocity is changing, and hence also Δp. To design a porous cover for transpiration cooling, it is necessary to know : (i) the spread of the jet with y, and from that, the distance between metering slots or holes to ensure a suitable insulating layer of cool air on the upper surface of the porous material, and (ii) the pressure drop for the two-dimensional flow situation

Two approaches to the problem are possible. The microscopic, analytic approach, or the macroscopic approach, discussed in Appendix A4.

Because a porous matrix is made up of randomly sintered particles with sizes spanning a given tolerance, it is not meaningful to consider the flow at a point. Following

Slattery (1972) the momentum equation was volume averaged, in much the same way that turbulent flows were averaged on a time base.

Two theorems, developed by Slattery (1972), were used, as were the Reynolds rules of averages. The theorems were for the volume average of gradient, and of the divergence, of a second order tensor or a spatial vector field, called $\underline{B}$.

$$\overline{\nabla \underline{B}} = \frac{1}{V} \int_{V_f} \nabla \underline{B} dV = \nabla \overline{\underline{B}} + \frac{1}{V} \int_{S_w} \underline{B}.\underline{n} dS \qquad \text{..... [A3.1]}$$

$$\overline{\mathrm{div} B} = \frac{1}{V} \int_{V_f} \mathrm{div} B d = \mathrm{div} \overline{\underline{B}} + \frac{1}{V} \int_{S_w} \underline{B}.\underline{n} dS \qquad \text{..... [A3.2]}$$

where V_f is the volume, S_w the surface area.

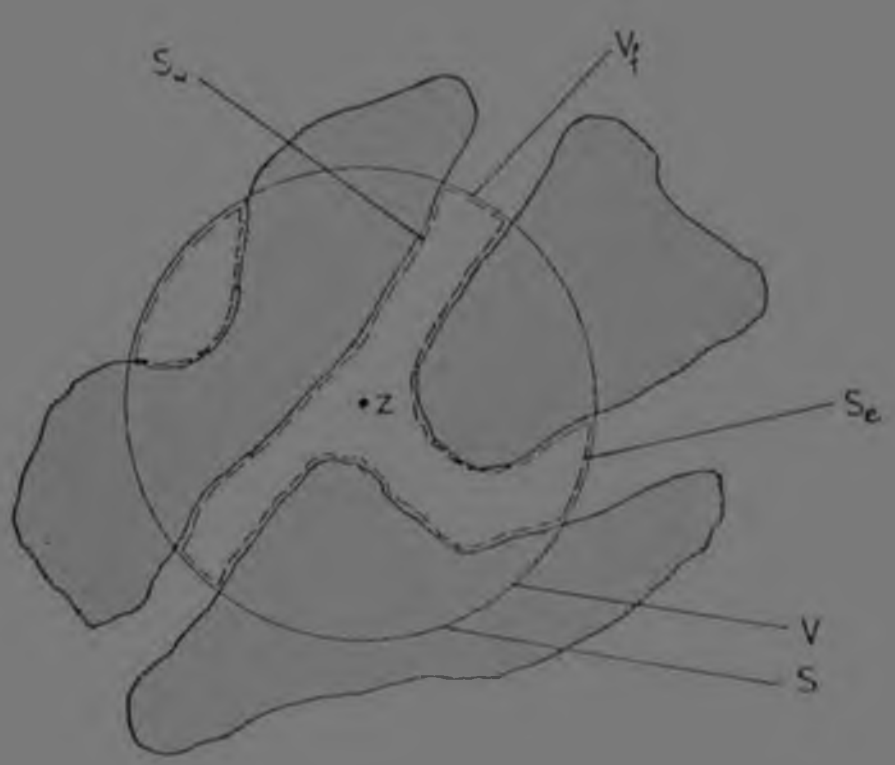


FIG A3.2 : THE POROUS MEDIUM, SHOWING VOLUME V_f, AND THE ENCLOSING SURFACE S. NOTE THAT S MUST ENCLOSE SOLID AND FLUID. S_w COINCIDES WITH THE PORE WALLS. $\underline{n}$ IS THE NORMAL VECTOR.

The Navier-Stokes equation for the steady flow of an incompressible newtonian fluid may be derived from Cauchy's first law of motion (assume no external forces were present) :

$$\rho \mathrm{div}(\underline{v}\ \underline{v}^{1}) = -\nabla p + \mu \mathrm{div}(\nabla \underline{v}) \qquad \ldots\ldots\ [A3.3]$$

Taking the local volume average of eqn.[A3.3] :-

$$\frac{1}{V}\int_{V_f} \rho \mathrm{div}(\underline{v}\ \underline{v})dV = -\frac{1}{V}\int_{V_f} \nabla p dV + \frac{1}{V}\int_{V_f} \mu \mathrm{div}(\nabla \underline{v})dV \quad \ldots\ [A3.4]$$

Noting that $(\underline{v}\ \underline{v}.\underline{n}) = 0$ on the wall, S_w, and introducing a quantity v', representing the deviation of the local point velocity from the local volume average velocity :-

$$\underline{v} = \overline{\underline{v}} + \underline{v}' \qquad \ldots\ldots\ [A3.5]$$

Note $\overline{\underline{v}} = \overline{\underline{v}} \quad \therefore \quad \overline{\underline{v}'} = 0$

Equation [A3.3] becomes :-

$$\rho \mathrm{div}(\underline{v}\ \underline{v}) = -\nabla \overline{p} + \mu(\overline{\nabla^2 \underline{v}}) - \rho \mathrm{div}(\overline{\underline{v}'\underline{v}'}) + \frac{1}{V}\int_{S_w} p n dS \qquad [A3.6]$$

The interesting feature of [A3.6] was the additional term, $-\rho \mathrm{div}(\overline{\underline{v}'\underline{v}'})$ which is very similar to the Reynolds stress term produced in the time based averaging process used for turbulent flows.

Various techniques have been suggested to simplify [A3.6], and for one dimensional creep flow (ie. delete inertial terms) the Darcy law can be derived. Another simplification for two dimensional, inertial flow, suggested by Whitaker (1969), introduced a total resistance tensor $\underline{R}$. The nine terms in this tensor would have to be evaluated experimentally, and were expected to be proportional to μ, some length scale and the permeability of the porous medium.

---

1 $\underline{v}\ \underline{v}$ is known as the dyadic product, and was treated as a second order tensor.

At the present stage it was felt that the above line of thought was not worth pursuing further : techniques for determining R were not known to the author.

A4 Tests on the Porous Matrix

At the present state of the art, it was felt that a macroscopic approach could be expected to yield results more quickly. A preliminary investigation was done, starting with a dimensional analysis.

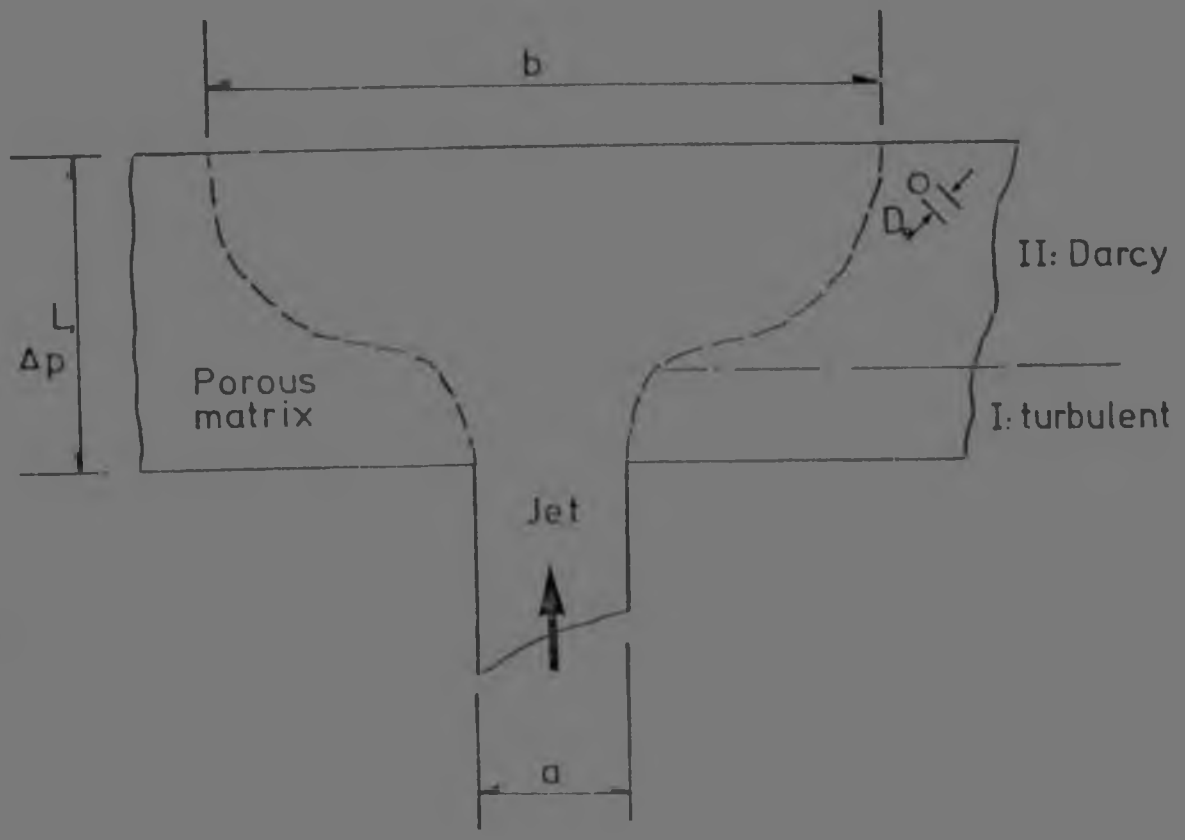


FIG A4.1 : SKETCH OF POROUS MATRIX WITH JET AT LOWER SURFACE

Because designers of transpiration cooled turbine nozzle guide vanes have a very limited pressure differential to work with, Δp was considered the most important quantity.

The variation of b with a, L and V is required if a uniform cold layer is to be present on the outer surface.

$$\Delta p = f(L,\ a,\ D,\ b,\ V,\ \mu,\ \rho) \qquad \ldots\ldots\ [A4.1]$$

Typically, the following relationship was produced :-

$$\frac{\Delta p}{\mu^2/\rho D^2} = (Re_D)^u (\frac{a}{D})^v (\frac{b}{D})^w (\frac{L}{D})^x$$

Because 3 length scales were present, these could be interchanged at will. The first dimensionless group was particularly interesting :-

$$\frac{\Delta p}{\mu^2/\rho D^2} = \frac{\Delta p}{\rho V^2}.Re_D^{\ 2} \qquad \ldots\ldots\ [A4.2]$$

$\Delta p/\rho V^2$ is the well known pressure drop coefficient C_p.

Define

$$C_{p_D}{}' = C_p.Re_D^{\ 2} \qquad \ldots\ldots\ [A4.3]$$

Some tests were performed on a matrix made of plastic spheres, D_o = 37,2 mm above an axisymmetric jet from a 80 mm pipe. The flow rate was measured with an orifice plate, and V was the average velocity in the pipe. A static pressure tapping was placed at the jet outlet.

A steam generator was placed upstream in the pipe, and the air passed over dry ice, thus producing a visible flow at the porous matrix surface. (See Fig A4.2). It was not possible to measure b with any reliability.



FIG A4.2 : LOW VELOCITY JET, V = 2,72 m/s, EMERGING FROM MATRIX

It was observed that at high velocity, the smoke formed a jet above the matrix, whereas at low velocity, the smoke filtered slowly through the matrix, and had spread much more. The conclusion reached was that for large L, an initial 'turbulent' region existed, causing a high pressure drop. This caused the jet to spread, hence slowing down to the laminar Reynolds number range. Creep flow resulted in this region - the loss of inertia being clearly visible when the smoke merely filtered through the last row of spheres. The 3 short lines on Fig A4.5 diverged from the solid line for increasing Re_L. This was thought to have been caused by the small additional pressure drop through the 'Darcy' region. Fig A4.3 shows turbulent flow emerging from the porous matrix.

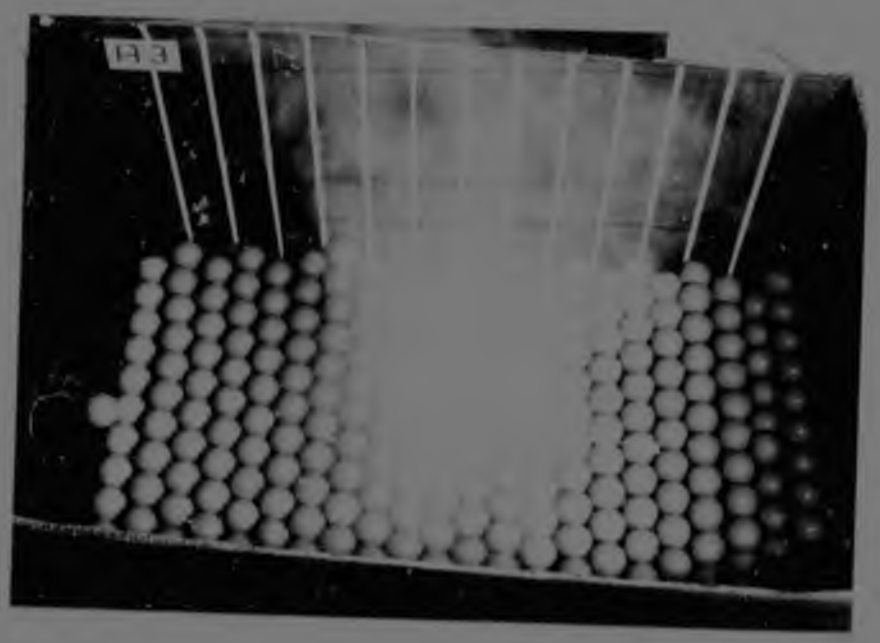


FIG A4.3 : TURBULENT JET : v = 6,5 m/s, EMERGING FROM MATRIX

The full results were not reported, but two of the graphs plotted are presented in Figs A4.4 and A4.5.

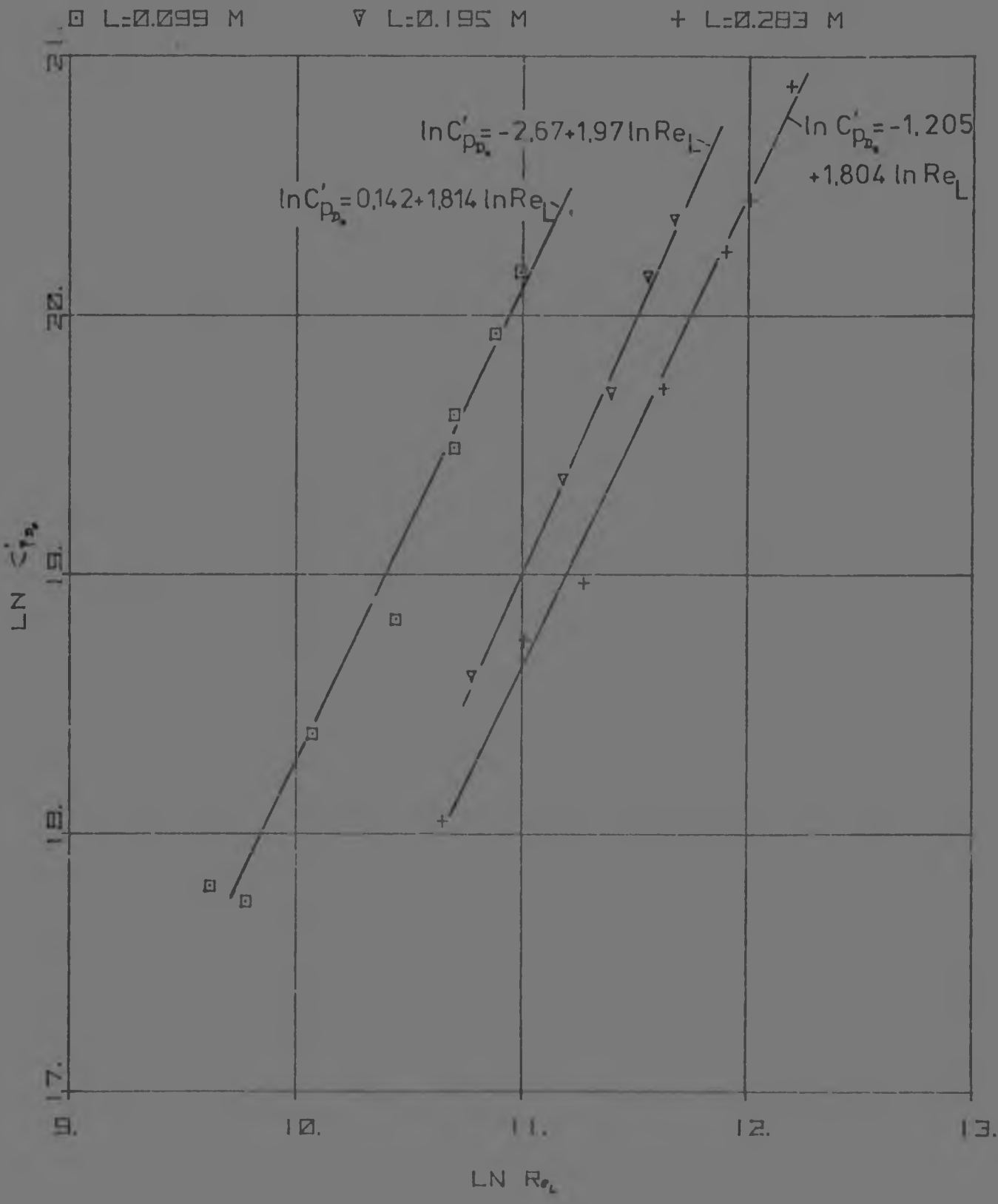


FIG A4.4 : PLOT OF $C'_{p_{D_o}}$ VS Re_L

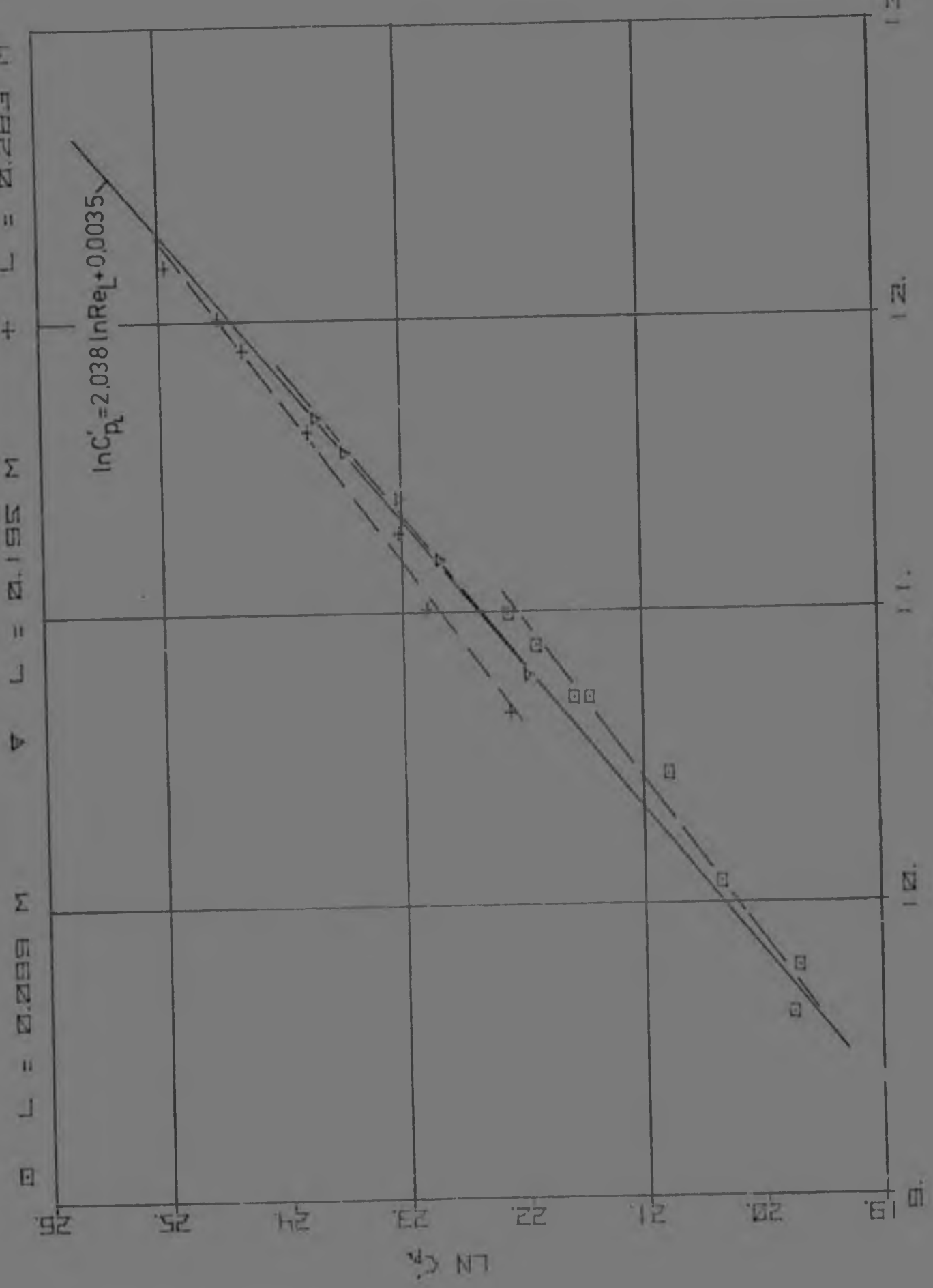


FIG A4.5 : PLOT OF C'_{pL} VS Re_L

APPENDIX B

B1 Design of the Wind Tunnel, Fan and Contraction

Subsonic wind tunnel design has become a well documented exercise. Basic decisions such as whether the tunnel should be open or closed circuit, and type of fan are very much cost dependent.

The tunnel built for this project was to form part of an existing unit. After certain sections had been constructed, it was found to be preferable to be independent of other research programmes, and a tunnel was designed around the parts already built. This was unfortunate, because the tunnel could have been better designed.

The open circuit tunnel consisted of a centrifugal fan, diffuser, settling chamber, contraction, entry section, working section and an exit diffuser.

Materials used were wood strips (100 mm wide), banded to 3 mm thick masonite, the smooth side of which formed the inside walls of the tunnel. The edges were supported with slotted angle iron. An outside company made the settling chamber and contraction of mild steel sheet. Details of the working section appear in Appendix B2. The entire tunnel is supported at shoulder height on wooden legs.

A centrifugal fan, somewhat overpowered by a 22 kW squirrel cage induction motor, was made available for the project. This unit was used to blow air down the tunnel, rather than sucking the air through the tunnel. If the ducting was attached to the fan inlet, it was expected that swirl due to the rotation of the fan would be transmitted back to the Working Section. The removal of such a vortex may have required straightner vanes, a complication which was to be avoided. The profile at the fan outlet was highly non-

uniform, but this was to be controlled with screens. In the event, this proved more difficult than was expected. The profile in the entry section was much improved by the addition of honeycomb in the settling chamber. Aluminium honeycomb, 50 mm thick with a cell size of 6 mm, was used.

The contraction had an area ratio of 3:1. Theoretically this should have reduced the velocity fluctuations by a ninth. A potential flow analysis (see Cheers, 1945) was used to design the contraction. The equations were handled on a Hewlett-Packard 9810 calculator. The streamline denoted as contraction wall was plotted by the calculator (Fig B1.2).



FIG B1.1A : PLAN VIEW OF THE WIND TUNNEL, SHOWING (A) THE SETTLING CHAMBER, (B) THE CONTRACTION, (C) THE ENTRY SECTION, (D) THE WORKING SECTION

uniform, but this was to be controlled with screens. In the event, this proved more difficult than was expected. The profile in the entry section was much improved by the addition of honeycomb in the settling chamber. Aluminium honeycomb, 50 mm thick with a cell size of 6 mm, was used.

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FIG B1.1A : PLAN VIEW OF THE WIND TUNNEL, SHOWING (A) THE SETTLING CHAMBER, (B) THE CONTRACTION, (C) THE ENTRY SECTION, (D) THE WORKING SECTION

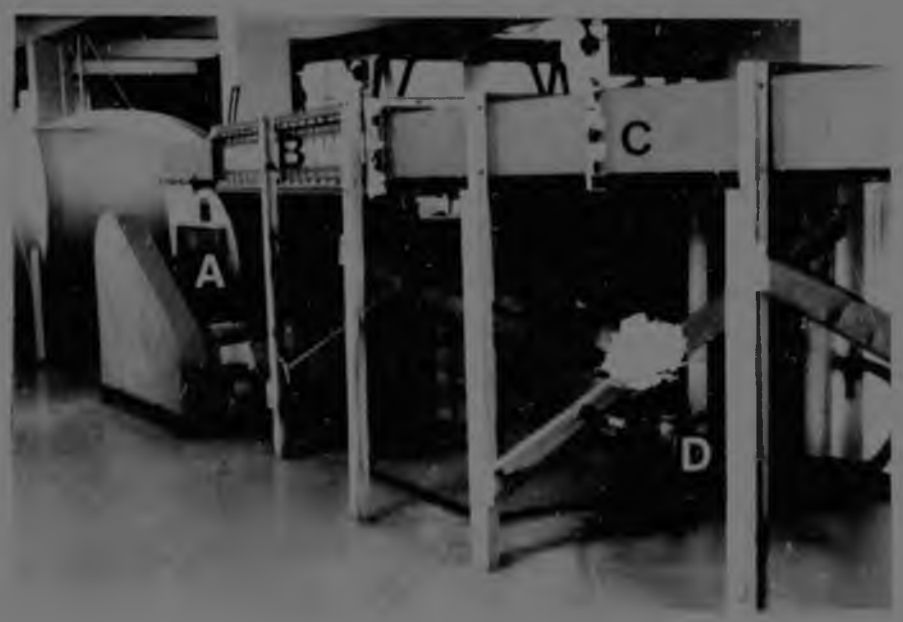

FIG B1.1B : SIDE VIEW OF THE TUNNEL WITH (A) THE FAN UNIT, (B) THE DIFFUSER, (C) SETTLING CHAMBER AND CONTRACTION, AND (D) THE COMPRESSED AIR SUPPLY

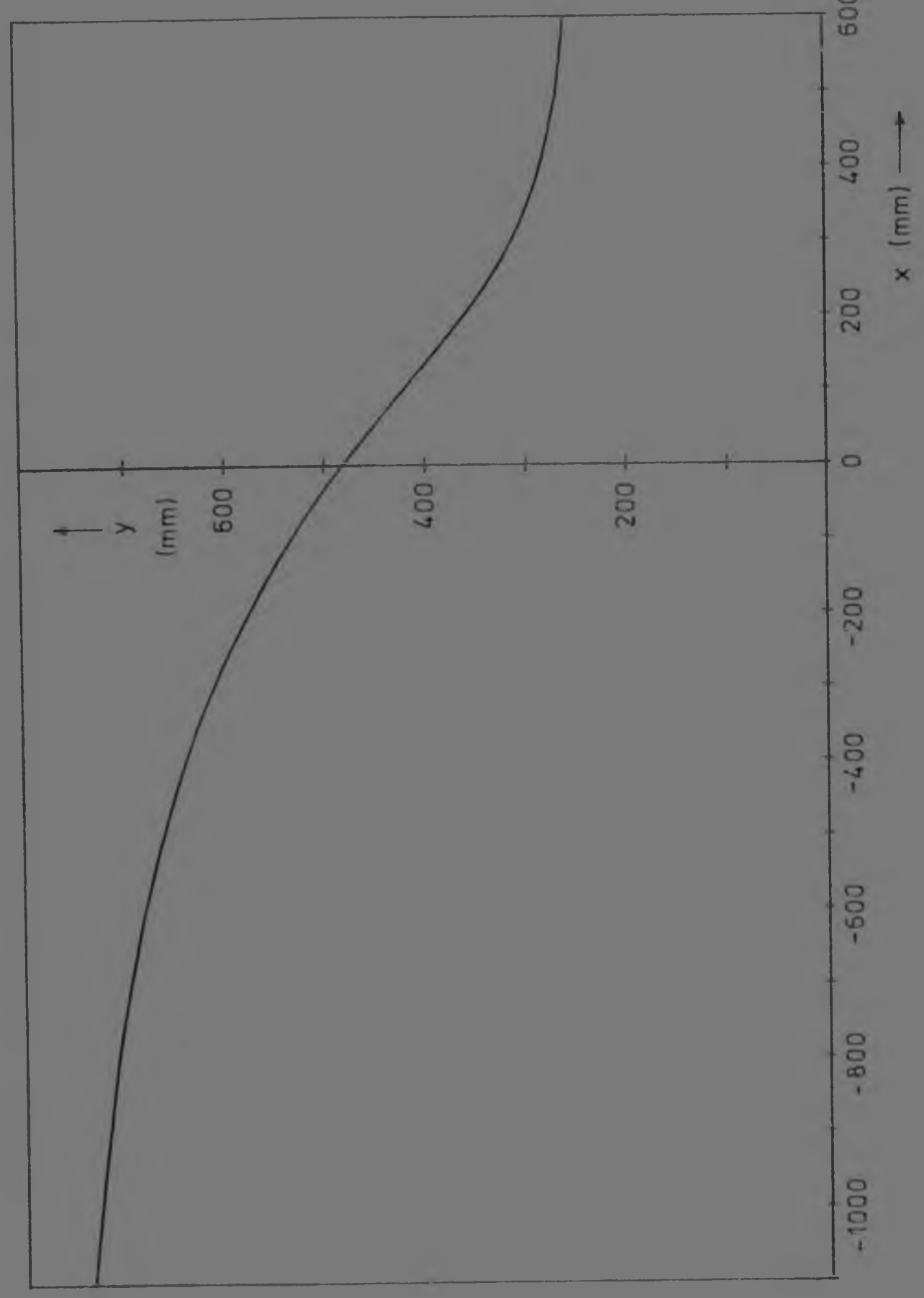

FIG B1.2 : CONTOUR OF WIND TUNNEL CONTRACTION

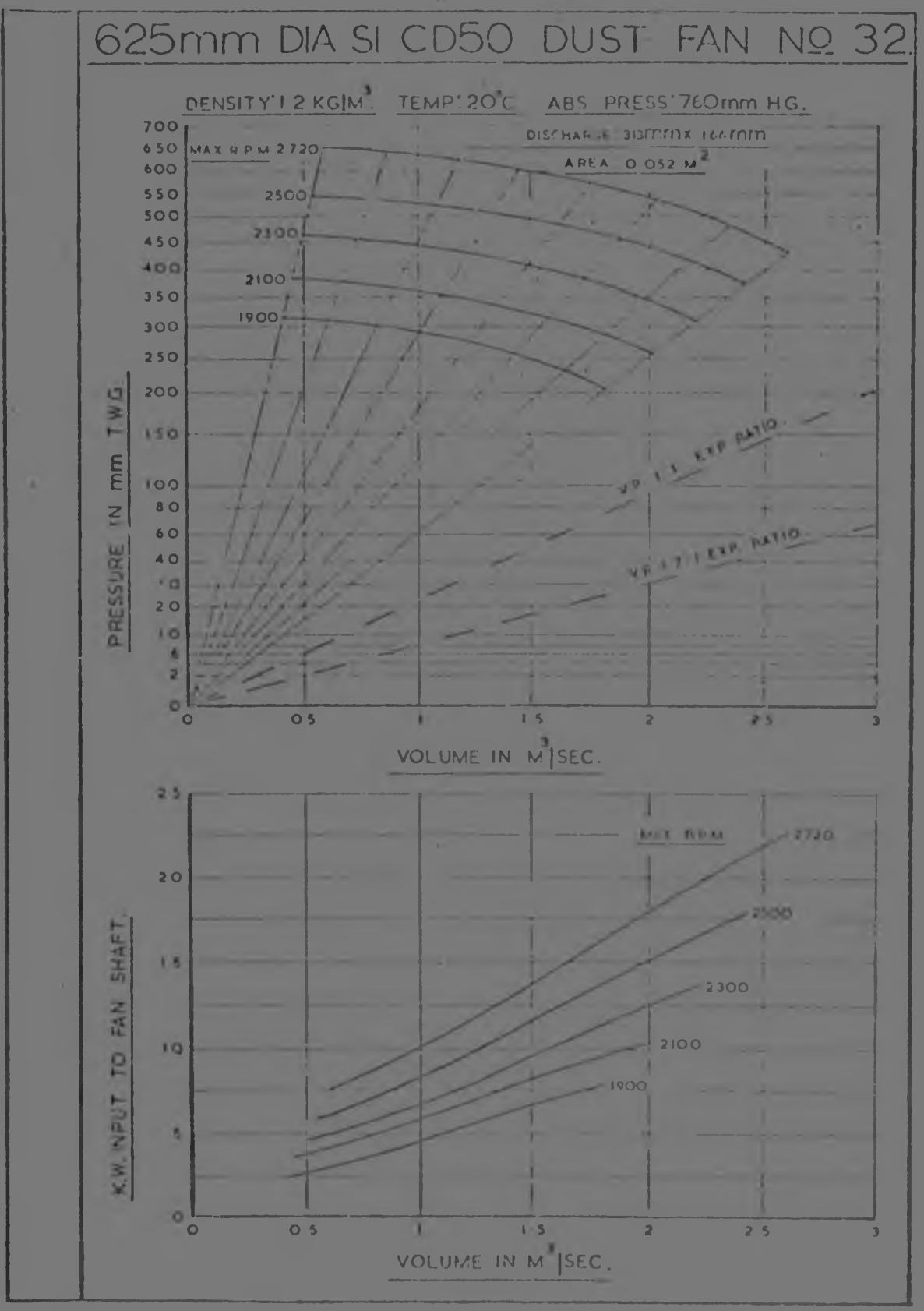

FIG B1.3 : FAN PERFORMANCE CURVE

B2 The Working Section

A working section producing two dimensional flow with Re_L = 1,2 x 10^6 was required. The plate was to be solid, interspersed with a porous section through which a secondary flow could be introduced.

The working section was made rectangular, with dimensions 0,496 x 0,209 m. At a flowrate of 1,5 m^3/s, a velocity of 17 m/s was expected in the jet. With the 1 m long, parallel duct ahead of the working section, various plates could be attached to the leading plate, allowing variation of Re_L. With a leading plate 0,8 m long, as used in most of the tests, Re_L = 1,2 x 10^6 was achieved at the end of the working section, which was 0,865 m long. A boundary layer bleed drew air off below the leading plate.

The plates and the roof of the working section were made of 3 mm aluminium sheet. Perspex (6,35 mm thick) was used for side walls. The porous plates had dimensions 500 x 244 x 6,35 mm. The porous plate leading and trailing edges were milled at 45°, and was pulled up to the aluminium plates with adjusting screws inside the plenum chamber. Filters were incorporated in the plenum chambers, to avoid the lower porous surface from becoming clogged with dirt or grease.

An exit diffuser was attached to the end of the working section. It was 1 m long, and prevented downstream conditions from affecting the flow in the jet. This section was on wheels, and could be removed to allow work inside the working section when setting up the hot wire transducer. The perspex sides were also removable.

B3 Engineering Drawing

Fig B3.1 is a reduction of the assembly drawing of the Working Section.

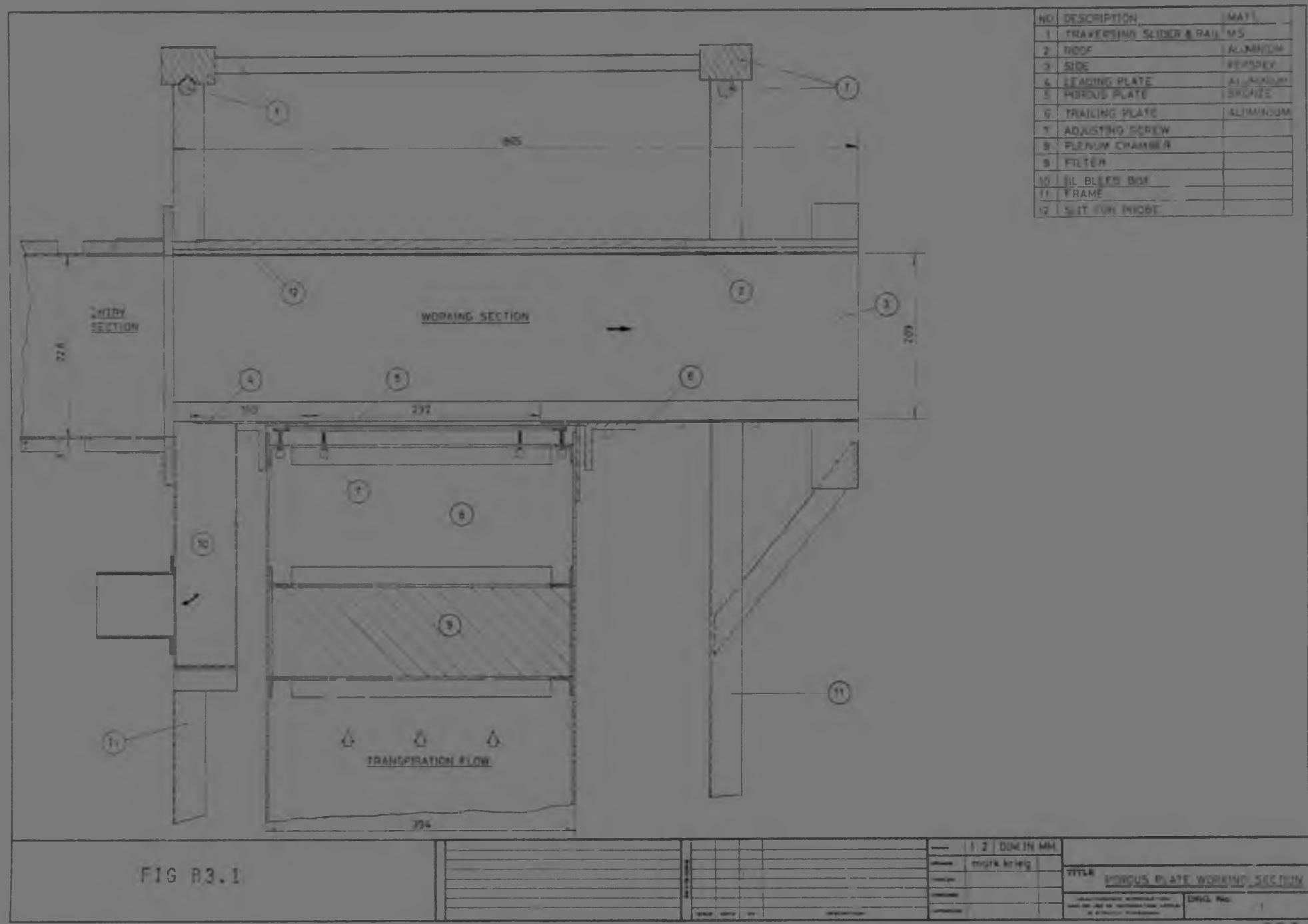
NO DESCRIPTION MATL
1 TRAVERSING SLIDER & RAIL MS
2 ROOF ALUMINIUM
3 SIDE PERSPEX
4 LEADING PLATE ALUMINIUM
5 POROUS PLATE BRONZE
6 TRAILING PLATE ALUMINIUM
7 ADJUSTING SCREW
8 PLENUM CHAMBER
9 FILTER
10 OIL BLEED BOX
11 FRAME
12 SLIT FOR PROBE
WORKING SECTION
ENTRY SECTION
TRANSPIRATION FLOW
1:2 DIM IN MM
mark krieg
TITLE POROUS PLATE WORKING SECTION
DWG. No.

FIG B3.1

APPENDIX C

C1 Calibration of the Orifice Plate

The orifice plate was calibrated according to BS 1042.

C2 Calibration of Thermocouple

Copper-constanten thermocouples were used. The calibration curve is shown in Fig C2.1 below.

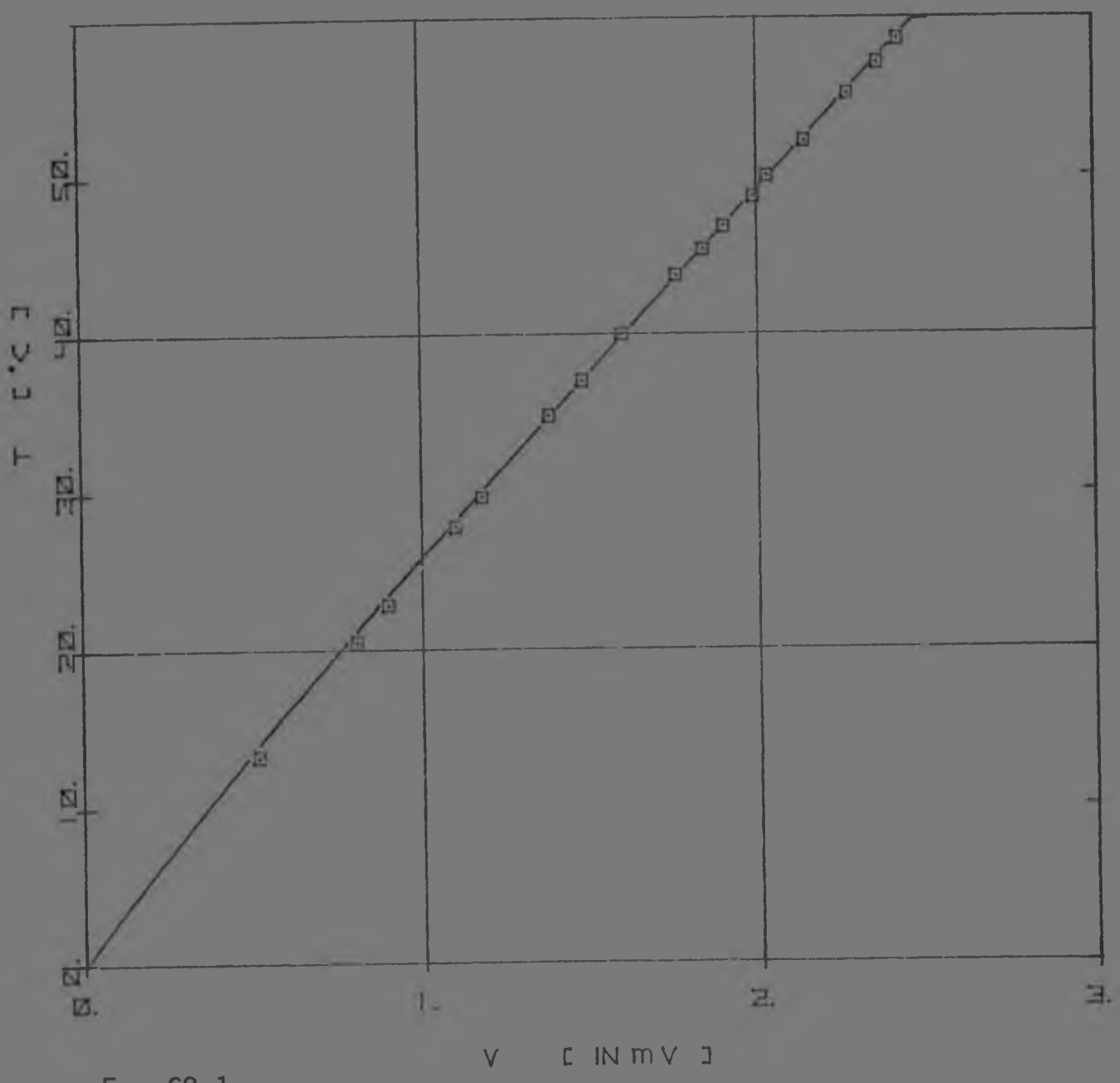

FIG C2.1

C3 The Calibration of the Hot Wires

The single sensor hot wires were calibrated using the Disa calibrating rig. This unit consisted of the Disa Pressure Control Unit, type 55 D 44, the Pressure Converter, type 55 D 46, and the nozzle unit, type 55 D 45. A Van Essen manometer model 6750 was used to measure the pressure drop across the nozzle.

The anemometer gain was adjusted using a square wave generator, and an oscilloscope to see when the amplifier became unstable. The zero flow voltage was determined, after amplification by the Auxilliary Unit, as was the hot wire resistance at the calibrating temperature.

Each hot wire (there were 4) was calibrated using the anemometer and the Auxilliary Unit.

King's Law was used to describe the calibration curves :-

$$V^2 = V_o^2 + BU^n \qquad \ldots\ldots [C3.1]$$

To obtain B and n, the data was plotted on log-log axes in the following form :-

$$\log\{(\frac{V}{V_o},)^2 - 1\} = n \log U$$

Clearly, if the lhs was plotted against log U, the slope was n. Note that $V_o' = cV_o$, where $c<1$. The value of c was varied to find the value which gave the best straight line through the points.

The linearisor used the function

$$V_{LIN} = K(V^2 - V_o^2)^{1/n} \qquad \ldots\ldots [C3.2]$$

$$\therefore V_{LIN} = K(V_o^2 - BU^n - V_o^2)^{1/n} \qquad \ldots\ldots [C3.3]$$

$$V_{LIN} = KBU = cU \qquad \ldots\ldots [C3.4]$$

to convert the non-linear anemometer output to a linear voltage. The exponent was set on the unit, and the hot wire was calibrated with the linearisor.

C4 Temperature Correction for the Anemometer Output

The heat loss from a hot-wire is influenced by the air velocity and by the air temperature. The anemometer output for a specific velocity must be corrected if the air temperature is different to the calibration temperature. This correction was performed from the following considerations :

The heat balance equation for a hot wire is :-

$$\frac{E^2}{R_w} = (T_w - T)h \qquad \ldots\ldots\ldots [C4.1]$$

E = voltage drop across the hot wire
R_w = working resistance of the hot wire
T_w = working temperature of the hot wire
T = fluid temperature
h = heat transfer coefficient.

For constant h, the expression for the correction of the anemometer output for a change in T :-

$$E_n^2 = E^2\frac{(T_w - T_n)}{(T_w - T)} \qquad \ldots\ldots\ldots [C4.2]$$

E_n = corrected voltage
T_n = calibration temperature

The resistance of the hot wire changes with temperature according to :

$$R = R_n\{1 + \alpha(T - T_n)\} \qquad \ldots\ldots\ldots [C4.3]$$

R is the resistance at temperature T, α is the thermal resistance coefficient :-

α = 0,0036 1/^{0}C ..... [C4.4]

Equation C4.2 may be rewritten :-

$$E_n^2 = E^2 \frac{(R_w - R_n)}{(R_w - R)} \quad \text{..... [C4.5]}$$

R was calculated from [C4.3], and the corrected anemometer reading from [C4.5].

C5 Correction for Proximity of the Wall

It was expected that the heat loss from the hot wire would increase very near a wall (y<2mm). Various attempts have been made to correct for this apparent increase in velocity, see Dryden (1936).

The change in voltage ΔV, can be calculated from

$$\Delta V = cn \frac{(T_w - T)^2}{y^2}$$

which was given by Horsley (1975). The value of c was estimated to be 2,53 x 10^{-6}, for y in mm. n was the exponent for the hot wire, discussed in C4.

APPENDIX D

D1 The Experimental Results

Presented here are the results of the velocity profiles measured in the boundary layer. The velocity measurements were corrected for temperature and the proximity of the wall.

Notes on experimental results

A power law was fitted to the input profile. It was given in the first line of printout. FD was u/u_{∞}. The coefficient of the first right hand term was the inverse of the power calculated.

A virtual origin for the first profile was calculated from

$$\delta = 0{,}383x/Re_x^{1/5} \qquad \ldots\ldots\ldots [D1.1]$$

Re_x was based on this virtual origin. The difference in x length between subsequent stations was added to the first value.

The programme, DP2, performed the integrations for δ^* and θ, and plotted the results. The graphs are given in Fig 7.10.

CURVE I FIT: LOG(FO)= 0.1145E+00*LOG(Y/D)+-0.7531E-0

E-758-17

2851

UINF= 17.160 M/S

REX= 0.1903E+07

T= 16.90 DEG.C

MU= 0.1798E-04 KG/MS

X= 2.079

RHO= 1.0002 KG/CU.M

NU= 0.1798E-04 M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.81	10.134	0.183	0.5907	0.0124
1.81	11.788	0.426	0.6871	0.0288
2.81	12.990	0.690	0.7570	0.0774
4.81	14.557	1.021	0.8487	0.1383
6.81	15.454	2.706	0.9007	0.1982
8.81	16.134	3.212	0.9401	0.2471
12.81	16.459	3.717	0.9594	0.2711
16.81	16.784	4.223	0.9783	0.4023
20.81	16.909	4.667	0.9856	0.5538
24.81	16.938	5.833	0.9873	0.6354
28.81	16.960	7.028	0.9885	0.7069
32.81	16.977	8.184	0.9895	0.8045
36.81	16.987	9.359	0.9901	0.9100
40.81	16.991	10.531	0.9908	

DEL= 43.79 MM DSTR= 5.48 MM THETA= 4.25 MM

RDEL= 0.4785E+05 RDSTR= 0.5233E+04 RTTA= 0.4365E+04

SHAPE FACTOR,HM= 1.29

STATION 2

UINF= 17.224 M/S

REX= 0.2[illegible]E+07 X= 2.155

T= 17.15 DEG.C RHO= 0.9963 KG/CU.M

MU= 0.1799E-04 KG/MS NU= 0.1800E-04 M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.63	6.459	0.151	0.4732	0.0178
1.17	7.617	0.271	0.5580	0.0341
2.13	8.763	0.512	0.6420	0.0620
3.10	9.583	0.719	0.7020	0.0903
4.13	10.277	0.992	0.7529	0.1203
6.13	11.369	1.472	0.8329	0.1786
8.13	12.053	1.953	0.8833	0.2369
9.13	12.334	2.673	0.9037	0.2370
11.13	12.592	3.394	0.9225	0.3315
14.13	12.761	4.114	0.9349	0.3859
17.13	12.879	4.835	0.9435	0.4399
20.13	12.929	5.555	0.9471	0.4939
23.13	12.981	6.516	0.9509	0.5701
27.13	13.049	7.477	0.9559	0.6541
31.13	13.115	8.438	0.9607	0.7381
35.13	13.168	9.399	0.9646	0.8220
39.13	13.230	10.600	0.9691	0.9277
44.13	13.283			

DEL= 46.65 MM DSTR= 5.58 MM THETA= 4.76 MM

RDEL= 0.4484E+05 RDSTR= 0.5368E+04 RTTA= 0.4582E+04

STATION 3

UINF= 18.002 M/S

REX= 0.2245E+07 X= 2.245

T= 17.40 DEG.C RHO= 0.9985 KG/CU.M

MU= 0.1803E-04 KG/MS NU= 0.1803E-04 M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	7.496	0.133	0.4178	0.0119
0.95	8.429	0.204	0.4548	0.0183
1.45	9.505	0.311	0.4997	0.0279
1.95	10.381	0.419	0.5382	0.0375
2.45	10.963	0.524	0.5703	0.0471
2.95	11.421	0.630	0.6227	0.0567
3.45	11.697	0.744	0.6661	0.0859
4.45	11.973	0.955	0.7089	0.1048
5.45	12.303	1.170	0.7396	0.1240
6.45	12.593	1.384	0.7891	0.1624
8.45	13.093	1.814	0.8226	0.2009
10.45	13.500	2.243	0.8434	0.2393
12.45	13.737	2.672	0.8641	0.2777
14.45	13.900	3.356	0.8860	0.3737
17.45	14.049	4.174	0.9060	0.4557
20.45	14.148	5.033	0.9299	0.5437
23.45	14.248	6.106	0.9457	0.6697
26.45	14.324	7.179	0.9647	0.7701
29.45	14.402	8.252	0.9803	0.8544
32.45	14.471	9.068		

DEL= 32.02 MM DSTR= 6.48 MM THETA= 4.65 MM

RDEL= 0.5[illegible]E+05 RDSTR= 0.6472E+04 RTTA= 0.4652E+04

STATION 4

UINF= 19.293 M/S

REX= 0.2514E+07 X= 2.364

T= 17.50 DEG.C RHO= 0.9980 KG/CU.M

MU= 0.1801E-04 KG/MS NU= 0.1804E-04 M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.63	6.958	0.126	0.3648	0.0121
1.17	7.977	0.234	0.3954	0.0167
1.63	8.765	0.324	0.4419	0.0243
2.13	9.620	0.424	0.4912	0.0343
2.63	10.268	0.523	0.5320	0.0454
3.13	10.868	0.623	0.5604	0.0551
3.87	11.615	0.771	0.5953	0.0743
4.87	12.459	0.970	0.6342	0.0975
5.87	12.773	1.170	0.6666	0.1127
7.87	13.448	1.570	0.7251	0.1511
9.87	14.072	1.967	0.7753	0.1895
12.87	14.839	2.577	0.8186	0.2470
15.87	15.422	3.178	0.8571	0.3046
18.87	15.859	3.779	0.8799	0.3622
21.87	17.233	4.380	0.8944	0.4198
24.87	17.508	4.981	0.9111	0.4774
27.87	17.731	5.582	0.9259	0.5542
31.87	19.201	6.783	0.9448	0.6501
36.87	19.424	7.784	0.9616	0.7461
41.87	19.702	8.784	0.9761	0.8421

DEL= 52.10 MM DSTR= 7.25 MM THETA= 4.00 MM

RDEL= 0.5587E+05 RDSTR= 0.7782E+04 RTTA= 0.5356E+04

CURVE 1 FIT: LOG(Y/D)= 0.4999E-01*LOG(Y/D)+ 0.1054E-02

E-10.57-17

3051

UINF= 18.716 M/S

REX= 0.1706E+07 M= 1.723

T= 22.91 DEG.C RHO= 0.9856 KG/CU.M

MU= 0.1817E-04 KG/MS NU= 0.1842E-04 M**2/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.62	11.874	0.171	0.6335	0.0125
1.17	12.574	0.322	0.6672	0.0236
1.67	13.035	0.462	0.7341	0.0337
2.17	13.785	0.617	0.7361	0.0438
2.67	14.107	0.767	0.7532	0.0541
3.17	14.560	0.908	0.7767	0.0642
3.67	15.243	1.058	0.8128	0.0746
4.17	15.654	1.197	0.8347	0.0847
4.67	15.953	1.338	0.8507	0.0948
5.17	16.348	1.485	0.8718	0.1048
5.67	16.744	1.630	0.8929	0.1150
6.17	17.044	1.772	0.9089	0.1251
6.67	17.321	1.917	0.9237	0.1353
7.17	17.553	2.065	0.9361	0.1455
7.67	17.727	2.211	0.9453	0.1556
8.17	17.827	2.356	0.9506	0.1657
8.67	17.927	2.504	0.9559	0.1759
9.17	18.026	2.651	0.9612	0.1860
9.67	18.059	2.797	0.9630	0.1962
10.17	18.126	2.945	0.9665	0.2063
10.67	18.193	3.092	0.9701	0.2164
11.17	18.259	3.240	0.9736	0.2266
11.67	18.326	3.387	0.9772	0.2367
12.17	18.393	3.535	0.9807	0.2468
12.67	18.459	3.682	0.9843	0.2570
13.17	18.526	3.830	0.9878	0.2671
13.67	18.593	3.977	0.9914	0.2772
14.17	18.659	4.125	0.9949	0.2874
14.67	18.726	4.272	0.9985	0.2975
15.17	18.793	4.420	1.0020	0.3077
15.67	18.859	4.567	1.0056	0.3178
16.17	18.926	4.715	1.0091	0.3279
16.67	18.993	4.862	1.0127	0.3381
17.17	19.059	5.010	1.0162	0.3482
17.67	19.126	5.157	1.0198	0.3583
18.17	19.193	5.305	1.0233	0.3685
18.67	19.259	5.452	1.0269	0.3786
19.17	19.326	5.600	1.0304	0.3887
19.67	19.393	5.747	1.0340	0.3989
20.17	19.459	5.895	1.0375	0.4090
20.67	19.526	6.042	1.0411	0.4191
21.17	19.593	6.190	1.0446	0.4293
21.67	19.659	6.337	1.0482	0.4394
22.17	19.726	6.485	1.0517	0.4495
22.67	19.793	6.632	1.0553	0.4597
23.17	19.859	6.780	1.0588	0.4698
23.67	19.926	6.927	1.0624	0.4799
24.17	19.993	7.075	1.0659	0.4901
24.67	20.059	7.222	1.0695	0.5002
25.17	20.126	7.370	1.0730	0.5103
25.67	20.193	7.517	1.0766	0.5205
26.17	20.259	7.665	1.0801	0.5306
26.67	20.326	7.812	1.0837	0.5407
27.17	20.393	7.960	1.0872	0.5509
27.67	20.459	8.107	1.0908	0.5610
28.17	20.526	8.255	1.0943	0.5711
28.67	20.593	8.402	1.0979	0.5813
29.17	20.659	8.550	1.1014	0.5914
29.67	20.726	8.697	1.1050	0.6015
30.17	20.793	8.845	1.1085	0.6117
30.67	20.859	8.992	1.1121	0.6218
31.17	20.926	9.140	1.1156	0.6319
31.67	20.993	9.287	1.1192	0.6421
32.17	21.059	9.435	1.1227	0.6522
32.67	21.126	9.582	1.1263	0.6623
33.17	21.193	9.730	1.1298	0.6725
33.67	21.259	9.877	1.1334	0.6826
34.17	21.326	10.025	1.1369	0.6927
34.67	21.393	10.172	1.1405	0.7029
35.17	21.459	10.320	1.1440	0.7130
35.67	21.526	10.467	1.1476	0.7231
36.17	21.593	10.615	1.1511	0.7333
36.67	21.659	10.762	1.1547	0.7434
37.17	21.726	10.910	1.1582	0.7535
37.67	21.793	11.057	1.1618	0.7637
38.17	21.859	11.205	1.1653	0.7738
38.67	21.926	11.352	1.1689	0.7839
39.17	21.993	11.500	1.1724	0.7941
39.67	22.059	11.647	1.1760	0.8042
40.17	22.126	11.795	1.1795	0.8143
40.67	22.193	11.942	1.1831	0.8245
41.17	22.259	12.090	1.1866	0.8346
41.67	22.326	12.237	1.1902	0.8447
42.17	22.393	12.385	1.1937	0.8549
42.67	22.459	12.532	1.1973	0.8650
43.17	22.526	12.680	1.2008	0.8751
43.67	22.593	12.827	1.2044	0.8853
44.17	22.659	12.975	1.2079	0.8954

DEL= 27.62 MM DSTR= 4.61 MM THETA= 3.63 MM

REYL= 0.3701E+05 RDSTR= 0.4956E+04 RTTA= 0.3595E+04

SHAPE FACTOR,H= 1.27

****

STATION 2

****

UINF= 18.713 M/S

REX= 0.1900E+07 M= 1.799

T= 21.70 DEG.C RHO= 0.9815 KG/CU.M

MU= 0.1821E-04 KG/MS NU= 0.1855E-04 M**2/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.62	7.785	0.146	0.4158	0.0125
1.17	8.742	0.277	0.4671	0.0236
1.67	9.358	0.393	0.5135	0.0337
2.17	10.155	0.529	0.5385	0.0438
2.67	10.854	0.655	0.5799	0.0539
3.17	11.306	0.776	0.6042	0.0640
3.67	11.806	0.902	0.6309	0.0741
4.17	12.306	1.028	0.6576	0.0842
4.67	12.806	1.154	0.6844	0.0943
5.17	13.306	1.280	0.7111	0.1044
5.67	13.806	1.406	0.7378	0.1145
6.17	14.306	1.532	0.7646	0.1246
6.67	14.806	1.658	0.7913	0.1347
7.17	15.306	1.784	0.8180	0.1448
7.67	15.806	1.910	0.8448	0.1549
8.17	16.306	2.036	0.8715	0.1650
8.67	16.806	2.162	0.8982	0.1751
9.17	17.306	2.288	0.9250	0.1852
9.67	17.806	2.414	0.9517	0.1953
10.17	18.306	2.540	0.9784	0.2054
10.67	18.806	2.666	1.0052	0.2155
11.17	19.306	2.792	1.0319	0.2256
11.67	19.806	2.918	1.0586	0.2357
12.17	20.306	3.044	1.0854	0.2458
12.67	20.806	3.170	1.1121	0.2559
13.17	21.306	3.296	1.1388	0.2660
13.67	21.806	3.422	1.1656	0.2761
14.17	22.306	3.548	1.1923	0.2862
14.67	22.806	3.674	1.2190	0.2963
15.17	23.306	3.800	1.2458	0.3064
15.67	23.806	3.926	1.2725	0.3165
16.17	24.306	4.052	1.2992	0.3266
16.67	24.806	4.178	1.3260	0.3367
17.17	25.306	4.304	1.3527	0.3468
17.67	25.806	4.430	1.3794	0.3569
18.17	26.306	4.556	1.4062	0.3670
18.67	26.806	4.682	1.4329	0.3771
19.17	27.306	4.808	1.4596	0.3872
19.67	27.806	4.934	1.4864	0.3973
20.17	28.306	5.060	1.5131	0.4074
20.67	28.806	5.186	1.5398	0.4175
21.17	29.306	5.312	1.5666	0.4276
21.67	29.806	5.438	1.5933	0.4377
22.17	30.306	5.564	1.6200	0.4478
22.67	30.806	5.690	1.6468	0.4579
23.17	31.306	5.816	1.6735	0.4680
23.67	31.806	5.942	1.7002	0.4781
24.17	32.306	6.068	1.7270	0.4882
24.67	32.806	6.194	1.7537	0.4983
25.17	33.306	6.320	1.7804	0.5084
25.67	33.806	6.446	1.8072	0.5185
26.17	34.306	6.572	1.8339	0.5286
26.67	34.806	6.698	1.8606	0.5387
27.17	35.306	6.824	1.8874	0.5488
27.67	35.806	6.950	1.9141	0.5589
28.17	36.306	7.076	1.9408	0.5690
28.67	36.806	7.202	1.9676	0.5791
29.17	37.306	7.328	1.9943	0.5892
29.67	37.806	7.454	2.0210	0.5993
30.17	38.306	7.580	2.0478	0.6094
30.67	38.806	7.706	2.0745	0.6195
31.17	39.306	7.832	2.1012	0.6296
31.67	39.806	7.958	2.1280	0.6397
32.17	40.306	8.084	2.1547	0.6498
32.67	40.806	8.210	2.1814	0.6599
33.17	41.306	8.336	2.2082	0.6700
33.67	41.806	8.462	2.2349	0.6801
34.17	42.306	8.588	2.2616	0.6902
34.67	42.806	8.714	2.2884	0.7003
35.17	43.306	8.840	2.3151	0.7104
35.67	43.806	8.966	2.3418	0.7205
36.17	44.306	9.092	2.3686	0.7306
36.67	44.806	9.218	2.3953	0.7407
37.17	45.306	9.344	2.4220	0.7508
37.67	45.806	9.470	2.4488	0.7609
38.17	46.306	9.596	2.4755	0.7710
38.67	46.806	9.722	2.5022	0.7811
39.17	47.306	9.848	2.5290	0.7912
39.67	47.806	9.974	2.5557	0.8013
40.17	48.306	10.100	2.5824	0.8114
40.67	48.806	10.226	2.6092	0.8215
41.17	49.306	10.352	2.6359	0.8316
41.67	49.806	10.478	2.6626	0.8417
42.17	50.306	10.604	2.6894	0.8518
42.67	50.806	10.730	2.7161	0.8619
43.17	51.306	10.856	2.7428	0.8720
43.67	51.806	10.982	2.7696	0.8821
44.17	52.306	11.108	2.7963	0.8922
44.67	52.806	11.234	2.8230	0.9023
45.17	53.306	11.360	2.8498	0.9124
45.67	53.806	11.486	2.8765	0.9225
46.17	54.306	11.612	2.9032	0.9326
46.67	54.806	11.738	2.9300	0.9427
47.17	55.306	11.864	2.9567	0.9528
47.67	55.806	11.990	2.9834	0.9629
48.17	56.306	12.116	3.0102	0.9730
48.67	56.806	12.242	3.0369	0.9831
49.17	57.306	12.368	3.0636	0.9932
49.67	57.806	12.494	3.0904	1.0033
50.17	58.306	12.620	3.1171	1.0134
50.67	58.806	12.746	3.1438	1.0235
51.17	59.306	12.872	3.1706	1.0336
51.67	59.806	12.998	3.1973	1.0437
52.17	60.306	13.124	3.2240	1.0538
52.67	60.806	13.250	3.2508	1.0639
53.17	61.306	13.376	3.2775	1.0740
53.67	61.806	13.502	3.3042	1.0841
54.17	62.306	13.628	3.3310	1.0942
54.67	62.806	13.754	3.3577	1.1043
55.17	63.306	13.880	3.3844	1.1144
55.67	63.806	14.006	3.4112	1.1245
56.17	64.306	14.132	3.4379	1.1346
56.67	64.806	14.258	3.4646	1.1447
57.17	65.306	14.384	3.4914	1.1548
57.67	65.806	14.510	3.5181	1.1649
58.17	66.306	14.636	3.5448	1.1750
58.67	66.806	14.762	3.5716	1.1851
59.17	67.306	14.888	3.5983	1.1952
59.67	67.806	15.014	3.6250	1.2053
60.17	68.306	15.140	3.6518	1.2154
60.67	68.806	15.266	3.6785	1.2255
61.17	69.306	15.392	3.7052	1.2356
61.67	69.806	15.518	3.7320	1.2457
62.17	70.306	15.644	3.7587	1.2558
62.67	70.806	15.770	3.7854	1.2659
63.17	71.306	15.896	3.8122	1.2760
63.67	71.806	16.022	3.8389	1.2861
64.17	72.306	16.148	3.8656	1.2962
64.67	72.806	16.274	3.8924	1.3063
65.17	73.306	16.400	3.9191	1.3164
65.67	73.806	16.526	3.9458	1.3265
66.17	74.306	16.652	3.9726	1.3366
66.67	74.806	16.778	3.9993	1.3467
67.17	75.306	16.904	4.0260	1.3568
67.67	75.806	17.030	4.0528	1.3669
68.17	76.306	17.156	4.0795	1.3770
68.67	76.806	17.282	4.1062	1.3871
69.17	77.306	17.408	4.1330	1.3972
69.67	77.806	17.534	4.1597	1.4073
70.17	78.306	17.660	4.1864	1.4174
70.67	78.806	17.786	4.2132	1.4275
71.17	79.306	17.912	4.2399	1.4376
71.67	79.806	18.038	4.2666	1.4477
72.17	80.306	18.164	4.2934	1.4578
72.67	80.806	18.290	4.3201	1.4679
73.17	81.306	18.416	4.3468	1.4780
73.67	81.806	18.542	4.3736	1.4881
74.17	82.306	18.668	4.4003	1.4982
74.67	82.806	18.794	4.4270	1.5083
75.17	83.306	18.920	4.4538	1.5184
75.67	83.806	19.046	4.4805	1.5285
76.17	84.306	19.172	4.5072	1.5386
76.67	84.806	19.298	4.5340	1.5487
77.17	85.306	19.424	4.5607	1.5588
77.67	85.806	19.550	4.5874	1.5689
78.17	86.306	19.676	4.6142	1.5790
78.67	86.806	19.802	4.6409	1.5891
79.17	87.306	19.928	4.6676	1.5992
79.67	87.806	20.054	4.6944	1.6093
80.17	88.306	20.180	4.7211	1.6194
80.67	88.806	20.306	4.7478	1.6295
81.17	89.306	20.432	4.7746	1.6396
81.67	89.806	20.558	4.8013	1.6497
82.17	90.306	20.684	4.8280	1.6598
82.67	90.806	20.810	4.8548	1.6699
83.17	91.306	20.936	4.8815	1.6800
83.67	91.806	21.062	4.9082	1.6901
84.17	92.306	21.188	4.9350	1.7002
84.67	92.806	21.314	4.9617	1.7103
85.17	93.306	21.440	4.9884	1.7204
85.67	93.806	21.566	5.0152	1.7305
86.17	94.306	21.692	5.0419	1.7406
86.67	94.806	21.818	5.0686	1.7507
87.17	95.306	21.944	5.0954	1.7608
87.67	95.806	22.070	5.1221	1.7709
88.17	96.306	22.196	5.1488	1.7810
88.67	96.806	22.322	5.1756	1.7911
89.17	97.306	22.448	5.2023	1.8012
89.67	97.806	22.574	5.2290	1.8113
90.17	98.306	22.700	5.2558	1.8214
90.67	98.806	22.826	5.2825	1.8315
91.17	99.306	22.952	5.3092	1.8416
91.67	99.806	23.078	5.3360	1.8517
92.17	100.306	23.204	5.3627	1.8618
92.67	100.806	23.330	5.3894	1.8719
93.17	101.306	23.456	5.4162	1.8820
93.67	101.806	23.582	5.4429	1.8921
94.17	102.306	23.708	5.4696	1.9022
94.67	102.806	23.834	5.4964	1.9123
95.17	103.306	23.960	5.5231	1.9224
95.67	103.806	24.086	5.5498	1.9325
96.17	104.306	24.212	5.5766	1.9426
96.67	104.806	24.338	5.6033	1.9527
97.17	105.306	24.464	5.6300	1.9628
97.67	105.806	24.590	5.6568	1.9729
98.17	106.306	24.716	5.6835	1.9830
98.67	106.806	24.842	5.7102	1.9931
99.17	107.306	24.968	5.7370	2.0032
99.67	107.806	25.094	5.7637	2.0133
100.17	108.306	25.220	5.7904	2.0234
100.67	108.806	25.346	5.8172	2.0335
101.17	109.306	25.472	5.8439	2.0436
101.67	109.806	25.598	5.8706	2.0537
102.17	110.306	25.724	5.8974	2.0638
102.67	110.806	25.850	5.9241	2.0739
103.17	111.306	25.976	5.9508	2.0840
103.67	111.806	26.102	5.9776	2.0941
104.17	112.306	26.228	6.0043	2.1042
104.67	112.806	26.354	6.0310	2.1143
105.17	113.306	26.480	6.0578	2.1244
105.67	113.806	26.606	6.0845	2.1345
106.17	114.306	26.732	6.1112	2.1446
106.67	114.806	26.858	6.1380	2.1547
107.17	115.306	26.984	6.1647	2.1648
107.67	115.806	27.110	6.1914	2.1749
108.17	116.306	27.236	6.2182	2.1850
108.67	116.806	27.362	6.2449	2.1951
109.17	117.306	27.488	6.2716	2.2052
109.67	117.806	27.614	6.2984	2.2153
110.17	118.306	27.740	6.3251	2.2254
110.67	118.806	27.866	6.3518	2.2355
111.17	119.306	27.992	6.3786	2.2456
111.67	119.806	28.118	6.4053	2.2557
112.17	120.306	28.244	6.4320	2.2658
112.67	120.806	28.370	6.4588	2.2759
113.17	121.306	28.496	6.4855	2.2860
113.67	121.806	28.622	6.5122	2.2961
114.17	122.306	28.748	6.5390	2.3062
114.67	122.806	28.874	6.5657	2.3163
115.17	123.306	29.000	6.5924	2.3264
115.67	123.806	29.126	6.6192	2.3365
116.17	124.306	29.252	6.6459	2.3466
116.67	124.806	29.378	6.6726	2.3567
117.17	125.306	29.504	6.6994	2.3668
117.67	125.806	29.630	6.7261	2.3769
118.17	126.306	29.756	6.7528	2.3870
118.67	126.806	29.882	6.7796	2.3971
119.17	127.306	30.008	6.8063	2.4072
119.67	127.806	30.134	6.8330	2.4173
120.17	128.306	30.260	6.8598	2.4274
120.67	128.806	30.386	6.8865	2.4375
121.17	129.306	30.512	6.9132	2.4476
121.67	129.806	30.638	6.9400	2.4577
122.17	130.306	30.764	6.9667	2.4678
122.67	130.806	30.890	6.9934	2.4779
123.17	131.306	31.016	7.0202	2.4880
123.67	131.806	31.142	7.0469	2.4981
124.17	132.306	31.268	7.0736	2.5082
124.67	132.806	31.394	7.1004	2.5183
125.17	133.306	31.520	7.1271	2.5284
125.67	133.806	31.646	7.1538	2.5385
126.17	134.306	31.772	7.1806	2.5486
126.67	134.806	31.898	7.2073	2.5587
127.17	135.306	32.024	7.2340	2.5688
127.67	135.806	32.150	7.2608	2.5789
128.17	136.306	32.276	7.2875	2.5890
128.67	136.806	32.402	7.3142	2.5991
129.17	137.306	32.528	7.3410	2.6092
129.67	137.806	32.654	7.3677	2.6193
130.17	138.306	32.780	7.3944	2.6294
130.67	138.806	32.906	7.4212	2.6395
131.17	139.306	33.032	7.4479	2.6496
131.67	139.806	33.158	7.4746	2.6597
132.17	140.306	33.284	7.5014	2.6698
132.67	140.806	33.410	7.5281	2.6799
133.17	141.306	33.536	7.5548	2.6900
133.67	141.806	33.662	7.5816	2.7001
134.17	142.306	33.788	7.6083	2.7102
134.67	142.806	33.914	7.6350	2.7203
135.17	143.306	34.040	7.6618	2.7304
135.67	143.806	34.166	7.6885	2.7405
136.17	144.306	34.292	7.7152	2.7506
136.67	144.806	34.418	7.7420	2.7607
137.17	145.306	34.544	7.7687	2.7708
137.67	145.806	34.670	7.7954	2.7809
138.17	146.306	34.796	7.8222	2.7910
138.67	146.806	34.922	7.8489	2.8011
139.17	147.306	35.048	7.8756	2.8112
139.67	147.806	35.174	7.9024	2.8213
140.17	148.306	35.300	7.9291	2.8314
140.67	148.806	35.426	7.9558	2.8415
141.17	149.306	35.552	7.9826	2.8516
141.67	149.806	35.678	8.0093	2.8617
142.17	150.306	35.804	8.0360	2.8718
142.67	150.806	35.930	8.0628	2.8819
143.17	151.306	36.056	8.0895	2.8920
143.67	151.806	36.182	8.1162	2.9021
144.17	152.306	36.308	8.1430	2.9122
144.67	152.806	36.434	8.1697	2.9223
145.17	153.306	36.560	8.1964	2.9324
145.67	153.806	36.686	8.2232	2.9425
146.17	154.306	36.812	8.2499	2.9526
146.67	154.806	36.938	8.2766	2.9627
147.17	155.306	37.064	8.3034	2.9728
147.67	155.806	37.190	8.3301	2.9829
148.17	156.306	37.316	8.3568	2.9930
148.67	156.806	37.442	8.3836	3.0031
149.17	157.306	37.568	8.4103	3.0132
149.67	157.806	37.694	8.4370	3.0233
150.17	158.306	37.820	8.4638	3.0334
150.67	158.806	37.946	8.4905	3.0435
151.17	159.306	38.072	8.5172	3.0536
151.67	159.806	38.198	8.5440	3.0637
152.17	160.306	38.324	8.5707	3.0738
152.67	160.806	38.450	8.5974	3.0839
153.17	161.306	38.576	8.6242	3.0940
153.67	161.806	38.702	8.6509	3.1041
154.17	162.306	38.828	8.6776	3.1142
154.67	162.806	38.954	8.7044	3.1243
155.17	163.306	39.080	8.7311	3.1344
155.67	163.806	39.206	8.7578	3.1445
156.17	164.306	39.332	8.7846	3.1546
156.67	164.806	39.458	8.8113	3.1647
157.17	165.306	39.584	8.8380	3.1748
157.67	165.806	39.710	8.8648	3.1849
158.17	166.306	39.836	8.8915	3.1950
158.67	166.806	39.962	8.9182	3.2051
159.17	167.306	40.088	8.9450	3.2152
159.67	167.806	40.214	8.9717	3.2253
160.17	168.306	40.340	8.9984	3.2354
160.67	168.806	40.466	9.0252	3.2455
161.17	169.306	40.592	9.0519	3.2556
161.67	169.806	40.718	9.0786	3.2657
162.17	170.306	40.844	9.1054	3.2758
162.67	170.806	40.970	9.1321	3.2859
163.17	171.306	41.096	9.1588	3.2960
163.67	171.806	41.222	9.1856	3.3061
164.17	172.306	41.348	9.2123	3.3162
164.67	172.806	41.474	9.2390	3.3263
165.17	173.306	41.600	9.2658	3.3364
165.67	173.806	41.726	9.2925	3.3465
166.17	174.306	41.852	9.3192	3.3566
166.67	174.806	41.978	9.3460	3.3667
167.17	175.306	42.104	9.3727	3.3768
167.67	175.806	42.230	9.3994	3.3869
168.17	176.306	42.356	9.4262	3.3970
168.67	176.806	42.482	9.4529	3.4071
169.17	177.306	42.608	9.4796	3.4172
169.67	177.806	42.734	9.5064	3.4273
170.17	178.306	42.860	9.5331	3.4374
170.67	178.806	42.986	9.5598	3.4475
171.17	179.306	43.112	9.5866	3.4576
171.67	179.806	43.238	9.6133	3.4677
172.17	180.306	43.364	9.6400	3.4778
172.67	180.806	43.490	9.6668	3.4879
173.17	181.306	43.616	9.6935	3.4980
173.67	181.806	43.742	9.7202	3.5081
174.17	182.306	43.868	9.7470	3.5182
174.67	182.806	43.994	9.7737	3.5283
175.17	183.306	44.120	9.8004	3.5384
175.67	183.806	44.246	9.8272	3.5485
176.17	184.306	44.372	9.8539	3.5586
176.67	184.806	44.498	9.8806	3.5687
177.17	185.306	44.624	9.9074	3.5788
177.67	185.806	44.750	9.9341	3.5889
178.17	186.306	44.876	9.9608	3.5990
178.67	186.806	45.002	9.9876	3.6091
179.17	187.306	45.128	10.0143	3.6192
179.67	187.806	45.254	10.0410	3.6293
180.17	188.306	45.380	10.0678	3.6394
180.67	188.806	45.506	10.0945	3.6495
181.17	189.306	45.632	10.1212	3.6596
181.67	189.806	45.758	10.1480	3.6697
182.17	190.306	45.884	10.1747	3.6798
182.67	190.806	46.010	10.2014	3.6899
183.17	191.306	46.136	10.2282	3.7000
183.67	191.806	46.262	10.2549	3.7101
184.17	192.306	46.388	10.2816	3.7202
184.67	192.806	46.514	10.3084	3.7303
185.17

PUTVF 1 CITY LOCIFOI= 0.1888E+03*LOG(Y/D1+ 0.1708E-02

UINF= 17.628 M/S

REX= 0.1655E+07 X= 1.723

T= 17.00 DEG.C RHO= 0.9968 KG/CU.M

MU= 0.1803E-04 KG/MS NU= 0.1809E-04 M**2/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.43	10.066	0.1288	0.5116	0.0152
1.43	10.477	0.4283	0.5325	0.0508
2.43	12.013	0.7278	0.6106	0.0863
3.43	13.746	1.0273	0.7004	0.1219
4.43	14.955	1.3268	0.7618	0.1574
5.43	15.756	1.6263	0.8026	0.1930
6.43	16.336	1.9258	0.8321	0.2285
7.43	16.807	2.2253	0.8560	0.2641
8.43	17.224	2.5248	0.8772	0.2996
9.43	17.579	2.8243	0.8953	0.3351
10.43	17.867	3.1238	0.9100	0.3707
11.43	18.113	3.4233	0.9225	0.4062
12.43	18.326	3.7228	0.9333	0.4418
13.43	18.509	4.0223	0.9426	0.4773
14.43	18.670	4.3218	0.9508	0.5129
15.43	18.813	4.6213	0.9581	0.5484
16.43	18.940	4.9208	0.9645	0.5839
17.43	19.053	5.2203	0.9703	0.6195
18.43	19.155	5.5198	0.9755	0.6550
19.43	19.248	5.8193	0.9802	0.6906
20.43	19.332	6.1188	0.9845	0.7261
21.43	19.409	6.4183	0.9884	0.7617
22.43	19.480	6.7178	0.9920	0.7972
23.43	19.545	7.0173	0.9953	0.8327
24.43	19.606	7.3168	0.9984	0.8683
25.43	19.663	7.6163	1.0013	0.9038
26.43	19.716	7.9158	1.0040	0.9394
27.43	19.766	8.2153	1.0066	0.9749
28.43	19.813	8.5148	1.0090	1.0105
29.43	19.858	8.8143	1.0113	1.0460
30.43	19.900	9.1138	1.0134	1.0815
31.43	19.940	9.4133	1.0155	1.1171
32.43	19.978	9.7128	1.0174	1.1526
33.43	20.014	10.0123	1.0192	1.1882
34.43	20.048	10.3118	1.0209	1.2237
35.43	20.081	10.6113	1.0226	1.2592
36.43	20.112	10.9108	1.0241	1.2948
37.43	20.142	11.2103	1.0256	1.3303
38.43	20.171	11.5098	1.0271	1.3659
39.43	20.199	11.8093	1.0285	1.4014
40.43	20.226	12.1088	1.0298	1.4369
41.43	20.252	12.4083	1.0311	1.4725
42.43	20.277	12.7078	1.0323	1.5080
43.43	20.301	13.0073	1.0335	1.5436
44.43	20.324	13.3068	1.0347	1.5791
45.43	20.347	13.6063	1.0358	1.6146
46.43	20.369	13.9058	1.0369	1.6502
47.43	20.390	14.2053	1.0379	1.6857
48.43	20.411	14.5048	1.0389	1.7213
49.43	20.431	14.8043	1.0399	1.7568
50.43	20.450	15.1038	1.0408	1.7923
51.43	20.469	15.4033	1.0417	1.8279
52.43	20.487	15.7028	1.0426	1.8634
53.43	20.505	16.0023	1.0435	1.8990
54.43	20.522	16.3018	1.0443	1.9345
55.43	20.539	16.6013	1.0451	1.9700
56.43	20.555	16.9008	1.0459	2.0056
57.43	20.571	17.2003	1.0467	2.0411
58.43	20.586	17.4998	1.0474	2.0767
59.43	20.601	17.7993	1.0482	2.1122
60.43	20.616	18.0988	1.0489	2.1477
61.43	20.630	18.3983	1.0496	2.1833
62.43	20.644	18.6978	1.0503	2.2188
63.43	20.658	18.9973	1.0509	2.2544
64.43	20.671	19.2968	1.0516	2.2899
65.43	20.684	19.5963	1.0522	2.3254
66.43	20.697	19.8958	1.0528	2.3610
67.43	20.709	20.1953	1.0534	2.3965
68.43	20.721	20.4948	1.0540	2.4321
69.43	20.733	20.7943	1.0546	2.4676
70.43	20.745	21.0938	1.0552	2.5031
71.43	20.756	21.3933	1.0557	2.5387
72.43	20.767	21.6928	1.0563	2.5742
73.43	20.778	21.9923	1.0568	2.6098
74.43	20.788	22.2918	1.0573	2.6453
75.43	20.798	22.5913	1.0578	2.6808
76.43	20.808	22.8908	1.0583	2.7164
77.43	20.818	23.1903	1.0588	2.7519
78.43	20.828	23.4898	1.0593	2.7875
79.43	20.837	23.7893	1.0598	2.8230
80.43	20.846	24.0888	1.0603	2.8585
81.43	20.855	24.3883	1.0607	2.8941
82.43	20.864	24.6878	1.0612	2.9296
83.43	20.873	24.9873	1.0616	2.9652
84.43	20.881	25.2868	1.0621	3.0007
85.43	20.889	25.5863	1.0625	3.0362
86.43	20.897	25.8858	1.0629	3.0718
87.43	20.905	26.1853	1.0633	3.1073
88.43	20.913	26.4848	1.0637	3.1429
89.43	20.920	26.7843	1.0641	3.1784
90.43	20.928	27.0838	1.0645	3.2139
91.43	20.935	27.3833	1.0649	3.2495
92.43	20.942	27.6828	1.0653	3.2850
93.43	20.949	27.9823	1.0656	3.3206
94.43	20.956	28.2818	1.0660	3.3561
95.43	20.963	28.5813	1.0663	3.3916
96.43	20.969	28.8808	1.0667	3.4272
97.43	20.976	29.1803	1.0670	3.4627
98.43	20.982	29.4798	1.0674	3.4983
99.43	20.988	29.7793	1.0677	3.5338
100.43	20.994	30.0788	1.0680	3.5693
101.43	21.000	30.3783	1.0683	3.6049
102.43	21.006	30.6778	1.0687	3.6404
103.43	21.012	30.9773	1.0690	3.6760
104.43	21.017	31.2768	1.0693	3.7115
105.43	21.023	31.5763	1.0696	3.7470
106.43	21.028	31.8758	1.0699	3.7826
107.43	21.033	32.1753	1.0702	3.8181
108.43	21.038	32.4748	1.0705	3.8537
109.43	21.043	32.7743	1.0708	3.8892
110.43	21.048	33.0738	1.0711	3.9247
111.43	21.053	33.3733	1.0714	3.9603
112.43	21.058	33.6728	1.0717	3.9958
113.43	21.063	33.9723	1.0720	4.0313
114.43	21.067	34.2718	1.0723	4.0669
115.43	21.072	34.5713	1.0726	4.1024
116.43	21.076	34.8708	1.0728	4.1380
117.43	21.080	35.1703	1.0731	4.1735
118.43	21.085	35.4698	1.0734	4.2090
119.43	21.089	35.7693	1.0736	4.2446
120.43	21.093	36.0688	1.0739	4.2801
121.43	21.097	36.3683	1.0742	4.3157
122.43	21.101	36.6678	1.0744	4.3512
123.43	21.105	36.9673	1.0747	4.3867
124.43	21.109	37.2668	1.0749	4.4223
125.43	21.113	37.5663	1.0752	4.4578
126.43	21.116	37.8658	1.0754	4.4934
127.43	21.120	38.1653	1.0757	4.5289
128.43	21.124	38.4648	1.0759	4.5644
129.43	21.127	38.7643	1.0762	4.6000
130.43	21.131	39.0638	1.0764	4.6355
131.43	21.134	39.3633	1.0767	4.6711
132.43	21.138	39.6628	1.0769	4.7066
133.43	21.141	39.9623	1.0772	4.7421
134.43	21.144	40.2618	1.0774	4.7777
135.43	21.148	40.5613	1.0776	4.8132
136.43	21.151	40.8608	1.0779	4.8488
137.43	21.154	41.1603	1.0781	4.8843
138.43	21.157	41.4598	1.0783	4.9198
139.43	21.160	41.7593	1.0786	4.9554
140.43	21.163	42.0588	1.0788	4.9909
141.43	21.166	42.3583	1.0790	5.0265
142.43	21.169	42.6578	1.0793	5.0620
143.43	21.172	42.9573	1.0795	5.0975
144.43	21.175	43.2568	1.0797	5.1331
145.43	21.178	43.5563	1.0799	5.1686
146.43	21.181	43.8558	1.0802	5.2042
147.43	21.184	44.1553	1.0804	5.2397
148.43	21.186	44.4548	1.0806	5.2752
149.43	21.189	44.7543	1.0808	5.3108
150.43	21.192	45.0538	1.0811	5.3463
151.43	21.194	45.3533	1.0813	5.3819
152.43	21.197	45.6528	1.0815	5.4174
153.43	21.200	45.9523	1.0817	5.4529
154.43	21.202	46.2518	1.0819	5.4885
155.43	21.205	46.5513	1.0821	5.5240
156.43	21.207	46.8508	1.0823	5.5596
157.43	21.210	47.1503	1.0825	5.5951
158.43	21.212	47.4498	1.0827	5.6306
159.43	21.214	47.7493	1.0829	5.6662
160.43	21.217	48.0488	1.0831	5.7017
161.43	21.219	48.3483	1.0833	5.7373
162.43	21.221	48.6478	1.0835	5.7728
163.43	21.224	48.9473	1.0837	5.8083
164.43	21.226	49.2468	1.0839	5.8439
165.43	21.228	49.5463	1.0841	5.8794
166.43	21.230	49.8458	1.0843	5.9150
167.43	21.232	50.1453	1.0845	5.9505
168.43	21.234	50.4448	1.0847	5.9860
169.43	21.236	50.7443	1.0849	6.0216
170.43	21.238	51.0438	1.0851	6.0571
171.43	21.240	51.3433	1.0853	6.0927
172.43	21.242	51.6428	1.0855	6.1282
173.43	21.244	51.9423	1.0857	6.1637
174.43	21.246	52.2418	1.0859	6.1993
175.43	21.248	52.5413	1.0861	6.2348
176.43	21.250	52.8408	1.0863	6.2704
177.43	21.252	53.1403	1.0865	6.3059
178.43	21.254	53.4398	1.0867	6.3414
179.43	21.256	53.7393	1.0869	6.3770
180.43	21.258	54.0388	1.0871	6.4125
181.43	21.260	54.3383	1.0873	6.4481
182.43	21.262	54.6378	1.0875	6.4836
183.43	21.264	54.9373	1.0877	6.5191
184.43	21.266	55.2368	1.0879	6.5547
185.43	21.268	55.5363	1.0881	6.5902
186.43	21.270	55.8358	1.0883	6.6258
187.43	21.272	56.1353	1.0885	6.6613
188.43	21.274	56.4348	1.0887	6.6968
189.43	21.276	56.7343	1.0889	6.7324
190.43	21.278	57.0338	1.0891	6.7679
191.43	21.280	57.3333	1.0893	6.8035
192.43	21.282	57.6328	1.0895	6.8390
193.43	21.284	57.9323	1.0897	6.8745
194.43	21.286	58.2318	1.0899	6.9101
195.43	21.288	58.5313	1.0901	6.9456
196.43	21.290	58.8308	1.0903	6.9812
197.43	21.292	59.1303	1.0905	7.0167
198.43	21.294	59.4298	1.0907	7.0522
199.43	21.296	59.7293	1.0909	7.0878
200.43	21.298	60.0288	1.0911	7.1233
201.43	21.300	60.3283	1.0913	7.1589
202.43	21.302	60.6278	1.0915	7.1944
203.43	21.304	60.9273	1.0917	7.2299
204.43	21.306	61.2268	1.0919	7.2655
205.43	21.308	61.5263	1.0921	7.3010
206.43	21.310	61.8258	1.0923	7.3366
207.43	21.312	62.1253	1.0925	7.3721
208.43	21.314	62.4248	1.0927	7.4076
209.43	21.316	62.7243	1.0929	7.4432
210.43	21.318	63.0238	1.0931	7.4787
211.43	21.320	63.3233	1.0933	7.5143
212.43	21.322	63.6228	1.0935	7.5498
213.43	21.324	63.9223	1.0937	7.5853
214.43	21.326	64.2218	1.0939	7.6209
215.43	21.328	64.5213	1.0941	7.6564
216.43	21.330	64.8208	1.0943	7.6920
217.43	21.332	65.1203	1.0945	7.7275
218.43	21.334	65.4198	1.0947	7.7630
219.43	21.336	65.7193	1.0949	7.7986
220.43	21.338	66.0188	1.0951	7.8341
221.43	21.340	66.3183	1.0953	7.8697
222.43	21.342	66.6178	1.0955	7.9052
223.43	21.344	66.9173	1.0957	7.9407
224.43	21.346	67.2168	1.0959	7.9763
225.43	21.348	67.5163	1.0961	8.0118
226.43	21.350	67.8158	1.0963	8.0474
227.43	21.352	68.1153	1.0965	8.0829
228.43	21.354	68.4148	1.0967	8.1184
229.43	21.356	68.7143	1.0969	8.1540
230.43	21.358	69.0138	1.0971	8.1895
231.43	21.360	69.3133	1.0973	8.2251
232.43	21.362	69.6128	1.0975	8.2606
233.43	21.364	69.9123	1.0977	8.2961
234.43	21.366	70.2118	1.0979	8.3317
235.43	21.368	70.5113	1.0981	8.3672
236.43	21.370	70.8108	1.0983	8.4028
237.43	21.372	71.1103	1.0985	8.4383
238.43	21.374	71.4098	1.0987	8.4738
239.43	21.376	71.7093	1.0989	8.5094
240.43	21.378	72.0088	1.0991	8.5449
241.43	21.380	72.3083	1.0993	8.5805
242.43	21.382	72.6078	1.0995	8.6160
243.43	21.384	72.9073	1.0997	8.6515
244.43	21.386	73.2068	1.0999	8.6871
245.43	21.388	73.5063	1.1001	8.7226
246.43	21.390	73.8058	1.1003	8.7582
247.43	21.392	74.1053	1.1005	8.7937
248.43	21.394	74.4048	1.1007	8.8292
249.43	21.396	74.7043	1.1009	8.8648
250.43	21.398	75.0038	1.1011	8.9003
251.43	21.400	75.3033	1.1013	8.9359
252.43	21.402	75.6028	1.1015	8.9714
253.43	21.404	75.9023	1.1017	9.0069
254.43	21.406	76.2018	1.1019	9.0425
255.43	21.408	76.5013	1.1021	9.0780
256.43	21.410	76.8008	1.1023	9.1136
257.43	21.412	77.1003	1.1025	9.1491
258.43	21.414	77.3998	1.1027	9.1846
259.43	21.416	77.6993	1.1029	9.2202
260.43	21.418	77.9988	1.1031	9.2557
261.43	21.420	78.2983	1.1033	9.2913
262.43	21.422	78.5978	1.1035	9.3268
263.43	21.424	78.8973	1.1037	9.3623
264.43	21.426	79.1968	1.1039	9.3979
265.43	21.428	79.4963	1.1041	9.4334
266.43	21.430	79.7958	1.1043	9.4690
267.43	21.432	80.0953	1.1045	9.5045
268.43	21.434	80.3948	1.1047	9.5400
269.43	21.436	80.6943	1.1049	9.5756
270.43	21.438	80.9938	1.1051	9.6111
271.43	21.440	81.2933	1.1053	9.6467
272.43	21.442	81.5928	1.1055	9.6822
273.43	21.444	81.8923	1.1057	9.7177
274.43	21.446	82.1918	1.1059	9.7533
275.43	21.448	82.4913	1.1061	9.7888
276.43	21.450	82.7908	1.1063	9.8244
277.43	21.452	83.0903	1.1065	9.8599
278.43	21.454	83.3898	1.1067	9.8954
279.43	21.456	83.6893	1.1069	9.9310
280.43	21.458	83.9888	1.1071	9.9665
281.43	21.460	84.2883	1.1073	10.0021
282.43	21.462	84.5878	1.1075	10.0376
283.43	21.464	84.8873	1.1077	10.0731
284.43	21.466	85.1868	1.1079	10.1087
285.43	21.468	85.4863	1.1081	10.1442
286.43	21.470	85.7858	1.1083	10.1798
287.43	21.472	86.0853	1.1085	10.2153
288.43	21.474	86.3848	1.1087	10.2508
289.43	21.476	86.6843	1.1089	10.2864
290.43	21.478	86.9838	1.1091	10.3219
291.43	21.480	87.2833	1.1093	10.3575
292.43	21.482	87.5828	1.1095	10.3930
293.43	21.484	87.8823	1.1097	10.4285
294.43	21.486	88.1818	1.1099	10.4641
295.43	21.488	88.4813	1.1101	10.4996
296.43	21.490	88.7808	1.1103	10.5352
297.43	21.492	89.0803	1.1105	10.5707
298.43	21.494	89.3798	1.1107	10.6062
299.43	21.496	89.6793	1.1109	10.6418
300.43	21.498	89.9788	1.1111	10.6773
301.43	21.500	90.2783	1.1113	10.7129
302.43	21.502	90.5778	1.1115	10.7484
303.43	21.504	90.8773	1.1117	10.7839
304.43	21.506	91.1768	1.1119	10.8195
305.43	21.508	91.4763	1.1121	10.8550
306.43	21.510	91.7758	1.1123	10.8906
307.43	21.512	92.0753	1.1125	10.9261
308.43	21.514	92.3748	1.1127	10.9616
309.43	21.516	92.6743	1.1129	10.9972
310.43	21.518	92.9738	1.1131	11.0327
311.43	21.520	93.2733	1.1133	11.0683
312.43	21.522	93.5728	1.1135	11.1038
313.43	21.524	93.8723	1.1137	11.1393
314.43	21.526	94.1718	1.1139	11.1749
315.43	21.528	94.4713	1.1141	11.2104
316.43	21.530	94.7708	1.1143	11.2460
317.43	21.532	95.0703	1.1145	11.2815
318.43	21.534	95.3698	1.1147	11.3170
319.43	21.536	95.6693	1.1149	11.3526
320.43	21.538	95.9688	1.1151	11.3881
321.43	21.540	96.2683	1.1153	11.4237
322.43	21.542	96.5678	1.1155	11.4592
323.43	21.544	96.8673	1.1157	11.4947
324.43	21.546	97.1668	1.1159	11.5303
325.43	21.548	97.4663	1.1161	11.5658
326.43	21.550	97.7658	1.1163	11.6014
327.43	21.552	98.0653	1.1165	11.6369
328.43	21.554	98.3648	1.1167	11.6724
329.43	21.556	98.6643	1.1169	11.7080
330.43	21.558	98.9638	1.1171	11.7435
331.43	21.560	99.2633	1.1173	11.7791
332.43	21.562	99.5628	1.1175	11.8146
333.43	21.564	99.8623	1.1177	11.8501
334.43	21.566	100.1618	1.1179	11.8857
335.43	21.568	100.4613	1.1181	11.9212
336.43	21.570	100.7608	1.1183	11.9568
337.43	21.572	101.0603	1.1185	11.9923
338.43	21.574	101.3598	1.1187	12.0278
339.43	21.576	101.6593	1.1189	12.0634
340.43	21.578	101.9588	1.1191	12.0989
341.43	21.580	102.2583	1.1193	12.1345
342.43	21.582	102.5578	1.1195	12.1700
343.43	21.584	102.8573	1.1197	12.2055
344.43	21.586	103.1568	1.1199	12.2411
345.43	21.588	103.4563	1.1201	12.2766
346.43	21.590	103.7558	1.1203	12.3122
347.43	21.592	104.0553	1.1205	12.3477
348.43	21.594	104.3548	1.1207	12.3832
349.43	21.596	104.6543	1.1209	12.4188
350.43	21.598	104.9538	1.1211	12.4543
351.43	21.600	105.2533	1.1213	12.4899
352.43	21.602	105.5528	1.1215	12.5254
353.43	21.604	105.8523	1.1217	12.5609
354.43	21.606	106.1518	1.1219	12.5965
355.43	21.608	106.4513	1.1221	12.6320
356.43	21.610	106.7508	1.1223	12.6676
357.43	21.612	107.0503	1.1225	12.7031
358.43	21.614	107.3498	1.1227	12.7386
359.43	21.616	107.6493	1.1229	12.7742
360.43	21.618	107.9488	1.1231	12.8097
361.43	21.620	108.2483	1.1233	12.8453
362.43	21.622	108.5478	1.1235	12.8808
363.43	21.624	108.8473	1.1237	12.9163
364.43	21.626	109.1468	1.1239	12.9519
365.43	21.628	109.4463	1.1241	12.9874
366.43	21.630	109.7458	1.1243	13.0230
367.43	21.632	110.0453	1.1245	13.0585
368.43	21.634	110.3448	1.1247	13.0940
369.43	21.636	110.6443	1.1249	13.1296
370.43	21.638	110.9438	1.1251	13.1651
371.43	21.640	111.2433	1.1253	13.2007
372.43	21.642	111.5428	1.1255	13.2362
373.43	21.644	111.8423	1.1257	13.2717
374.43	21.646	112.1418	1.1259	13.3073
375.43	21.648	112.4413	1.1261	13.3428
376.43	21.650	112.7408	1.1263	13.3784
377.43	21.652	113.0403	1.1265	13.4139
378.43	21.654	113.3398	1.1267	13.4494
379.43	21.656	113.6393	1.1269	13.4850
380.43	21.658	113.9388	1.1271	13.5205
381.43	21.660	114.2383	1.1273	13.5561
382.43	21.662	114.5378	1.1275	13.5916
383.43	21.664	114.8373	1.1277	13.6271
384.43	21.666	115.1368	1.1279	13.6627
385.43	21.668	115.4363	1.1281	13.6982
386.43	21.670	115.7358	1.1283	13.7338
387.43	21.672	116.0353	1.1285	13.7693
388.43	21.674	116.3348	1.1287	13.8048
389.43	21.676	116.6343	1.1289	13.8404
390.43	21.678	116.9338	1.1291	13.8759
391.43	21.680	117.2333	1.1293	13.9115
392.43	21.682	117.5328	1.1295	13.9470
393.43	21.684	117.8323	1.1297	13.9825
394.43	21.686	118.1318	1.1299	14.0181
395.43	21.688	118.4313	1.1301	14.0536
396.43	21.690	118.7308	1.1303	14.0892
397.43	21.692	119.0303	1.1305	14.1247
398.43	21.694	119.3298	1.1307	14.1602
399.43	21.696	119.6293	1.1309	14.1958
400.43	21.698	119.9288	1.1311	14.2313
401.43	21.700	120.2283	1.1313	14.2669
402.43	21.702	120.5278	1.1315	14.3024
403.43	21.704	120.8273	1.1317	14.3379
404.43	21.706	121.1268	1.1319	14.3735
405.43	21.708	121.4263	1.1321	14.4090
406.43	21.710	121.7258	1.1323	14.4446
407.43	21.712	122.0253	1.1325	14.4801
408.43	21.714	122.3248	1.1327	14.5156
409.43	21.716	122.6243	1.1329	14.5512
410.43	21.718	122.9238	1.1331	14.5867
411.43	21.720	123.2233	1.1333	14.6223
412.43	21.722	123.5228	1.1335	14.6578
413.43	21.724	123.8223	1.1337	14.6933
414.43	21.726	124.1218	1.1339	14.7289
415.43	21.728	124.4213	1.1341	14.7644
416.43	21.730	124.7208	1.1343	14.8000
417.43	21.732	125.0203	1.1345	14.8355
418.43	21.734	125.3198	1.1347	14.8710
419.43	21.736	125.6193	1.1349	14.9066
420.43	21.738	125.9188	1.1351	14.9421
421.43	21.740	126.2183	1.1353	14.9777
422.43	21.742	126.5178	1.1355	15.0132
423.43	21.744	126.8173	1.1357	15.0487
424.43	21.746	127.1168	1.1359	15.0843
425.43	21.748	127.4163	1.1361	15.1198
426.43	21.750	127.7158	1.1363	15.1554
427.43	21.752	128.0153	1.1365	15.1909
428.43	21.754	128.3148	1.1367	15.2264
429.43	21.756	128.6143	1.1369	15.2620
430.43	21.758	128.9138	1.1371	15.2975
431.43	21.760	129.2133	1.1373	15.3331
432.43	21.762	129.5128	1.1375	15.3686
433.43	21.764	129.8123	1.1377	15.4041
434.43	21.766	130.1118	1.1379	15.4397
435.43	21.768	130.4113	1.1381	15.4752
436.43	21.770	130.7108	1.1383	15.5108
437.43	21.772	131.0103	1.1385	15.5463
438.43	21.774	131.3098	1.1387	15.5818
439.43	21.776	131.6093	1.1389	15.6174
440.43	21.778	131.9088	1.1391	15.6529
441.43	21.780	132.2083	1.1393	15.6885
442.43	21.782	132.5078	1.1395	15.7240
443.43	21.784	132.8073	1.1397	15.7595
444.43	21.786	133.1068	1.1399	15.7951
445.43	21.788	133.4063	1.1401	15.8306
446.43	21.790	133.7058	1.1403	15.8662
447.43	21.792	134.0053	1.1405	15.9017
448.43	21.794	134.3048	1.1407	15.9372
449.43	21.796	134.6043	1.1409	15.9728
450.43	21.798	134.9038	1.1

CURVE 1 FIT: LOG(FD)= 0.1103E+00*LOG(Y/D)+-0.2175E-04

E-13,79-17

3052

UINF= 19.642 M/S

REX= 0.[illegible] X= 2.107

T= 22.80 DEG.C RHO= 0.9800 KG/CU.M

MU= 0.1827E-05 KG/MS NU= 0.1864E-04 M**2/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	4.726	0.147	0.2030	0.0118
1.27	8.251	0.301	0.3711	0.0243
2.07	10.956	0.533	0.5123	0.0434
3.77	14.272	0.894	0.7266	0.0733
5.77	15.917	1.368	0.7877	0.1102
7.77	16.753	1.843	0.8101	0.1484
9.77	17.425	2.317	0.8282	0.1866
12.77	18.283	3.029	0.8518	0.2439
15.77	19.031	3.740	0.8707	0.3012
20.77	19.825	4.925	0.8906	0.3967
27.77	19.965	6.585	0.9319	0.5304
34.77	19.968	8.245	0.9269	0.6641
41.77	19.927	9.905	0.9765	0.7977
46.77	19.960	10.817	0.9846	0.8713

DEL= 43.62 MM DSTR= 5.41 MM THETA= 4.22 MM

RDEL= 0.4579E+05 RDSTR= 0.5697E+04 RTTA= 0.4433E+04

SHAPE FACTOR.HH 1.28

STATION 3

UINF= 19.804 M/S

REX= 0.2318E+07 X= 2.193

T= 23.02 DEG.C RHO= 0.9779 KG/CU.M

MU= 0.1826E-04 KG/MS NU= 0.1868E-04 M**2/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	7.463	0.137	0.3603	0.0125
1.63	9.756	0.359	0.4709	0.0329
2.53	11.447	0.560	0.5524	0.0511
3.63	12.917	0.800	0.6235	0.0731
5.13	14.262	1.131	0.6884	0.1033
6.63	15.291	1.462	0.7381	0.1334
8.13	16.036	1.792	0.7741	0.1636
9.63	16.724	2.123	0.8073	0.1938
11.13	17.316	2.454	0.8359	0.2240
12.63	17.813	2.784	0.8599	0.2542
14.63	18.424	3.225	0.8894	0.2944
17.63	19.173	3.887	0.9256	0.3547
21.63	19.869	4.768	0.9593	0.4353
26.63	20.267	5.871	0.9785	0.5360
32.63	20.527	7.193	0.9910	0.6567
38.63	20.610	8.516	0.9950	0.7775
46.63	20.734	9.839	0.9961	0.8983

DEL= 49.69 MM DSTR= 6.37 MM THETA= 4.84 MM

RDEL= 0.5274E+05 RDSTR= 0.6763E+04 RTTA= 0.4815E+04

STATION 4

UINF= 19.980 M/S

REX= 0.2460E+07 X= 2.272

T= 23.27 DEG.C RHO= 0.9767 KG/CU.M

MU= 0.1829E-04 KG/MS NU= 0.1873E-04 M**2/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	5.347	0.132	0.2678	0.0120
1.62	8.285	0.399	0.4149	0.0310
2.62	10.227	0.630	0.5120	0.0501
3.62	11.727	0.894	0.5871	0.0692
5.12	13.210	1.265	0.6614	0.0979
6.62	14.418	1.636	0.7219	0.1266
8.12	15.313	2.007	0.7667	0.1553
10.32	16.303	2.557	0.8163	0.1980
13.82	17.333	3.427	0.8679	0.2653
18.32	18.218	4.542	0.9122	0.3517
23.82	18.857	5.912	0.9442	0.4574
29.32	19.288	7.282	0.9658	0.5632
34.82	19.531	8.652	0.9780	0.6690
40.32	19.732	10.022	0.9881	0.7748

DEL= 51.70 MM DSTR= 7.16 MM THETA= 4.68 MM

RDEL= 0.5013E+05 RDSTR= 0.7763E+04 RTTA= 0.5091E+04

STATION 4

UINF= 21.091 M/S

REX= 0.2674E+07 X= 2.372

T= 23.40 DEG.C RHO= 0.9780 KG/CU.M

MU= 0.1830E-04 KG/MS NU= 0.1871E-04 M**2/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	5.693	0.124	0.2699	0.0118
1.62	8.859	0.348	0.4200	0.0308
2.62	10.876	0.572	0.5156	0.0498
3.62	12.507	0.796	0.5929	0.0688
5.12	14.015	1.107	0.6645	0.0973
6.62	15.317	1.417	0.7262	0.1258
8.12	16.277	1.727	0.7717	0.1543
10.32	17.333	2.197	0.8217	0.1962
13.82	18.414	2.956	0.8729	0.2625
18.32	19.365	3.926	0.9180	0.3488
23.82	20.055	5.305	0.9507	0.4545
29.32	20.511	6.684	0.9724	0.5603
34.82	20.803	8.063	0.9863	0.6661
40.32	20.940	9.442	0.9928	0.7719

DEL= 52.61 MM DSTR= 8.22 MM THETA= 5.00 MM

RDEL= 0.5331E+05 RDSTR= 0.8271E+04 RTTA= 0.5063E+04

CURVE 1 FITS LOCIF01= 0.17772E+01*LOG(X/D01)+ 0.76396E-01

UINF= 19.485 M/S

RE*= 0.13048487 XX= 1.928

T0= 19.49 DEG.C RHO= 0.9048 KG/CU.M

MUE= 0.18268-05 KG/MS NUE= 0.18136-05 M**2/S

Y(MM)	U (M/S)	Y/DTA	U/UE	Y/DEL
0.62	15.998	0.147	0.8180	0.0123
1.27	17.434	0.296	0.8911	0.0251
1.91	18.272	0.441	0.9340	0.0377
2.54	18.741	0.589	0.9580	0.0503
3.17	18.977	0.736	0.9701	0.0628
3.81	19.098	0.884	0.9763	0.0754
4.44	19.159	1.031	0.9794	0.0880
5.08	19.190	1.178	0.9810	0.1005
5.71	19.206	1.325	0.9818	0.1131
6.35	19.214	1.473	0.9822	0.1257
6.98	19.218	1.620	0.9824	0.1382
7.62	19.220	1.767	0.9825	0.1508
8.25	19.221	1.915	0.9826	0.1634
8.89	19.222	2.062	0.9826	0.1759
9.52	19.222	2.209	0.9826	0.1885
10.16	19.222	2.357	0.9826	0.2011
10.79	19.222	2.504	0.9826	0.2136
11.43	19.222	2.651	0.9826	0.2262
12.06	19.222	2.799	0.9826	0.2388
12.70	19.222	2.946	0.9826	0.2513
13.33	19.222	3.093	0.9826	0.2639
13.97	19.222	3.241	0.9826	0.2765
14.60	19.222	3.388	0.9826	0.2890
15.24	19.222	3.535	0.9826	0.3016
15.87	19.222	3.683	0.9826	0.3142
16.51	19.222	3.830	0.9826	0.3267
17.14	19.222	3.977	0.9826	0.3393
17.78	19.222	4.125	0.9826	0.3519
18.41	19.222	4.272	0.9826	0.3644
19.05	19.222	4.419	0.9826	0.3770
19.68	19.222	4.567	0.9826	0.3896
20.32	19.222	4.714	0.9826	0.4021
20.95	19.222	4.861	0.9826	0.4147
21.59	19.222	5.009	0.9826	0.4273
22.22	19.222	5.156	0.9826	0.4398
22.86	19.222	5.303	0.9826	0.4524
23.49	19.222	5.451	0.9826	0.4650
24.13	19.222	5.598	0.9826	0.4775
24.76	19.222	5.745	0.9826	0.4901
25.40	19.222	5.893	0.9826	0.5027
26.03	19.222	6.040	0.9826	0.5152
26.67	19.222	6.187	0.9826	0.5278
27.30	19.222	6.335	0.9826	0.5404
27.94	19.222	6.482	0.9826	0.5529
28.57	19.222	6.629	0.9826	0.5655
29.21	19.222	6.777	0.9826	0.5781
29.84	19.222	6.924	0.9826	0.5906
30.48	19.222	7.071	0.9826	0.6032
31.11	19.222	7.219	0.9826	0.6158
31.75	19.222	7.366	0.9826	0.6283
32.38	19.222	7.513	0.9826	0.6409
33.02	19.222	7.661	0.9826	0.6535
33.65	19.222	7.808	0.9826	0.6660
34.29	19.222	7.955	0.9826	0.6786
34.92	19.222	8.103	0.9826	0.6912
35.56	19.222	8.250	0.9826	0.7037
36.19	19.222	8.397	0.9826	0.7163
36.83	19.222	8.545	0.9826	0.7289
37.46	19.222	8.692	0.9826	0.7414
38.10	19.222	8.839	0.9826	0.7540
38.73	19.222	8.987	0.9826	0.7666
39.37	19.222	9.134	0.9826	0.7791
40.00	19.222	9.281	0.9826	0.7917
40.64	19.222	9.429	0.9826	0.8043
41.27	19.222	9.576	0.9826	0.8168
41.91	19.222	9.723	0.9826	0.8294
42.54	19.222	9.871	0.9826	0.8420
43.18	19.222	10.018	0.9826	0.8545
43.81	19.222	10.165	0.9826	0.8671
44.45	19.222	10.313	0.9826	0.8797
45.08	19.222	10.460	0.9826	0.8922
45.72	19.222	10.607	0.9826	0.9048
46.35	19.222	10.755	0.9826	0.9174
46.99	19.222	10.902	0.9826	0.9299
47.62	19.222	11.049	0.9826	0.9425
48.26	19.222	11.197	0.9826	0.9551
48.89	19.222	11.344	0.9826	0.9676
49.53	19.222	11.491	0.9826	0.9802
50.16	19.222	11.639	0.9826	0.9928
50.80	19.222	11.786	0.9826	1.0053
51.43	19.222	11.933	0.9826	1.0179
52.07	19.222	12.081	0.9826	1.0305
52.70	19.222	12.228	0.9826	1.0430
53.34	19.222	12.375	0.9826	1.0556
53.97	19.222	12.523	0.9826	1.0682
54.61	19.222	12.670	0.9826	1.0807
55.24	19.222	12.817	0.9826	1.0933
55.88	19.222	12.965	0.9826	1.1059
56.51	19.222	13.112	0.9826	1.1184
57.15	19.222	13.259	0.9826	1.1310
57.78	19.222	13.407	0.9826	1.1436
58.42	19.222	13.554	0.9826	1.1561
59.05	19.222	13.701	0.9826	1.1687
59.69	19.222	13.849	0.9826	1.1813
60.32	19.222	13.996	0.9826	1.1938
60.96	19.222	14.143	0.9826	1.2064
61.59	19.222	14.291	0.9826	1.2190
62.23	19.222	14.438	0.9826	1.2315
62.86	19.222	14.585	0.9826	1.2441
63.50	19.222	14.733	0.9826	1.2567
64.13	19.222	14.880	0.9826	1.2692
64.77	19.222	15.027	0.9826	1.2818
65.40	19.222	15.175	0.9826	1.2944
66.04	19.222	15.322	0.9826	1.3069
66.67	19.222	15.469	0.9826	1.3195
67.31	19.222	15.617	0.9826	1.3321
67.94	19.222	15.764	0.9826	1.3446
68.58	19.222	15.911	0.9826	1.3572
69.21	19.222	16.059	0.9826	1.3698
69.85	19.222	16.206	0.9826	1.3823
70.48	19.222	16.353	0.9826	1.3949
71.12	19.222	16.501	0.9826	1.4075
71.75	19.222	16.648	0.9826	1.4200
72.39	19.222	16.795	0.9826	1.4326
73.02	19.222	16.943	0.9826	1.4452
73.66	19.222	17.090	0.9826	1.4577
74.29	19.222	17.237	0.9826	1.4703
74.93	19.222	17.385	0.9826	1.4829
75.56	19.222	17.532	0.9826	1.4954
76.20	19.222	17.679	0.9826	1.5080
76.83	19.222	17.827	0.9826	1.5206
77.47	19.222	17.974	0.9826	1.5331
78.10	19.222	18.121	0.9826	1.5457
78.74	19.222	18.269	0.9826	1.5583
79.37	19.222	18.416	0.9826	1.5708
80.01	19.222	18.563	0.9826	1.5834
80.64	19.222	18.711	0.9826	1.5960
81.28	19.222	18.858	0.9826	1.6085
81.91	19.222	19.005	0.9826	1.6211
82.55	19.222	19.153	0.9826	1.6337
83.18	19.222	19.300	0.9826	1.6462
83.82	19.222	19.447	0.9826	1.6588
84.45	19.222	19.595	0.9826	1.6714
85.09	19.222	19.742	0.9826	1.6839
85.72	19.222	19.889	0.9826	1.6965
86.36	19.222	20.037	0.9826	1.7091
86.99	19.222	20.184	0.9826	1.7216
87.63	19.222	20.331	0.9826	1.7342
88.26	19.222	20.479	0.9826	1.7468
88.90	19.222	20.626	0.9826	1.7593
89.53	19.222	20.773	0.9826	1.7719
90.17	19.222	20.921	0.9826	1.7845
90.80	19.222	21.068	0.9826	1.7970
91.44	19.222	21.215	0.9826	1.8096
92.07	19.222	21.363	0.9826	1.8222
92.71	19.222	21.510	0.9826	1.8347
93.34	19.222	21.657	0.9826	1.8473
93.98	19.222	21.805	0.9826	1.8599
94.61	19.222	21.952	0.9826	1.8724
95.25	19.222	22.099	0.9826	1.8850
95.88	19.222	22.247	0.9826	1.8976
96.52	19.222	22.394	0.9826	1.9101
97.15	19.222	22.541	0.9826	1.9227
97.79	19.222	22.689	0.9826	1.9353
98.42	19.222	22.836	0.9826	1.9478
99.06	19.222	22.983	0.9826	1.9604
99.69	19.222	23.131	0.9826	1.9730
100.33	19.222	23.278	0.9826	1.9855
100.96	19.222	23.425	0.9826	1.9981
101.60	19.222	23.573	0.9826	2.0107
102.23	19.222	23.720	0.9826	2.0232
102.87	19.222	23.867	0.9826	2.0358
103.50	19.222	24.015	0.9826	2.0484
104.14	19.222	24.162	0.9826	2.0609
104.77	19.222	24.309	0.9826	2.0735
105.41	19.222	24.457	0.9826	2.0861
106.04	19.222	24.604	0.9826	2.0986
106.68	19.222	24.751	0.9826	2.1112
107.31	19.222	24.899	0.9826	2.1238
107.95	19.222	25.046	0.9826	2.1363
108.58	19.222	25.193	0.9826	2.1489
109.22	19.222	25.341	0.9826	2.1615
109.85	19.222	25.488	0.9826	2.1740
110.49	19.222	25.635	0.9826	2.1866
111.12	19.222	25.783	0.9826	2.1992
111.76	19.222	25.930	0.9826	2.2117
112.39	19.222	26.077	0.9826	2.2243
113.03	19.222	26.225	0.9826	2.2369
113.66	19.222	26.372	0.9826	2.2494
114.30	19.222	26.519	0.9826	2.2620
114.93	19.222	26.667	0.9826	2.2746
115.57	19.222	26.814	0.9826	2.2871
116.20	19.222	26.961	0.9826	2.2997
116.84	19.222	27.109	0.9826	2.3123
117.47	19.222	27.256	0.9826	2.3248
118.11	19.222	27.403	0.9826	2.3374
118.74	19.222	27.551	0.9826	2.3500
119.38	19.222	27.698	0.9826	2.3625
120.01	19.222	27.845	0.9826	2.3751
120.65	19.222	27.993	0.9826	2.3877
121.28	19.222	28.140	0.9826	2.4002
121.92	19.222	28.287	0.9826	2.4128
122.55	19.222	28.435	0.9826	2.4254
123.19	19.222	28.582	0.9826	2.4379
123.82	19.222	28.729	0.9826	2.4505
124.46	19.222	28.877	0.9826	2.4631
125.09	19.222	29.024	0.9826	2.4756
125.73	19.222	29.171	0.9826	2.4882
126.36	19.222	29.319	0.9826	2.5008
127.00	19.222	29.466	0.9826	2.5133
127.63	19.222	29.613	0.9826	2.5259
128.27	19.222	29.761	0.9826	2.5385
128.90	19.222	29.908	0.9826	2.5510
129.54	19.222	30.055	0.9826	2.5636
130.17	19.222	30.203	0.9826	2.5762
130.81	19.222	30.350	0.9826	2.5887
131.44	19.222	30.497	0.9826	2.6013
132.08	19.222	30.645	0.9826	2.6139
132.71	19.222	30.792	0.9826	2.6264
133.35	19.222	30.939	0.9826	2.6390
133.98	19.222	31.087	0.9826	2.6516
134.62	19.222	31.234	0.9826	2.6641
135.25	19.222	31.381	0.9826	2.6767
135.89	19.222	31.529	0.9826	2.6893
136.52	19.222	31.676	0.9826	2.7018
137.16	19.222	31.823	0.9826	2.7144
137.79	19.222	31.971	0.9826	2.7270
138.43	19.222	32.118	0.9826	2.7395
139.06	19.222	32.265	0.9826	2.7521
139.70	19.222	32.413	0.9826	2.7647
140.33	19.222	32.560	0.9826	2.7772
140.97	19.222	32.707	0.9826	2.7898
141.60	19.222	32.855	0.9826	2.8024
142.24	19.222	33.002	0.9826	2.8149
142.87	19.222	33.149	0.9826	2.8275
143.51	19.222	33.297	0.9826	2.8401
144.14	19.222	33.444	0.9826	2.8526
144.78	19.222	33.591	0.9826	2.8652
145.41	19.222	33.739	0.9826	2.8778
146.05	19.222	33.886	0.9826	2.8903
146.68	19.222	34.033	0.9826	2.9029
147.32	19.222	34.181	0.9826	2.9155
147.95	19.222	34.328	0.9826	2.9280
148.59	19.222	34.475	0.9826	2.9406
149.22	19.222	34.623	0.9826	2.9532
149.86	19.222	34.770	0.9826	2.9657
150.49	19.222	34.917	0.9826	2.9783
151.13	19.222	35.065	0.9826	2.9909
151.76	19.222	35.212	0.9826	3.0034
152.40	19.222	35.359	0.9826	3.0160
153.03	19.222	35.507	0.9826	3.0286
153.67	19.222	35.654	0.9826	3.0411
154.30	19.222	35.801	0.9826	3.0537
154.94	19.222	35.949	0.9826	3.0663
155.57	19.222	36.096	0.9826	3.0788
156.21	19.222	36.243	0.9826	3.0914
156.84	19.222	36.391	0.9826	3.1040
157.48	19.222	36.538	0.9826	3.1165
158.11	19.222	36.685	0.9826	3.1291
158.75	19.222	36.833	0.9826	3.1417
159.38	19.222	36.980	0.9826	3.1542
160.02	19.222	37.127	0.9826	3.1668
160.65	19.222	37.275	0.9826	3.1794
161.29	19.222	37.422	0.9826	3.1919
161.92	19.222	37.569	0.9826	3.2045
162.56	19.222	37.717	0.9826	3.2171
163.19	19.222	37.864	0.9826	3.2296
163.83	19.222	38.011	0.9826	3.2422
164.46	19.222	38.159	0.9826	3.2548
165.10	19.222	38.306	0.9826	3.2673
165.73	19.222	38.453	0.9826	3.2799
166.37	19.222	38.601	0.9826	3.2925
167.00	19.222	38.748	0.9826	3.3050
167.64	19.222	38.895	0.9826	3.3176
168.27	19.222	39.043	0.9826	3.3302
168.91	19.222	39.190	0.9826	3.3427
169.54	19.222	39.337	0.9826	3.3553
170.18	19.222	39.485	0.9826	3.3679
170.81	19.222	39.632	0.9826	3.3804
171.45	19.222	39.779	0.9826	3.3930
172.08	19.222	39.927	0.9826	3.4056
172.72	19.222	40.074	0.9826	3.4181
173.35	19.222	40.221	0.9826	3.4307
173.99	19.222	40.369	0.9826	3.4433
174.62	19.222	40.516	0.9826	3.4558
175.26	19.222	40.663	0.9826	3.4684
175.89	19.222	40.811	0.9826	3.4810
176.53	19.222	40.958	0.9826	3.4935
177.16	19.222	41.105	0.9826	3.5061
177.80	19.222	41.253	0.9826	3.5187
178.43	19.222	41.400	0.9826	3.5312
179.07	19.222	41.547	0.9826	3.5438
179.70	19.222	41.695	0.9826	3.5564
180.34	19.222	41.842	0.9826	3.5689
180.97	19.222	41.989	0.9826	3.5815
181.61	19.222	42.137	0.9826	3.5941
182.24	19.222	42.284	0.9826	3.6066
182.88	19.222	42.431	0.9826	3.6192
183.51	19.222	42.579	0.9826	3.6318
184.15	19.222	42.726	0.9826	3.6443
184.78	19.222	42.873	0.9826	3.6569
185.42	19.222	43.021	0.9826	3.6695
186.05	19.222	43.168	0.9826	3.6820
186.69	19.222	43.315	0.9826	3.6946
187.32	19.222	43.463	0.9826	3.7072
187.96	19.222	43.610	0.9826	3.7197
188.59	19.222	43.757	0.9826	3.7323
189.23	19.222	43.905	0.9826	3.7449
189.86	19.222	44.052	0.9826	3.7574
190.50	19.222	44.199	0.9826	3.7700
191.13	19.222	44.347	0.9826	3.7826
191.77	19.222	44.494	0.9826	3.7951
192.40	19.222	44.641	0.9826	3.8077
193.04	19.222	44.789	0.9826	3.8203
193.67	19.222	44.936	0.9826	3.8328
194.31	19.222	45.083	0.9826	3.8454
194.94	19.222	45.231	0.9826	3.8580
195.58	19.222	45.378	0.9826	3.8705
196.21	19.222	45.525	0.9826	3.8831
196.85	19.222	45.673	0.9826	3.8957
197.48	19.222	45.820	0.9826	3.9082
198.12	19.222	45.967	0.9826	3.9208
198.75	19.222	46.115	0.9826	3.9334
199.39	19.222	46.262	0.9826	3.9459
200.02	19.222	46.409	0.9826	3.9585
200.66	19.222	46.557	0.9826	3.9711
201.29	19.222	46.704	0.9826	3.9836
201.93	19.222	46.851	0.9826	3.9962
202.56	19.222	46.999	0.9826	4.0088
203.20	19.222	47.146	0.9826	4.0213
203.83	19.222	47.293	0.9826	4.0339
204.47	19.222	47.441	0.9826	4.0465
205.10	19.222	47.588	0.9826	4.0590
205.74	19.222	47.735	0.9826	4.0716
206.37	19.222	47.883	0.9826	4.0842
207.01	19.222	48.030	0.9826	4.0967
207.64	19.222	48.177	0.9826	4.1093
208.28	19.222	48.325	0.9826	4.1219
208.91	19.222	48.472	0.9826	4.1344
209.55	19.222	48.619	0.9826	4.1470
210.18	19.222	48.767	0.9826	4.1596
210.82	19.222	48.914	0.9826	4.1721
211.45	19.222	49.061	0.9826	4.1847
212.09	19.222	49.209	0.9826	4.1973
212.72	19.222	49.356	0.9826	4.2098
213.36	19.222	49.503	0.9826	4.2224
213.99	19.222	49.651	0.9826	4.2350
214.63	19.222	49.798	0.9826	4.2475
215.26	19.222	49.945	0.9826	4.2601
215.90	19.222	50.093	0.9826	4.2727
216.53	19.222	50.240	0.9826	4.2852
217.17	19.222	50.387	0.9826	4.2978
217.80	19.222	50.535	0.9826	4.3104
218.44	19.222	50.682	0.9826	4.3229
219.07	19.222	50.829	0.9826	4.3355
219.71	19.222	50.977	0.9826	4.3481
220.34	19.222	51.124	0.9826	4.3606
220.98	19.222	51.271	0.9826	4.3732
221.61	19.222	51.419	0.9826	4.3858
222.25	19.222	51.566	0.9826	4.3983
222.88	19.222	51.713	0.9826	4.4109
223.52	19.222	51.861	0.9826	4.4235
224.15	19.222	52.008	0.9826	4.4360
224.79	19.222	52.155	0.9826	4.4486
225.42	19.222	52.303	0.9826	4.4612
226.06	19.222	52.450	0.9826	4.4737
226.69	19.222	52.597	0.9826	4.4863
227.33	19.222	52.745	0.9826	4.4989
227.96	19.222	52.892	0.9826	4.5114
228.60	19.222	53.039	0.9826	4.5240
229.23	19.222	53.187	0.9826	4.5366
229.87	19.222	53.334	0.9826	4.5491
230.50	19.222	53.481	0.9826	4.5617
231.14	19.222	53.629	0.9826	4.5743
231.77	19.222	53.776	0.9826	4.5868
232.41	19.222	53.923	0.9826	4.5994
233.04	19.222	54.071	0.9826	4.6120
233.68	19.222	54.218	0.9826	4.6245
234.31	19.222	54.365	0.9826	4.6371
234.95	19.222	54.513	0.9826	4.6497
235.58	19.222	54.660	0.9826	4.6622
236.22	19.222	54.807	0.9826	4.6748
236.85	19.222	54.955	0.9826	4.6874
237.49	19.222	55.102	0.9826	4.6999
238.12	19.222	55.249	0.9826	4.7125
238.76	19.222	55.397	0.9826	4.7251
239.39	19.222	55.544	0.9826	4.7376
240.03	19.222	55.691	0.9826	4.7502
240.66	19.222	55.839	0.9826	4.7628
241.30	19.222	55.986	0.9826	4.7753
241.93	19.222	56.133	0.9826	4.7879
242.57	19.222	56.281	0.9826	4.8005
243.20	19.222	56.428	0.9826	4.8130
243.84	19.222	56.575	0.9826	4.8256
244.47	19.222	56.723	0.9826	4.8382
245.11	19.222	56.870	0.9826	4.8507
245.74	19.222	57.017	0.9826	4.8633
246.38	19.222	57.165	0.9826	4.8759
247.01	19.222	57.312	0.9826	4.8884
247.65	19.222	57.459	0.9826	4.9010
248.28	19.222	57.607	0.9826	4.9136
248.92	19.222	57.754	0.9826	4.9261
249.55	19.222	57.901	0.9826	4.9387
250.19	19.222	58.049	0.9826	4.9513
250.82	19.222	58.196	0.9826	4.9638
251.46	19.222	58.343	0.9826	4.9764
252.09	19.222	58.491	0.9826	4.9890
252.73	19.222	58.638	0.9826	5.0015
253.36	19.222	58.785	0.9826	5.0141
254.00	19.222	58.933	0.9826	5.0267
254.63	19.222	59.080	0.9826	5.0392
255.27	19.222	59.227	0.9826	5.0518
255.90	19.222	59.375	0.9826	5.0644
256.54	19.222	59.522	0.9826	5.0769
257.17	19.222	59.669	0.9826	5.0895
257.81	19.222	59.817	0.9826	5.1021
258.44	19.222	59.964	0.9826	5.1146
259.08	19.222	60.111	0.9826	5.1272
259.71	19.222	60.259	0.9826	5.1398
260.35	19.222	60.406	0.9826	5.1523
260.98	19.222	60.553	0.9826	5.1649
261.62	19.222	60.701	0.9826	5.1775
262.25	19.222	60.848	0.9826	5.1900
262.89	19.222	60.995	0.9826	5.2026
263.52	19.222	61.143	0.9826	5.2152
264.16	19.222	61.290	0.9826	5.2277
264.79	19.222	61.437	0.9826	5.2403
265.43	19.222	61.585	0.9826	5.2529
266.06	19.222	61.732	0.9826	5.2654
266.70	19.222	61.879	0.9826	5.2780
267.33	19.222	62.027	0.9826	5.2906
267.97	19.222	62.174	0.9826	5.3031
268.60	19.222	62.321	0.9826	5.3157
269.24	19.222	62.469	0.9826	5.3283
269.87	19.222	62.616	0.9826	5.3408
270.51	19.222	62.763	0.9826	5.3534
271.14	19.222	62.911	0.9826	5.3660
271.78	19.222	63.058	0.9826	5.3785
272.41	19.222	63.205	0.9826	5.3911
273.05	19.222	63.353	0.9826	5.4037
273.68	19.222	63.500	0.9826	5.4162
274.32	19.222	63.647	0.9826	5.4288
274.95	19.222	63.795	0.9826	5.4414
275.59	19.222	63.942	0.9826	5.4539
276.22	19.222	64.089	0.9826	5.4665
276.86	19.222	64.237	0.9826	5.4791
277.49	19.222	64.384	0.9826	5.4916
278.13	19.222	64.531	0.9826	5.5042
278.76	19.222	64.679	0.9826	5.5168
279.40	19.222	64.826	0.9826	5.5293
280.03	19.222	64.973	0.9826	5.5419
280.67	19.222	65.121	0.9826	5.5545
281.30	19.222	65.268	0.9826	5.5670
281.94	19.222	65.415	0.9826	5.5796
282.57	19.222	65.563	0.9826	5.5922
283.21	19.222	65.710	0.9826	5.6047
283.84	19.222	65.857	0.9826	5.6173
284.48	19.222	66.005	0.9826	5.6299
285.11	19.222	66.152	0.9826	5.6424
285.75	19.222	66.299	0.9826	5.6550
286.38	19.222	66.447	0.9826	5.6676
287.02	19.222	66.594	0.9826	5.6801
287.65	19.222	66.741	0.9826	5.6927
288.29	19.222	66.889	0.9826	5.7053
288.92	19.222	67.036	0.9826	5.7178
289.56	19.222	67.183	0.9826	5.7304
290.19	19.222	67.331	0.9826	5.7430
290.83	19.222	67.478	0.9826	5.7555
291.46	19.222	67.625	0.9826	5.7681
292.10	19.222	67.773	0.9826	5.7807
292.73	19.222	67.920	0.9826	5.7932
293.37	19.222	68.067	0.9826	5.8058
294.00	19.222	68.215	0.9826	5.8184
294.64	19.222	68.362	0.9826	5.8309
295.27	19.222	68.509	0.9826	5.8435

E-643-13

0302

STATION 1

CURVE FIT: LOGIFDI= 0.1069E+00*LOG(Y/D)+-0.675CE-02

UINF= 15.184 M/S

REX= 0.1550E+07

T= 23.71 DEG.C

MU= 0.1821E-04 KG/MS

X= 1.929

RHO= 0.9773 KG/CU.M

NU= 0.1863E-04 M**2/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	6.757	0.150	0.4448	0.0129
1.30	8.222	0.322	0.5411	0.0271
2.30	9.884	0.570	0.6507	0.0480
3.30	10.947	0.817	0.7207	0.0688
4.30	11.730	1.064	0.7723	0.0896
5.30	12.403	1.311	0.8165	0.1104
6.80	13.133	1.684	0.8646	0.1417
8.30	13.703	2.056	0.9021	0.1729
9.80	14.177	2.428	0.9333	0.2042
11.30	14.573	2.800	0.9594	0.2354
12.80	14.874	3.173	0.9792	0.2667
14.30	15.078	3.545	0.9926	0.2979
16.30	15.184	4.040	1.0000	0.3396
18.30	15.184	4.535	1.0000	0.3813
20.30	15.184	5.030	1.0000	0.4230
22.30	15.184	5.525	1.0000	0.4647
24.30	15.184	6.020	1.0000	0.5064
26.30	15.184	6.515	1.0000	0.5481
28.30	15.184	7.010	1.0000	0.5898
31.30	15.184	7.755	1.0000	0.6523
34.30	15.184	8.500	1.0000	0.7148
37.30	15.184	9.245	1.0000	0.7773
43.30	15.184	10.730	1.0000	0.9023

DEL= 42.92 MM DSTR= 5.23 MM THETA= 4.14 MM

RDEL= 0.3431E+05 RDSTR= 0.4284E+04 RTTA= 0.3355E+04

SHAPE FACTOR,H= 1.28

POWER LAW: N= 7.22

STATION 2

UINF= 15.317 M/S

REX= 0.1602E+07

X= 2.005

T= 23.51 DEG.C

RHO= 0.9779 KG/CU.M

MU= 0.1830E-04 KG/MS

NU= 0.1871E-04 M**2/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	7.159	0.133	0.4674	0.0117
1.30	8.602	0.225	0.5616	0.0199
2.30	9.913	0.375	0.6472	0.0331
3.70	11.279	0.589	0.7365	0.0531
4.80	11.926	0.803	0.7787	0.0717
6.30	12.626	1.016	0.8243	0.0900
7.80	13.279	1.232	0.8670	0.1089
9.30	13.819	1.449	0.9023	0.1283
10.80	14.240	1.665	0.9298	0.1477
12.30	14.553	1.882	0.9503	0.1671
13.80	14.777	2.098	0.9649	0.1865
15.30	14.928	2.314	0.9747	0.2059
16.80	15.031	2.531	0.9815	0.2253
18.30	15.097	2.748	0.9858	0.2447
19.80	15.140	2.964	0.9886	0.2641
21.30	15.167	3.180	0.9904	0.2835
22.80	15.183	3.397	0.9914	0.3029
24.30	15.193	3.613	0.9921	0.3223
25.80	15.199	3.829	0.9925	0.3417
27.30	15.203	4.046	0.9928	0.3611
28.80	15.205	4.262	0.9930	0.3805
30.30	15.207	4.479	0.9931	0.3999
31.80	15.208	4.695	0.9932	0.4193
33.30	15.209	4.911	0.9933	0.4387
34.80	15.210	5.128	0.9933	0.4581
36.30	15.210	5.344	0.9934	0.4775
37.80	15.211	5.561	0.9934	0.4969
39.30	15.211	5.777	0.9934	0.5163
40.80	15.211	5.993	0.9934	0.5357
42.30	15.211	6.210	0.9934	0.5551
43.80	15.211	6.426	0.9934	0.5745

DEL= 52.79 MM DSTR= 6.16 MM THETA= 4.67 MM

RDEL= 0.4637E+05 RDSTR= 0.5411E+04 RTTA= 0.3870E+04

STATION 3

UINF= 15.044 M/S

REX= 0.1782E+07

X= 2.094

T= 23.74 DEG.C

RHO= 0.9772 KG/CU.M

MU= 0.1831E-04 KG/MS

NU= 0.1874E-04 M**2/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	6.753	0.127	0.4278	0.0123
1.30	8.097	0.267	0.5128	0.0259
2.30	9.237	0.473	0.5851	0.0458
3.70	10.124	0.778	0.6413	0.0757
4.30	10.773	0.884	0.6825	0.0856
5.30	11.233	1.089	0.7116	0.1056
6.80	11.843	1.398	0.7503	0.1354
8.30	12.302	1.706	0.7793	0.1653
9.80	12.677	2.014	0.8031	0.1952
11.30	12.986	2.323	0.8227	0.2251
12.80	13.234	2.631	0.8386	0.2550
14.30	13.439	2.939	0.8518	0.2848
16.30	13.678	3.351	0.8670	0.3247
19.30	13.812	3.967	0.8755	0.3844
22.30	14.194	4.584	0.8999	0.4442
27.30	14.490	5.612	0.9184	0.5438
32.30	14.739	6.639	0.9337	0.6434
34.30	15.045	7.873	0.9557	0.7629
44.30	15.058	9.100	0.9703	0.8824

DEL= 50.21 MM DSTR= 6.68 MM THETA= 4.86 MM

RDEL= 0.4272E+05 RDSTR= 0.5870E+04 RTTA= 0.4006E+04

CURVE 1 RE= 2.00/FT= 0.11796+06 M/SEC/DX= 1.45858E-02

E-9.69-13

0402

U INF= 15.361 M/S

REX= 0.210 7EA+07 X= 2.750

T= 23.68 DEG.C RHO= 0.9775 KG/CU.M

MUE 0.1833E-04 KG/MS NU= 0.18773E-04 M**2/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	0.21 0.137	0.4104	0.2137	
0.83	0.282 0.183	0.5472	0.2850	
1.03	0.312 0.203	0.6312	0.3284	
1.23	0.363 0.236	0.7316	0.3804	
1.43	0.401 0.261	0.8076	0.4199	
1.63	0.433 0.282	0.8720	0.4535	
1.83	0.460 0.299	0.9263	0.4817	
2.03	0.484 0.315	0.9746	0.5068	
2.23	0.505 0.328	1.0168	0.5287	
2.43	0.523 0.340	1.0530	0.5475	
2.63	0.539 0.350	1.0852	0.5643	
2.83	0.553 0.359	1.1134	0.5790	
3.03	0.565 0.367	1.1376	0.5916	
3.23	0.576 0.374	1.1598	0.6032	
3.43	0.585 0.380	1.1779	0.6126	
3.63	0.593 0.385	1.1941	0.6210	
3.83	0.600 0.390	1.2082	0.6283	
4.03	0.606 0.394	1.2203	0.6346	
4.23	0.611 0.397	1.2304	0.6398	
4.43	0.615 0.399	1.2385	0.6440	
4.63	0.618 0.401	1.2446	0.6471	
4.83	0.620 0.403	1.2487	0.6492	
5.03	0.622 0.404	1.2527	0.6513	
5.23	0.623 0.405	1.2548	0.6524	
5.43	0.624 0.405	1.2568	0.6534	
5.63	0.625 0.406	1.2589	0.6545	
5.83	0.626 0.406	1.2609	0.6555	
6.03	0.627 0.407	1.2630	0.6566	
6.23	0.628 0.408	1.2650	0.6576	
6.43	0.629 0.408	1.2671	0.6587	
6.63	0.630 0.409	1.2691	0.6597	
6.83	0.631 0.410	1.2712	0.6608	
7.03	0.632 0.410	1.2732	0.6618	
7.23	0.633 0.411	1.2753	0.6629	
7.43	0.634 0.412	1.2773	0.6639	
7.63	0.635 0.412	1.2794	0.6650	
7.83	0.636 0.413	1.2814	0.6660	
8.03	0.637 0.414	1.2835	0.6671	
8.23	0.638 0.414	1.2855	0.6681	
8.43	0.639 0.415	1.2876	0.6692	
8.63	0.640 0.416	1.2896	0.6702	
8.83	0.641 0.416	1.2917	0.6713	
9.03	0.642 0.417	1.2937	0.6723	
9.23	0.643 0.418	1.2958	0.6734	
9.43	0.644 0.418	1.2978	0.6744	
9.63	0.645 0.419	1.2999	0.6755	
9.83	0.646 0.420	1.3019	0.6765	
10.03	0.647 0.420	1.3040	0.6776	
10.23	0.648 0.421	1.3060	0.6786	
10.43	0.649 0.422	1.3081	0.6797	
10.63	0.650 0.422	1.3101	0.6807	
10.83	0.651 0.423	1.3122	0.6818	
11.03	0.652 0.424	1.3142	0.6828	
11.23	0.653 0.424	1.3163	0.6839	
11.43	0.654 0.425	1.3183	0.6849	
11.63	0.655 0.426	1.3204	0.6860	
11.83	0.656 0.426	1.3224	0.6870	
12.03	0.657 0.427	1.3245	0.6881	
12.23	0.658 0.428	1.3265	0.6891	
12.43	0.659 0.428	1.3286	0.6902	
12.63	0.660 0.429	1.3306	0.6912	
12.83	0.661 0.430	1.3327	0.6923	
13.03	0.662 0.430	1.3347	0.6933	
13.23	0.663 0.431	1.3368	0.6944	
13.43	0.664 0.432	1.3388	0.6954	
13.63	0.665 0.432	1.3409	0.6965	
13.83	0.666 0.433	1.3429	0.6975	
14.03	0.667 0.434	1.3450	0.6986	
14.23	0.668 0.434	1.3470	0.6996	
14.43	0.669 0.435	1.3491	0.7007	
14.63	0.670 0.436	1.3511	0.7017	
14.83	0.671 0.436	1.3532	0.7028	
15.03	0.672 0.437	1.3552	0.7038	
15.23	0.673 0.438	1.3573	0.7049	
15.43	0.674 0.438	1.3593	0.7059	
15.63	0.675 0.439	1.3614	0.7070	
15.83	0.676 0.440	1.3634	0.7080	
16.03	0.677 0.440	1.3655	0.7091	
16.23	0.678 0.441	1.3675	0.7101	
16.43	0.679 0.442	1.3696	0.7112	
16.63	0.680 0.442	1.3716	0.7122	
16.83	0.681 0.443	1.3737	0.7133	
17.03	0.682 0.444	1.3757	0.7143	
17.23	0.683 0.444	1.3778	0.7154	
17.43	0.684 0.445	1.3798	0.7164	
17.63	0.685 0.446	1.3819	0.7175	
17.83	0.686 0.446	1.3839	0.7185	
18.03	0.687 0.447	1.3860	0.7196	
18.23	0.688 0.448	1.3880	0.7206	
18.43	0.689 0.448	1.3901	0.7217	
18.63	0.690 0.449	1.3921	0.7227	
18.83	0.691 0.450	1.3942	0.7238	
19.03	0.692 0.450	1.3962	0.7248	
19.23	0.693 0.451	1.3983	0.7259	
19.43	0.694 0.452	1.4003	0.7269	
19.63	0.695 0.452	1.4024	0.7280	
19.83	0.696 0.453	1.4044	0.7290	
20.03	0.697 0.454	1.4065	0.7301	
20.23	0.698 0.454	1.4085	0.7311	
20.43	0.699 0.455	1.4106	0.7322	
20.63	0.700 0.456	1.4126	0.7332	
20.83	0.701 0.456	1.4147	0.7343	
21.03	0.702 0.457	1.4167	0.7353	
21.23	0.703 0.458	1.4188	0.7364	
21.43	0.704 0.458	1.4208	0.7374	
21.63	0.705 0.459	1.4229	0.7385	
21.83	0.706 0.460	1.4249	0.7395	
22.03	0.707 0.460	1.4270	0.7406	
22.23	0.708 0.461	1.4290	0.7416	
22.43	0.709 0.462	1.4311	0.7427	
22.63	0.710 0.462	1.4331	0.7437	
22.83	0.711 0.463	1.4352	0.7448	
23.03	0.712 0.464	1.4372	0.7458	
23.23	0.713 0.464	1.4393	0.7469	
23.43	0.714 0.465	1.4413	0.7479	
23.63	0.715 0.466	1.4434	0.7490	
23.83	0.716 0.466	1.4454	0.7500	
24.03	0.717 0.467	1.4475	0.7511	
24.23	0.718 0.468	1.4495	0.7521	
24.43	0.719 0.468	1.4516	0.7532	
24.63	0.720 0.469	1.4536	0.7542	
24.83	0.721 0.470	1.4557	0.7553	
25.03	0.722 0.470	1.4577	0.7563	
25.23	0.723 0.471	1.4598	0.7574	
25.43	0.724 0.472	1.4618	0.7584	
25.63	0.725 0.472	1.4639	0.7595	
25.83	0.726 0.473	1.4659	0.7605	
26.03	0.727 0.474	1.4680	0.7616	
26.23	0.728 0.474	1.4700	0.7626	
26.43	0.729 0.475	1.4721	0.7637	
26.63	0.730 0.476	1.4741	0.7647	
26.83	0.731 0.476	1.4762	0.7658	
27.03	0.732 0.477	1.4782	0.7668	
27.23	0.733 0.478	1.4803	0.7679	
27.43	0.734 0.478	1.4823	0.7689	
27.63	0.735 0.479	1.4844	0.7700	
27.83	0.736 0.480	1.4864	0.7710	
28.03	0.737 0.480	1.4885	0.7721	
28.23	0.738 0.481	1.4905	0.7731	
28.43	0.739 0.482	1.4926	0.7742	
28.63	0.740 0.482	1.4946	0.7752	
28.83	0.741 0.483	1.4967	0.7763	
29.03	0.742 0.484	1.4987	0.7773	
29.23	0.743 0.484	1.5008	0.7784	
29.43	0.744 0.485	1.5028	0.7794	
29.63	0.745 0.486	1.5049	0.7805	
29.83	0.746 0.486	1.5069	0.7815	
30.03	0.747 0.487	1.5090	0.7826	
30.23	0.748 0.488	1.5110	0.7836	
30.43	0.749 0.488	1.5131	0.7847	
30.63	0.750 0.489	1.5151	0.7857	
30.83	0.751 0.490	1.5172	0.7868	
31.03	0.752 0.490	1.5192	0.7878	
31.23	0.753 0.491	1.5213	0.7889	
31.43	0.754 0.492	1.5233	0.7899	
31.63	0.755 0.492	1.5254	0.7910	
31.83	0.756 0.493	1.5274	0.7920	
32.03	0.757 0.494	1.5295	0.7931	
32.23	0.758 0.494	1.5315	0.7941	
32.43	0.759 0.495	1.5336	0.7952	
32.63	0.760 0.496	1.5356	0.7962	
32.83	0.761 0.496	1.5377	0.7973	
33.03	0.762 0.497	1.5397	0.7983	
33.23	0.763 0.498	1.5418	0.7994	
33.43	0.764 0.498	1.5438	0.8004	
33.63	0.765 0.499	1.5459	0.8015	
33.83	0.766 0.500	1.5479	0.8025	
34.03	0.767 0.500	1.5500	0.8036	
34.23	0.768 0.501	1.5520	0.8046	
34.43	0.769 0.502	1.5541	0.8057	
34.63	0.770 0.502	1.5561	0.8067	
34.83	0.771 0.503	1.5582	0.8078	
35.03	0.772 0.504	1.5602	0.8088	
35.23	0.773 0.504	1.5623	0.8099	
35.43	0.774 0.505	1.5643	0.8109	
35.63	0.775 0.506	1.5664	0.8120	
35.83	0.776 0.506	1.5684	0.8130	
36.03	0.777 0.507	1.5705	0.8141	
36.23	0.778 0.508	1.5725	0.8151	
36.43	0.779 0.508	1.5746	0.8162	
36.63	0.780 0.509	1.5766	0.8172	
36.83	0.781 0.510	1.5787	0.8183	
37.03	0.782 0.510	1.5807	0.8193	
37.23	0.783 0.511	1.5828	0.8204	
37.43	0.784 0.512	1.5848	0.8214	
37.63	0.785 0.512	1.5869	0.8225	
37.83	0.786 0.513	1.5889	0.8235	
38.03	0.787 0.514	1.5910	0.8246	
38.23	0.788 0.514	1.5930	0.8256	
38.43	0.789 0.515	1.5951	0.8267	
38.63	0.790 0.516	1.5971	0.8277	
38.83	0.791 0.516	1.5992	0.8288	
39.03	0.792 0.517	1.6012	0.8298	
39.23	0.793 0.518	1.6033	0.8309	
39.43	0.794 0.518	1.6053	0.8319	
39.63	0.795 0.519	1.6074	0.8330	
39.83	0.796 0.520	1.6094	0.8340	
40.03	0.797 0.520	1.6115	0.8351	
40.23	0.798 0.521	1.6135	0.8361	
40.43	0.799 0.522	1.6156	0.8372	
40.63	0.800 0.522	1.6176	0.8382	
40.83	0.801 0.523	1.6197	0.8393	
41.03	0.802 0.524	1.6217	0.8403	
41.23	0.803 0.524	1.6238	0.8414	
41.43	0.804 0.525	1.6258	0.8424	
41.63	0.805 0.526	1.6279	0.8435	
41.83	0.806 0.526	1.6299	0.8445	
42.03	0.807 0.527	1.6320	0.8456	
42.23	0.808 0.528	1.6340	0.8466	
42.43	0.809 0.528	1.6361	0.8477	
42.63	0.810 0.529	1.6381	0.8487	
42.83	0.811 0.530	1.6402	0.8498	
43.03	0.812 0.530	1.6422	0.8508	
43.23	0.813 0.531	1.6443	0.8519	
43.43	0.814 0.532	1.6463	0.8529	
43.63	0.815 0.532	1.6484	0.8540	
43.83	0.816 0.533	1.6504	0.8550	
44.03	0.817 0.534	1.6525	0.8561	
44.23	0.818 0.534	1.6545	0.8571	
44.43	0.819 0.535	1.6566	0.8582	
44.63	0.820 0.536	1.6586	0.8592	
44.83	0.821 0.536	1.6607	0.8603	
45.03	0.822 0.537	1.6627	0.8613	
45.23	0.823 0.538	1.6648	0.8624	
45.43	0.824 0.538	1.6668	0.8634	
45.63	0.825 0.539	1.6689	0.8645	
45.83	0.826 0.540	1.6709	0.8655	
46.03	0.827 0.540	1.6730	0.8666	
46.23	0.828 0.541	1.6750	0.8676	
46.43	0.829 0.542	1.6771	0.8687	
46.63	0.830 0.542	1.6791	0.8697	
46.83	0.831 0.543	1.6812	0.8708	
47.03	0.832 0.544	1.6832	0.8718	
47.23	0.833 0.544	1.6853	0.8729	
47.43	0.834 0.545	1.6873	0.8739	
47.63	0.835 0.546	1.6894	0.8750	
47.83	0.836 0.546	1.6914	0.8760	
48.03	0.837 0.547	1.6935	0.8771	
48.23	0.838 0.548	1.6955	0.8781	
48.43	0.839 0.548	1.6976	0.8792	
48.63	0.840 0.549	1.6996	0.8802	
48.83	0.841 0.550	1.7017	0.8813	
49.03	0.842 0.550	1.7037	0.8823	
49.23	0.843 0.551	1.7058	0.8834	
49.43	0.844 0.552	1.7078	0.8844	
49.63	0.845 0.552	1.7099	0.8855	
49.83	0.846 0.553	1.7119	0.8865	
50.03	0.847 0.554	1.7140	0.8876	
50.23	0.848 0.554	1.7160	0.8886	
50.43	0.849 0.555	1.7181	0.8897	
50.63	0.850 0.556	1.7201	0.8907	
50.83	0.851 0.556	1.7222	0.8918	
51.03	0.852 0.557	1.7242	0.8928	
51.23	0.853 0.558	1.7263	0.8939	
51.43	0.854 0.558	1.7283	0.8949	
51.63	0.855 0.559	1.7304	0.8960	
51.83	0.856 0.560	1.7324	0.8970	
52.03	0.857 0.560	1.7345	0.8981	
52.23	0.858 0.561	1.7365	0.8991	
52.43	0.859 0.562	1.7386	0.9002	
52.63	0.860 0.562	1.7406	0.9012	
52.83	0.861 0.563	1.7427	0.9023	
53.03	0.862 0.564	1.7447	0.9033	
53.23	0.863 0.564	1.7468	0.9044	
53.43	0.864 0.565	1.7488	0.9054	
53.63	0.865 0.566	1.7509	0.9065	
53.83	0.866 0.566	1.7529	0.9075	
54.03	0.867 0.567	1.7550	0.9086	
54.23	0.868 0.568	1.7570	0.9096	
54.43	0.869 0.568	1.7591	0.9107	
54.63	0.870 0.569	1.7611	0.9117	
54.83	0.871 0.570	1.7632	0.9128	
55.03	0.872 0.570	1.7652	0.9138	
55.23	0.873 0.571	1.7673	0.9149	
55.43	0.874 0.572	1.7693	0.9159	
55.63	0.875 0.572	1.7714	0.9170	
55.83	0.876 0.573	1.7734	0.9180	
56.03	0.877 0.574	1.7755	0.9191	
56.23	0.878 0.574	1.7775	0.9201	
56.43	0.879 0.575	1.7796	0.9212	
56.63	0.880 0.576	1.7816	0.9222	
56.83	0.881 0.576	1.7837	0.9233	
57.03	0.882 0.577	1.7857	0.9243	
57.23	0.883 0.578	1.7878	0.9254	
57.43	0.884 0.578	1.7898	0.9264	
57.63	0.885 0.579	1.7919	0.9275	
57.83	0.886 0.580	1.7939	0.9285	
58.03	0.887 0.580	1.7960	0.9296	
58.23	0.888 0.581	1.7980	0.9306	
58.43	0.889 0.582	1.8001	0.9317	
58.63	0.890 0.582	1.8021	0.9327	
58.83	0.891 0.583	1.8042	0.9338	
59.03	0.892 0.584	1.8062	0.9348	
59.23	0.893 0.584	1.8083	0.9359	
59.43	0.894 0.585	1.8103	0.9369	
59.63	0.895 0.586	1.8124	0.9380	
59.83	0.896 0.586	1.8144	0.9390	
60.03	0.897 0.587	1.8165	0.9401	
60.23	0.898 0.588	1.8185	0.9411	
60.43	0.899 0.588	1.8206	0.9422	
60.63	0.900 0.589	1.8226	0.9432	
60.83	0.901 0.590	1.8247	0.9443	
61.03	0.902 0.590	1.8267	0.9453	
61.23	0.903 0.591	1.8288	0.9464	
61.43	0.904 0.592	1.8308	0.9474	
61.63	0.905 0.592	1.8329	0.9485	
61.83	0.906 0.593	1.8349	0.9495	
62.03	0.907 0.594	1.8370	0.9506	
62.23	0.908 0.594	1.8390	0.9516	
62.43	0.909 0.595	1.8411	0.9527	
62.63	0.910 0.596	1.8431	0.9537	
62.83	0.911 0.596	1.8452	0.9548	
63.03	0.912 0.597	1.8472	0.9558	
63.23	0.913 0.598	1.8493	0.9569	
63.43	0.914 0.598	1.8513	0.9579	
63.63	0.915 0.599	1.8534	0.9590	
63.83	0.916 0.600	1.8554	0.9600	
64.03	0.917 0.600	1.8575	0.9611	
64.23	0.918 0.601	1.8595	0.9621	
64.43	0.919 0.602	1.8616	0.9632	
64.63	0.920 0.602	1.8636	0.9642	
64.83	0.921 0.603	1.8657	0.9653	
65.03	0.922 0.604	1.8677	0.9663	
65.23	0.923 0.604	1.8698	0.9674	
65.43	0.924 0.605	1.8718	0.9684	
65.63	0.925 0.606	1.8739	0.9695	
65.83	0.926 0.606	1.8759	0.9705	
66.03	0.927 0.607	1.8780	0.9716	
66.23	0.928 0.608	1.8800	0.9726	
66.43	0.929 0.608	1.8821	0.9737	
66.63	0.930 0.609	1.8841	0.9747	
66.83	0.931 0.610	1.8862	0.9758	
67.03	0.932 0.610	1.8882	0.9768	
67.23	0.933 0.611	1.8903	0.9779	
67.43	0.934 0.612	1.8923	0.9789	
67.63	0.935 0.612	1.8944	0.9800	
67.83	0.936 0.613	1.8964	0.9810	
68.03	0.937 0.614	1.8985	0.9821	
68.23	0.938 0.614	1.9005	0.9831	
68.43	0.939 0.615	1.9026	0.9842	
68.63	0.940 0.616	1.9046	0.9852	
68.83	0.941 0.616	1.9067	0.9863	
69.03	0.942 0.617	1.9087	0.9873	
69.23	0.943 0.618	1.9108	0.9884	
69.43	0.944 0.618	1.9128	0.9894	
69.63	0.945 0.619	1.9149	0.9905	
69.83	0.946 0.620	1.9169	0.9915	
70.03	0.947 0.620	1.9190	0.9926	
70.23	0.948 0.621	1.9210	0.9936	
70.43	0.949 0.622	1.9231	0.9947	
70.63	0.950 0.622	1.9251	0.9957	
70.83	0.951 0.623	1.9272	0.9968	
71.03	0.952 0.624	1.9292	0.9978	
71.23	0.953 0.624	1.9313	0.9989	
71.43	0.954 0.625	1.9333	0.9999	

DEL= 46.42 MM DSTR= 9.24 MM THETA= 4.62 MM

RDEL= 0.302E+05 RDSTR= 0.601E+04 RTTA= 0.301E+04

SHAPE FACTOR= 1.97

START N.S.

U INF= 15.354 M/S

REX= 0.210 7E+07 X= 2.821

T= 23.68 DEG.C RHO= 0.9778 KG/CU.M

MUE= 0.1833E-04 KG/MS NU= 0.18756E-04 M**2/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	0.21 0.137	0.4104	0.2137	
0.83	0.282 0.183	0.5472	0.2850	
1.03	0.312 0.203	0.6312	0.3284	
1.23	0.363 0.236	0.7316	0.3804	
1.43	0.401 0.261	0.8076	0.4199	
1.63	0.433 0.282	0.8720	0.4535	
1.83	0.460 0.299	0.9263	0.4817	
2.03	0.484 0.315	0.9746	0.5068	
2.23	0.505 0.328	1.0168	0.5287	
2.43	0.523 0.340	1.0530	0.5475	
2.63	0.539 0.350	1.0852	0.5643	
2.83	0.553 0.359	1.1134	0.5790	
3.03	0.565 0.367	1.1376	0.5916	
3.23	0.576 0.374	1.1598	0.6032	
3.43	0.585 0.380	1.1779	0.6126	
3.63	0.593 0.385	1.1941	0.6210	
3.83	0.600 0.390	1.2082	0.6283	
4.03	0.606 0.394	1.2203	0.6346	
4.23	0.611 0.397	1.2304	0.6398	
4.43	0.615 0.399	1.2385	0.6440	
4.63	0.618 0.401	1.2446	0.6471	
4.83	0.620 0.403	1.2487	0.6492	
5.03	0.622 0.404	1.2527	0.6513	
5.23	0.623 0.405	1.2548	0.6524	
5.43	0.624 0.405	1.2568	0.6534	
5.63	0.625 0.406	1.2589	0.6545	
5.83	0.626 0.406	1.2609	0.6555	
6.03	0.627 0.407	1.2630	0.6566	
6.23	0.628 0.408	1.2650	0.6576	
6.43	0.629 0.408	1.2671	0.6587	
6.63	0.630 0.409	1.2691	0.6597	
6.83	0.631 0.410	1.2712	0.6608	
7.03	0.632 0.410	1.2732	0.6618	
7.23	0.633 0.411	1.2753	0.6629	
7.43	0.634 0.412	1.2773	0.6639	
7.63	0.635 0.412	1.2794	0.6650	
7.83	0.636 0.413	1.2814	0.6660	
8.03	0.637 0.414	1.2835	0.6671	
8.23	0.638 0.414	1.2855	0.6681	
8.43	0.639 0.415	1.2876	0.6692	
8.63	0.640 0.416	1.2896	0.6702	
8.83	0.641 0.416	1.2917	0.6713	
9.03	0.642 0.417	1.2937	0.6723	
9.23	0.643 0.418	1.2958	0.6734	
9.43	0.644 0.418	1.2978	0.6744	
9.63	0.645 0.419	1.2999	0.6755	
9.83	0.646 0.420	1.3019	0.6765	
10.03	0.647 0.420	1.3040	0.6776	
10.23	0.648 0.421	1.3060	0.6786	
10.43	0.649 0.422	1.3081	0.6797	
10.63	0.650 0.422	1.3101	0.6807	
10.83	0.651 0.423	1.3122	0.6818	
11.03	0.652 0.424	1.3142	0.6828	
11.23	0.653 0.424	1.3163	0.6839	
11.43	0.654 0.425	1.3183	0.6849	
11.63	0.655 0.426	1.3204	0.6860	
11.83	0.656 0.426	1.3224	0.6870	
12.03	0.657 0.427	1.3245	0.6881	
12.23	0.658 0.428	1.3265	0.6891	
12.43	0.659 0.428	1.3286	0.6902	
12.63	0.660 0.429	1.3306	0.6912	
12.83	0.661 0.430	1.3327	0.6923	
13.03	0.662 0.430	1.3347	0.6933	
13.23	0.663 0.431	1.3368	0.6944	
13.43	0.664 0.432	1.3388	0.6954	
13.63	0.665 0.432	1.3409	0.6965	
13.83	0.666 0.433	1.3429	0.6975	
14.03	0.667 0.434	1.3450	0.6986	
14.23	0.668 0.434	1.3470	0.6996	
14.43	0.669 0.435	1.3491	0.7007	
14.63	0.670 0.436	1.3511	0.7017	
14.83	0.671 0.436	1.3532	0.7028	
15.03	0.672 0.437	1.3552	0.7038	
15.23	0.673 0.438	1.3573	0.7049	
15.43	0.674 0.438	1.3593	0.7059	
15.63	0.675 0.439	1.3614	0.7070	
15.83	0.676 0.440	1.3634	0.7080	
16.03	0.677 0.440	1.3655	0.7091	
16.23	0.678 0.441	1.3675	0.7101	
16.43	0.679 0.442	1.3696	0.7112	
16.63	0.680 0.442	1.3716	0.7122	
16.83	0.681 0.443	1.3737	0.7133	
17.03	0.682 0.444	1.3757	0.7143	
17.23	0.683 0.444	1.3778	0.7154	
17.43	0.684 0.445	1.3798	0.7164	
17.63	0.685 0.446	1.3819	0.7175	
17.83	0.686 0.446	1.3839	0.7185	
18.03	0.687 0.447	1.3860	0.7196	
18.23	0.688 0.448	1.3880	0.7206	
18.43	0.689 0.448	1.3901	0.7217	
18.63	0.690 0.449	1.3921	0.7227	
18.83	0.691 0.450	1.3942	0.7238	
19.03	0.692 0.450	1.3962	0.7248	
19.23	0.693 0.451	1.3983	0.7259	
19.43	0.694 0.452	1.4003	0.7269	
19.63	0.695 0.452	1.4024	0.7280	
19.83	0.696 0.453	1.4044	0.7290	
20.03	0.697 0.454	1.4065	0.7301	
20.23	0.698 0.454	1.4085	0.7311	
20.43	0.699 0.455	1.4106	0.7322	
20.63	0.700 0.456	1.4126	0.7332	
20.83	0.701 0.456	1.4147	0.7343	
21.03	0.702 0.457	1.4167	0.7353	
21.23	0.703 0.458	1.4188	0.7364	
21.43	0.704 0.458	1.4208	0.7374	
21.63	0.705 0.459	1.4229	0.7385	
21.83	0.706 0.460	1.4249	0.7395	
22.03	0.707 0.460	1.4270	0.7406	
22.23	0.708 0.461	1.4290	0.7416	
22.43	0.709 0.462	1.4311	0.7427	
22.63	0.710 0.462	1.4331	0.7437	
22.83	0.711 0.463	1.4352	0.7448	
23.03	0.712 0.464	1.4372	0.7458	
23.23	0.713 0.464	1.4393	0.7469	
23.43	0.714 0.465	1.4413	0.7479	
23.63	0.715 0.466	1.4434	0.7490	
23.83	0.716 0

CURVE FIT: LOG(F'D)= 0.1102E+00*LOG(Y/D)+-2.5725E-02

E-11,59-13

0301

UINF= 15.242 M/S
REX= 0.1712E+07 X= 2.074
T= 21.50 DEG.C RHO= 0.5986 KG/CU.M
MU= 0.1827E-04 KG/MS NU= 0.1840E-04 M**M/S

Y(MM)	U (M/S)		Y/DTTA	U/UE	Y/DEL
0.42	8.9	0.142	0.5805	0.0124	
0.80	9.6	0.238	0.9434	0.0196	
1.60	10.2	0.340	0.8742	0.0298	
2.80	10.7	0.560	0.9149	0.0490	
3.80	11.1	0.738	0.9778	0.0646	
5.20	11.7	1.255	0.9742	0.1099	
7.40	12.0	1.722	0.9894	0.1508	
9.60	12.3	2.140	0.9960	0.1874	
11.80	12.5	2.624	0.9939	0.2298	
13.80	12.7	3.083	0.9979	0.2700	
16.40	13.0	3.748	0.9967	0.3284	
20.60	13.4	4.662	0.9906	0.4084	
25.80	13.7	5.825	0.9981	0.5102	
30.80	14.1	6.964	0.9961	0.6099	
37.60	14.4	8.547	0.9976	0.7489	
45.60	14.9	10.385	0.9983	0.9098	

DEL= 85.75 MM DEST= 9.64 MM THETA= 6.38 MM
RDEL= 0.2718E+05 RDEST= 0.3060E+04 RTTA= 0.2026E+04
SHAPE FACTOR,H= 1.29

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STATION 2
****

UINF= 15.199 M/S
REX= 0.1761E+07 X= 2.177
T= 21.10 DEG.C RHO= 0.5994 KG/CU.M
MU= 0.1828E-04 KG/MS NU= 0.1856E-04 M**M/S

Y(MM)	U (M/S)		Y/DTTA	U/UE	Y/DEL
0.42	5.9	0.120	0.3071	0.0110	
1.18	7.1	0.222	0.6114	0.0201	
1.98	8.3	0.376	0.8607	0.0337	
2.78	9.4	0.575	0.9275	0.0517	
3.98	10.2	0.813	0.9071	0.0729	
4.58	10.9	1.032	0.9778	0.0921	
6.00	11.3	1.322	0.9733	0.1183	
7.40	11.8	1.741	0.9787	0.1619	
8.80	12.0	1.956	0.9840	0.1709	
10.40	12.2	2.159	0.9849	0.1937	
11.60	12.4	2.481	0.9913	0.2215	
13.40	12.6	2.756	0.9903	0.2573	
14.60	12.7	3.107	0.9912	0.2841	
16.60	13.0	3.494	0.9960	0.3245	
18.80	13.1	3.941	0.9973	0.3538	
22.60	13.2	4.788	0.9977	0.4113	
27.80	13.4	5.775	0.9954	0.4307	
35.60	13.6	5.401	0.9966	0.4974	
29.60	13.9	6.335	0.9979	0.5742	
34.60	14.1	7.337	0.9982	0.6742	
39.80	14.4	8.320	0.9938	0.7652	
44.80	14.7	9.363	0.9987	0.8522	

DEL= 52.58 MM DEST= 6.54 MM THETA= 4.80 MM
RDEL= 0.4260E+05 RDEST= 0.8350E+04 RTTA= 0.3926E+04

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STATION 3
****

UINF= 15.550 M/S
REX= 0.1874E+07 X= 2.241
T= 22.45 DEG.C RHO= 0.5914 KG/CU.M
MU= 0.1825E-04 KG/MS NU= 0.1850E-04 M**M/S

Y(MM)	U (M/S)		Y/DTTA	U/UE	Y/DEL
0.42	5.3	0.119	0.3704	0.0170	
0.80	6.5	0.195	0.6708	0.0303	
1.60	7.1	0.287	0.8433	0.0460	
2.80	8.0	0.558	0.9206	0.0809	
3.80	8.7	0.760	0.9682	0.0418	
4.80	9.4	0.962	0.9135	0.1027	
5.80	10.2	1.230	0.9551	0.1341	
7.60	10.9	1.519	0.9733	0.1655	
9.60	11.6	1.906	0.9555	0.1969	
11.80	12.1	2.264	0.9804	0.2283	
13.80	12.4	2.581	0.9874	0.2597	
16.60	12.7	2.960	0.9877	0.2910	
20.60	13.0	3.561	0.9804	0.3228	
25.80	13.1	4.245	0.9857	0.3578	
30.80	13.2	4.829	0.9892	0.3957	
37.60	13.5	5.204	0.9834	0.4588	
45.60	13.8	6.072	0.9830	0.5421	
50.60	14.1	6.931	0.9824	0.6067	
55.60	14.5	7.891	0.9841	0.7514	
61.60	14.9	8.947	0.9923	0.8769	

DEL= 87.70 MM DEST= 7.69 MM THETA= 5.21 MM
RDEL= 0.3059E+05 RDEST= 0.6823E+04 RTTA= 0.4358E+04

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STATION 4
****

UINF= 16.195 M/S
REX= 0.2036E+07 X= 2.341
T= 22.60 DEG.C RHO= 0.5930 KG/CU.M
MU= 0.1825E-04 KG/MS NU= 0.1851E-04 M**M/S

Y(MM)	U (M/S)		Y/DTTA	U/UE	Y/DEL
0.42	5.2	0.116	0.3124	0.0119	
1.02	5.8	0.196	0.5272	0.0272	
2.02	6.8	0.383	0.8712	0.0394	
3.02	7.6	0.570	0.8784	0.0586	
4.02	8.3	0.757	0.9108	0.0778	
5.02	9.0	0.944	0.9418	0.0971	
6.62	9.8	1.219	0.9747	0.1253	
8.02	10.7	1.505	0.9798	0.1547	
9.62	11.3	1.786	0.9806	0.1835	
11.02	12.0	2.066	0.9815	0.2124	
12.62	12.6	2.346	0.9884	0.2412	
14.02	13.0	2.627	0.9849	0.2700	
16.02	13.4	2.971	0.9907	0.3085	
18.02	13.8	3.335	0.9872	0.3450	
20.02	14.0	3.740	0.9742	0.3863	
22.02	14.2	4.123	0.9910	0.4238	
24.02	14.4	4.496	0.9904	0.4622	
27.02	14.	5.057	0.9143	0.5199	
30.02	15.2	5.952	0.9949	0.6150	
38.02	15.2	7.114	0.9533	0.7312	
44.02	15.5	8.236	0.9732	0.8456	

DEL= 92.03 MM DEST= 8.23 MM THETA= 5.35 MM
RDEL= 0.4526E+05 RDEST= 0.7263E+04 RTTA= 0.4653E+04

EDDY-L FITS LOGIFMIX D.1942E+02*EXP(-(Y/D)**2)+D.A316E-03

E-12.79-13

0401

UINF= 15.150 M/S
REX= D.16E0E+07
T= 20.31 DEG.C
NU= D.1814E-05 KG/MS

X= 1.004
RHO= D.1184 KG/CU.M
NU= D.1535E-05 M*M/S

Y(MM)	U (M/S)	Y/DTA	U/UINF	Y/DEL
0.62	0.000	0.186	0.0000	0.0127
1.25	0.378	0.378	0.0249	0.0255
1.88	1.016	0.564	0.0670	0.0384
2.50	1.965	0.751	0.1296	0.0511
3.13	3.106	0.939	0.2049	0.0639
3.75	4.359	1.126	0.2876	0.0767
4.38	5.639	1.314	0.3720	0.0895
5.00	6.880	1.501	0.4538	0.1023
5.63	8.033	1.689	0.5299	0.1150
6.25	9.071	1.876	0.5984	0.1278
6.88	9.973	2.064	0.6579	0.1406
7.50	10.730	2.251	0.7078	0.1534
8.13	11.341	2.439	0.7481	0.1661
8.75	11.814	2.626	0.7793	0.1789
9.38	12.161	2.814	0.8021	0.1917
10.00	12.396	3.001	0.8176	0.2045
10.63	12.535	3.189	0.8268	0.2172
11.25	12.600	3.376	0.8311	0.2300
11.88	12.609	3.564	0.8317	0.2428
12.50	12.577	3.751	0.8296	0.2556
13.13	12.516	3.939	0.8256	0.2683
13.75	12.435	4.126	0.8203	0.2811
14.38	12.339	4.314	0.8140	0.2939
15.00	12.232	4.501	0.8069	0.3067
15.63	12.119	4.689	0.7995	0.3195
16.25	12.000	4.876	0.7916	0.3322
16.88	11.878	5.064	0.7836	0.3450
17.50	11.753	5.251	0.7753	0.3578
18.13	11.626	5.439	0.7669	0.3706
18.75	11.497	5.626	0.7584	0.3833
19.38	11.367	5.814	0.7498	0.3961
20.00	11.236	6.001	0.7412	0.4089
20.63	11.104	6.189	0.7325	0.4217
21.25	10.971	6.376	0.7237	0.4344
21.88	10.837	6.564	0.7149	0.4472
22.50	10.703	6.751	0.7060	0.4600
23.13	10.568	6.939	0.6971	0.4728
23.75	10.433	7.126	0.6882	0.4856
24.38	10.297	7.314	0.6792	0.4983
25.00	10.161	7.501	0.6702	0.5111
25.63	10.025	7.689	0.6612	0.5239
26.25	9.888	7.876	0.6522	0.5367
26.88	9.751	8.064	0.6431	0.5494
27.50	9.614	8.251	0.6341	0.5622
28.13	9.476	8.439	0.6250	0.5750
28.75	9.339	8.626	0.6159	0.5878
29.38	9.201	8.814	0.6068	0.6006
30.00	9.063	9.001	0.5977	0.6133
30.63	8.925	9.189	0.5886	0.6261
31.25	8.787	9.376	0.5795	0.6389
31.88	8.649	9.564	0.5704	0.6517
32.50	8.511	9.751	0.5613	0.6644
33.13	8.372	9.939	0.5522	0.6772
33.75	8.234	10.126	0.5431	0.6900
34.38	8.095	10.314	0.5340	0.7028
35.00	7.957	10.501	0.5249	0.7156
35.63	7.818	10.689	0.5158	0.7283
36.25	7.680	10.876	0.5067	0.7411
36.88	7.541	11.064	0.4976	0.7539
37.50	7.403	11.251	0.4885	0.7667
38.13	7.264	11.439	0.4794	0.7794
38.75	7.126	11.626	0.4703	0.7922
39.38	6.987	11.814	0.4612	0.8050
40.00	6.849	12.001	0.4521	0.8178
40.63	6.710	12.189	0.4430	0.8306
41.25	6.572	12.376	0.4339	0.8433
41.88	6.433	12.564	0.4248	0.8561
42.50	6.295	12.751	0.4157	0.8689
43.13	6.156	12.939	0.4066	0.8817
43.75	6.018	13.126	0.3975	0.8944
44.38	5.880	13.314	0.3884	0.9072
45.00	5.742	13.501	0.3793	0.9200
45.63	5.604	13.689	0.3702	0.9328
46.25	5.466	13.876	0.3611	0.9456
46.88	5.328	14.064	0.3520	0.9583
47.50	5.190	14.251	0.3429	0.9711
48.13	5.052	14.439	0.3338	0.9839
48.75	4.914	14.626	0.3247	0.9967
49.38	4.776	14.814	0.3156	1.0094
50.00	4.638	15.001	0.3065	1.0222
50.63	4.500	15.189	0.2974	1.0350
51.25	4.362	15.376	0.2883	1.0478
51.88	4.224	15.564	0.2792	1.0606
52.50	4.086	15.751	0.2701	1.0733
53.13	3.948	15.939	0.2610	1.0861
53.75	3.810	16.126	0.2519	1.0989
54.38	3.672	16.314	0.2428	1.1117
55.00	3.534	16.501	0.2337	1.1244
55.63	3.396	16.689	0.2246	1.1372
56.25	3.258	16.876	0.2155	1.1500
56.88	3.120	17.064	0.2064	1.1628
57.50	2.982	17.251	0.1973	1.1756
58.13	2.844	17.439	0.1882	1.1883
58.75	2.706	17.626	0.1791	1.2011
59.38	2.568	17.814	0.1700	1.2139
60.00	2.430	18.001	0.1609	1.2267
60.63	2.292	18.189	0.1518	1.2394
61.25	2.154	18.376	0.1427	1.2522
61.88	2.016	18.564	0.1336	1.2650
62.50	1.878	18.751	0.1245	1.2778
63.13	1.740	18.939	0.1154	1.2905
63.75	1.602	19.126	0.1063	1.3033
64.38	1.464	19.314	0.0972	1.3161
65.00	1.326	19.501	0.0881	1.3289
65.63	1.188	19.689	0.0790	1.3417
66.25	1.050	19.876	0.0699	1.3544
66.88	0.912	20.064	0.0608	1.3672
67.50	0.774	20.251	0.0517	1.3800
68.13	0.636	20.439	0.0426	1.3928
68.75	0.498	20.626	0.0335	1.4055
69.38	0.360	20.814	0.0244	1.4183
70.00	0.222	21.001	0.0153	1.4311
70.63	0.084	21.189	0.0062	1.4439

DEL= 52.79 MM DSTR= 8.40 MM THETA= 4.59 MM
RDEL= 0.4355E+05 RDSTR= 0.6379E+04 RTHA= 0.3825E+04

STATION 3

UINF= 15.670 M/S
REX= D.1892E+07 X= 2.159
T= 22.15 DEG.C RHO= D.1202 KG/CU.M
MU= D.1826E-04 KG/MS NU= D.1519E-04 M*M/S

Y(MM)	U (M/S)	Y/DTA	U/UF	Y/DEL
0.62	0.000	0.170	0.0000	0.0122
1.25	0.121	0.341	0.0077	0.0245
1.88	0.344	0.511	0.0220	0.0367
2.50	0.661	0.681	0.0422	0.0490
3.13	1.064	0.852	0.0679	0.0612
3.75	1.544	1.022	0.0985	0.0735
4.38	2.084	1.192	0.1330	0.0857
5.00	2.673	1.363	0.1706	0.0980
5.63	3.299	1.533	0.2106	0.1102
6.25	3.951	1.703	0.2522	0.1225
6.88	4.617	1.874	0.2947	0.1347
7.50	5.287	2.044	0.3375	0.1470
8.13	5.951	2.214	0.3799	0.1592
8.75	6.600	2.385	0.4213	0.1715
9.38	7.226	2.555	0.4613	0.1837
10.00	7.822	2.725	0.4993	0.1960
10.63	8.381	2.896	0.5350	0.2082
11.25	8.898	3.066	0.5680	0.2205
11.88	9.369	3.236	0.5981	0.2327
12.50	9.791	3.407	0.6251	0.2450
13.13	10.161	3.577	0.6487	0.2572
13.75	10.478	3.747	0.6689	0.2695
14.38	10.741	3.918	0.6857	0.2817
15.00	10.951	4.088	0.6991	0.2940
15.63	11.109	4.258	0.7092	0.3062
16.25	11.217	4.429	0.7161	0.3185
16.88	11.278	4.599	0.7200	0.3307
17.50	11.295	4.769	0.7211	0.3430
18.13	11.272	4.940	0.7196	0.3552
18.75	11.213	5.110	0.7158	0.3675
19.38	11.122	5.280	0.7100	0.3797
20.00	11.003	5.451	0.7024	0.3920
20.63	10.861	5.621	0.6933	0.4042
21.25	10.699	5.791	0.6830	0.4165
21.88	10.520	5.962	0.6716	0.4287
22.50	10.327	6.132	0.6593	0.4410
23.13	10.123	6.302	0.6463	0.4532
23.75	9.910	6.473	0.6327	0.4655
24.38	9.690	6.643	0.6186	0.4777
25.00	9.465	6.813	0.6042	0.4900
25.63	9.236	6.984	0.5896	0.5022
26.25	9.004	7.154	0.5748	0.5145
26.88	8.770	7.324	0.5598	0.5267
27.50	8.535	7.495	0.5448	0.5390
28.13	8.299	7.665	0.5297	0.5512
28.75	8.063	7.835	0.5147	0.5635
29.38	7.827	8.006	0.4996	0.5757
30.00	7.592	8.176	0.4846	0.5880
30.63	7.357	8.346	0.4696	0.6002
31.25	7.123	8.517	0.4547	0.6125
31.88	6.890	8.687	0.4399	0.6247
32.50	6.659	8.857	0.4251	0.6370
33.13	6.429	9.028	0.4104	0.6492
33.75	6.201	9.198	0.3959	0.6615
34.38	5.975	9.368	0.3814	0.6737
35.00	5.751	9.539	0.3671	0.6860
35.63	5.530	9.709	0.3530	0.6982
36.25	5.312	9.879	0.3390	0.7105
36.88	5.096	10.050	0.3252	0.7227
37.50	4.884	10.220	0.3117	0.7350
38.13	4.675	10.390	0.2983	0.7472
38.75	4.469	10.561	0.2852	0.7595
39.38	4.267	10.731	0.2723	0.7717
40.00	4.069	10.901	0.2597	0.7840
40.63	3.875	11.072	0.2473	0.7962
41.25	3.685	11.242	0.2352	0.8085
41.88	3.500	11.412	0.2234	0.8207
42.50	3.319	11.583	0.2118	0.8330
43.13	3.143	11.753	0.2006	0.8452
43.75	2.972	11.923	0.1897	0.8575
44.38	2.806	12.094	0.1791	0.8697
45.00	2.645	12.264	0.1688	0.8820
45.63	2.490	12.434	0.1589	0.8942
46.25	2.341	12.605	0.1494	0.9065
46.88	2.197	12.775	0.1402	0.9187
47.50	2.059	12.945	0.1314	0.9310
48.13	1.928	13.116	0.1230	0.9432
48.75	1.803	13.286	0.1151	0.9555
49.38	1.685	13.456	0.1075	0.9677
50.00	1.574	13.627	0.1004	0.9800
50.63	1.470	13.797	0.0938	0.9922
51.25	1.373	13.967	0.0876	1.0045
51.88	1.284	14.138	0.0819	1.0167
52.50	1.202	14.308	0.0767	1.0290
53.13	1.128	14.478	0.0720	1.0412
53.75	1.062	14.649	0.0677	1.0535
54.38	1.004	14.819	0.0641	1.0657
55.00	0.954	14.989	0.0609	1.0780
55.63	0.913	15.160	0.0582	1.0902
56.25	0.880	15.330	0.0561	1.1025
56.88	0.856	15.500	0.0546	1.1147
57.50	0.841	15.671	0.0536	1.1270
58.13	0.834	15.841	0.0532	1.1392
58.75	0.835	16.011	0.0533	1.1515
59.38	0.844	16.182	0.0539	1.1637
60.00	0.861	16.352	0.0550	1.1760
60.63	0.886	16.522	0.0566	1.1882
61.25	0.919	16.693	0.0587	1.2005
61.88	0.960	16.863	0.0613	1.2127
62.50	1.009	17.033	0.0644	1.2250
63.13	1.066	17.204	0.0680	1.2372
63.75	1.131	17.374	0.0722	1.2495
64.38	1.203	17.544	0.0768	1.2617
65.00	1.283	17.715	0.0819	1.2740
65.63	1.370	17.885	0.0875	1.2862
66.25	1.464	18.055	0.0935	1.2985
66.88	1.565	18.226	0.0999	1.3107
67.50	1.673	18.396	0.1068	1.3230
68.13	1.787	18.566	0.1141	1.3352
68.75	1.908	18.737	0.1218	1.3475
69.38	2.035	18.907	0.1299	1.3597
70.00	2.168	19.077	0.1384	1.3720
70.63	2.307	19.248	0.1473	1.3842
71.25	2.452	19.418	0.1565	1.3965
71.88	2.603	19.588	0.1662	1.4087
72.50	2.759	19.759	0.1762	1.4210
73.13	2.921	19.929	0.1865	1.4332
73.75	3.088	20.099	0.1971	1.4455
74.38	3.260	20.270	0.2081	1.4577
75.00	3.437	20.440	0.2194	1.4700
75.63	3.619	20.610	0.2310	1.4822
76.25	3.805	20.781	0.2429	1.4945
76.88	3.996	20.951	0.2551	1.5067
77.50	4.191	21.121	0.2676	1.5190
78.13	4.390	21.292	0.2803	1.5312
78.75	4.593	21.462	0.2933	1.5435
79.38	4.800	21.632	0.3065	1.5557
80.00	5.010	21.803	0.3199	1.5680
80.63	5.224	21.973	0.3336	1.5802
81.25	5.441	22.143	0.3474	1.5925
81.88	5.661	22.314	0.3615	1.6047
82.50	5.884	22.484	0.3757	1.6170
83.13	6.110	22.654	0.3901	1.6292
83.75	6.338	22.825	0.4047	1.6415
84.38	6.569	22.995	0.4194	1.6537
85.00	6.802	23.165	0.4343	1.6660
85.63	7.037	23.336	0.4493	1.6782
86.25	7.274	23.506	0.4644	1.6905
86.88	7.513	23.676	0.4797	1.7027
87.50	7.753	23.847	0.4950	1.7150
88.13	7.995	24.017	0.5105	1.7272
88.75	8.238	24.187	0.5260	1.7395
89.38	8.482	24.358	0.5417	1.7517
90.00	8.727	24.528	0.5573	1.7640
90.63	8.973	24.698	0.5731	1.7762
91.25	9.220	24.869	0.5889	1.7885
91.88	9.467	25.039	0.6047	1.8007
92.50	9.715	25.209	0.6206	1.8130
93.13	9.963	25.380	0.6365	1.8252
93.75	10.211	25.550	0.6524	1.8375
94.38	10.459	25.720	0.6682	1.8497
95.00	10.707	25.891	0.6841	1.8620
95.63	10.954	26.061	0.6999	1.8742
96.25	11.201	26.231	0.7156	1.8865
96.88	11.447	26.402	0.7313	1.8987
97.50	11.693	26.572	0.7469	1.9110
98.13	11.938	26.742	0.7625	1.9232
98.75	12.182	26.913	0.7780	1.9355
99.38	12.425	27.083	0.7935	1.9477
100.00	12.667	27.253	0.8089	1.9600
100.63	12.908	27.424	0.8243	1.9722
101.25	13.148	27.594	0.8396	1.9845
101.88	13.387	27.764	0.8548	1.9967
102.50	13.624	27.935	0.8700	2.0090
103.13	13.860	28.105	0.8851	2.0212
103.75	14.095	28.275	0.9001	2.0335
104.38	14.328	28.446	0.9150	2.0457
105.00	14.560	28.616	0.9298	2.0580
105.63	14.790	28.786	0.9445	2.0702
106.25	15.018	28.957	0.9591	2.0825
106.88	15.245	29.127	0.9736	2.0947
107.50	15.470	29.297	0.9879	2.1070
108.13	15.693	29.468	1.0022	2.1192
108.75	15.914	29.638	1.0163	2.1315
109.38	16.134	29.808	1.0303	2.1437
110.00	16.352	29.979	1.0443	2.1560
110.63	16.568	30.149	1.0581	2.1682
111.25	16.782	30.319	1.0718	2.1805
111.88	16.994	30.490	1.0853	2.1927
112.50	17.204	30.660	1.0988	2.2050
113.13	17.412	30.830	1.1121	2.2172
113.75	17.618	31.001	1.1253	2.2295
114.38	17.822	31.171	1.1384	2.2417
115.00	18.024	31.341	1.1513	2.2540
115.63	18.224	31.512	1.1641	2.2662
116.25	18.422	31.682	1.1768	2.2785
116.88	18.618	31.852	1.1893	2.2907
117.50	18.812	32.023	1.2017	2.3030
118.13	19.004	32.193	1.2140	2.3152
118.75	19.194	32.363	1.2261	2.3275
119.38	19.382	32.534	1.2381	2.3397
120.00	19.568	32.704	1.2500	2.3520
120.63	19.752	32.874	1.2617	2.3642
121.25	19.934	33.045	1.2733	2.3765
121.88	20.114	33.215	1.2848	2.3887
122.50	20.292	33.385	1.2961	2.4010
123.13	20.468	33.556	1.3073	2.4132
123.75	20.642	33.726	1.3184	2.4255
124.38	20.814	33.896	1.3293	2.4377
125.00	20.984	34.067	1.3402	2.4500
125.63	21.152	34.237	1.3509	2.4622
126.25	21.318	34.407	1.3615	2.4745
126.88	21.482	34.578	1.3720	2.4867
127.50	21.644	34.748	1.3824	2.4990
128.13	21.804	34.918	1.3926	2.5112
128.75	21.962	35.089	1.4027	2.5235
129.38	22.118	35.259	1.4127	2.5357
130.00	22.272	35.429	1.4226	2.5480
130.63	22.424	35.600	1.4323	2.5602
131.25	22.574	35.770	1.4419	2.5725
131.88	22.722	35.940	1.4513	2.5847
132.50	22.868	36.111	1.4606	2.5970
133.13	23.012	36.281	1.4698	2.6092
133.75	23.154	36.451	1.4788	2.6215
134.38	23.294	36.622	1.4877	2.6337
135.00	23.432	36.792	1.4965	2.6460
135.63	23.568	36.962	1.5052	2.6582
136.25	23.702	37.133	1.5137	2.6705
136.88	23.834	37.303	1.5221	2.6827
137.50	23.964	37.473	1.5304	2.6950
138.13	24.092	37.644	1.5385	2.7072
138.75	24.218	37.814	1.5466	2.7195
139.38	24.342	37.984	1.5545	2.7317
140.00	24.464	38.155	1.5623	2.7440
140.63	24.584	38.325	1.5699	2.7562
141.25	24.702	38.495	1.5774	2.7685
141.88	24.818	38.666	1.5848	2.7807
142.50	24.932	38.836	1.5921	2.7930
143.13	25.044	39.006	1.5992	2.8052
143.75	25.154	39.177	1.6062	2.8175
144.38	25.262	39.347	1.6131	2.8297
145.00	25.368	39.517	1.6199	2.8420
145.63	25.472	39.688	1.6265	2.8542
146.25	25.574	39.858	1.6330	2.8665
146.88	25.674	40.028	1.6394	2.8787
147.50	25.772	40.199	1.6457	2.8910
148.13	25.868	40.369	1.6518	2.9032
148.75	25.962	40.539	1.6578	2.9155
149.38	26.054	40.710	1.6637	2.9277
150.00	26.144	40.880	1.6695	2.9400
150.63	26.232	41.050	1.6751	2.9522
151.25	26.318	41.221	1.6806	2.9645
151.88	26.402	41.391	1.6860	2.9767
152.50	26.484	41.561	1.6913	2.9890
153.13	26.564	41.732	1.6964	3.0012
153.75	26.642	41.902	1.7014	3.0135
154.38	26.718	42.072	1.7063	3.0257
155.00	26.792	42.243	1.7110	3.0380
155.63	26.864	42.413	1.7156	3.0502
156.25	26.934	42.583	1.7201	3.0625
156.88	27.002	42.754	1.7244	3.0747
157.50	27.068	42.924	1.7286	3.0870
158.13	27.132	43.094	1.7327	3.0992
158.75	27.194	43.265	1.7366	3.1115
159.38	27.254	43.435	1.7404	3.1237
160.00	27.312	43.605	1.7441	3.1360
160.63	27.368	43.776	1.7476	3.1482
161.25	27.422	43.946	1.7510	3.1605
161.88	27.474	44.116	1.7543	3.1727
162.50	27.524	44.287	1.7575	3.1850
163.13	27.572	44.457	1.7605	3.1972
163.75	27.618	44.627	1.7634	3.2095
164.38	27.662	44.798	1.7662	3.2217
165.00	27.704	44.968	1.7689	3.2340
165.63	27.744	45.138	1.7714	3.2462
166.25	27.782	45.309	1.7738	3.2585
166.88	27.818	45.479	1.7761	3.2707
167.50	27.852	45.649	1.7782	3.2830
168.13	27.884	45.820	1.7803	3.2952
168.75	27.914	45.990	1.7822	3.3075
169.38	27.942	46.160	1.7840	3.3197
170.00	27.968	46.331	1.7856	3.3320
170.63	27.992	46.501	1.7872	3.3442
171.25	28.014	46.671	1.7886	3.3565
171.88	28.034	46.842	1.7899	3.3687
172.50	28.052	47.012	1.7911	3.3810
173.13	28.068	47.182	1.7921	3.3932
173.75	28.082	47.353	1.7931	3.4055
174.38	28.094	47.523	1.7939	3.4177
175.00	28.104	47.693	1.7945	3.4300
175.63	28.112	47.864	1.7951	3.4422
176.25	28.118	48.034	1.7955	3.4545
176.88	28.122	48.204	1.7958	3.4667
177.50	28.124	48.375	1.7960	3.4790
178.13	28.124	48.545	1.7960	3.4912
178.75	28.122	48.715	1.7959	3.5035
179.38	28.118	48.886	1.7956	3.5157
180.00	28.112	49.056	1.7952	3.5280
180.63	28.104	49.226	1.7947	3.5402
181.25	28.094	49.397	1.7940	3.5525
181.88	28.082	49.567	1.7932	3.5647
182.50	28.068	49.737	1.7923	3.5770
183.13	28.052	49.908	1.7912	3.5892
183.75	28.034	50.078	1.7901	3.6015
184.38	28.014	50.248	1.7888	3.6137
185.00	27.992	50.419	1.7874	3.6260
185.63	27.968	50.589	1.7859	3.6382
186.25	27.942	50.759	1.7843	3.6505
186.88	27.914	50.930	1.7826	3.6627
187.50	27.884	51.100	1.7808	3.6750
188.13	27.852	51.270	1.7789	3.6872
188.75	27.818	51.441	1.7768	3.6995
189.38	27.782	51.611	1.7746	3.7117
190.00	27.744	51.781	1.7723	3.7240
190.63	27.704	51.952	1.7699	3.7362
191.25	27.662	52.122	1.7674	3.7485
191.88	27.618	52.292	1.7648	3.7607
192.50	27.572	52.463	1.7620	3.7730
193.13	27.524	52.633	1.7591	3.7852
193.75	27.474	52.803	1.7561	3.7975
194.38	27.422	52.974	1.7530	3.8097
195.00	27.368	53.144	1.7497	3.8220
195.63	27.312	53.314	1.7463	3.8342
196.25	27.254	53.485	1.7428	3.8465
196.88	27.194	53.655	1.7391	3.8587
197.50	27.132	53.825	1.7353	3.8710
198.13	27.068	53.996	1.7314	3.8832
198.75	27.002	54.166	1.7273	3.8955
199.38	26.934	54.336	1.7231	3.9077
200.00	26.864	54.507	1.7187	3.9200
200.63	26.792	54.677	1.7142	3.9322
201.25	26.718	54.847	1.7095	3.9445
201.88	26.642	55.018	1.7047	3.9567
202.50	26.564	55.188	1.6997	3.9690
203.13	26.484	55.358	1.6946	3.9812
203.75	26.402	55.529	1.6894	3.9935
204.38	26.318	55.699	1.6840	4.0057
205.00	26.232	55.869	1.6785	4.0180
205.63	26.144	56.040	1.6728	4.0302
206.25	26.054	56.210	1.6670	4.0425
206.88	25.962	56.380	1.6611	4.0547
207.50	25.868	56.551	1.6550	4.0670
208.13	25.772	56.721	1.6488	4.0792
208.75	25.674	56.891	1.6425	4.0915
209.38	25.574	57.062	1.6361	4.1037
210.00	25.472	57.232	1.6295	4.1160
210.63	25.368	57.402	1.6228	4.1282
211.25	25.262	57.573	1.6160	4.1405
211.88	25.154	57.743	1.6091	4.1527
212.50	25.044	57.913	1.6020	4.1650
213.13	24.932	58.084	1.5948	4.1772
213.75	24.818	58.254	1.5875	4.1895
214.38	24.702	58.424	1.5800	4.2017
215.00	24.584	58.595	1.5725	4.2140
215.63	24.464	58.765	1.5648	4.2262

E-14,13-13

0501

STATION 1

CURVE 1 FIT: LOG(FD)= 0.1146E+00*LOG(Y/D)+-0.4671E-02

UINF= 15.093 M/S
REX= 2.187E+07
T= 23.78 DEG.C
MU= 0.1832E-04 KG/MS

X= 2.234
RHO= 0.9744 KG/CU.M
NU= 0.1879E-04 M*M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.02	0.201	0.135	0.5872	0.0117
0.22	3.000	0.233	0.0447	0.0198
0.42	5.229	0.449	0.5970	0.0388
0.62	6.842	0.669	0.7457	0.0577
0.82	8.072	0.887	0.7565	0.0861
1.02	9.282	1.106	0.7762	0.1144
1.22	10.569	1.326	0.7931	0.1424
1.42	11.206	1.545	0.8048	0.1702
1.62	11.906	1.765	0.8242	0.1980
1.82	12.206	1.984	0.8369	0.2259
2.02	12.504	2.203	0.8493	0.2537
2.22	12.701	2.422	0.8577	0.2815
2.42	13.038	2.641	0.8672	0.3093
2.62	13.218	2.861	0.8782	0.3372
2.82	13.413	3.080	0.8883	0.3650
3.02	13.718	3.299	0.8987	0.3928
3.22	14.026	3.518	0.9093	0.4206
3.42	14.278	3.737	0.9183	0.4485
3.62	14.527	3.956	0.9273	0.4763
3.82	14.718	4.176	0.9342	0.5041
4.02	14.883	4.395	0.9402	0.5319
4.22	15.026	4.614	0.9453	0.5598
4.42	15.128	4.833	0.9493	0.5876
4.62	15.227	5.052	0.9532	0.6154

DEL= 46.62 MM DSTR= 5.87 MM THETA= 4.56 MM
RDEL= 0.4703E+05 RDSTR= 0.5922E+04 RTTA= 0.3845E+04
SHAPE FACTOR,H= 1.29
PLANE LAM. N= 6.93

STATION 2

UINF= 15.067 M/S
REX= 2.189E+07
T= 24.38 DEG.C
MU= 0.1830E-04 KG/MS

X= 2.280
RHO= 0.9741 KG/CU.M
NU= 0.1880E-04 M*M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.02	5.837	0.132	0.3934	0.0124
0.24	7.378	0.265	0.4972	0.0249
0.46	8.822	0.398	0.5943	0.0449
0.68	9.865	0.531	0.6643	0.0648
0.90	10.878	0.665	0.6994	0.0847
1.12	11.628	0.798	0.7276	0.1047
1.34	11.975	0.931	0.7593	0.1247
1.56	12.312	1.064	0.7771	0.1447
1.78	12.645	1.197	0.8520	0.1747
2.00	12.949	1.330	0.8721	0.2047
2.22	13.181	1.463	0.8878	0.2446
2.44	13.472	1.596	0.8980	0.2846
2.66	13.713	1.729	0.9078	0.3246
2.88	14.004	1.862	0.9263	0.3645
3.10	14.236	1.995	0.9507	0.4045
3.32	14.452	2.128	0.9771	0.4445
3.54	14.647	2.261	0.9688	0.4844
3.76	15.265	2.394	0.9660	0.7843
3.98	15.465	2.527	0.9786	0.8642

DEL= 50.04 MM DSTR= 6.52 MM THETA= 4.69 MM
RDEL= 0.4730E+05 RDSTR= 0.6524E+04 RTTA= 0.3906E+04

STATION 3

UINF= 16.144 M/S
REX= 2.203E+07
T= 24.80 DEG.C
MU= 0.1836E-04 KG/MS

X= 2.369
RHO= 0.9737 KG/CU.M
NU= 0.1886E-04 M*M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.02	4.637	0.116	0.2901	0.0119
0.22	5.974	0.227	0.3730	0.0234
0.42	7.060	0.419	0.4417	0.0426
0.62	8.009	0.610	0.5009	0.0618
0.82	8.858	0.737	0.5542	0.0810
1.02	9.463	0.933	0.5921	0.1002
1.22	10.019	1.169	0.6314	0.1194
1.42	10.454	1.439	0.6583	0.1442
1.62	11.008	1.714	0.7203	0.1770
1.82	11.496	1.994	0.7604	0.2059
2.02	11.906	2.273	0.7883	0.2346
2.22	12.259	2.548	0.8179	0.2634
2.42	12.564	2.817	0.8335	0.2922
2.62	12.829	3.210	0.8502	0.3306
2.82	13.089	3.709	0.8768	0.3882
3.02	13.349	4.208	0.8880	0.4457
3.22	13.722	4.707	0.9116	0.5033
3.42	14.569	5.074	0.9516	0.5609
3.62	14.865	5.356	0.9681	0.6185
3.82	15.199	7.125	0.9510	0.7337
4.02	15.594	8.429	0.9787	0.8488

DEL= 52.09 MM DSTR= 8.11 MM THETA= 5.36 MM
RDEL= 0.4645E+05 RDSTR= 0.6941E+04 RTTA= 0.4593E+04
SHAPE FACTOR,H= 1.51
PLANE LAM. N= 3.91

STATION 4

UINF= 16.776 M/S
REX= 2.213E+07
T= 25.27 DEG.C
MU= 0.1839E-04 KG/MS

X= 2.469
RHO= 0.9722 KG/CU.M
NU= 0.1891E-04 M*M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.02	4.221	0.106	0.2667	0.0113
1.44	5.523	0.207	0.3427	0.0221
2.41	6.543	0.378	0.4039	0.0403
3.41	7.305	0.549	0.4529	0.0586
4.41	7.909	0.720	0.4934	0.0768
5.21	8.577	0.891	0.5292	0.0951
6.69	9.523	1.149	0.5873	0.1221
8.21	10.172	1.405	0.6287	0.1498
9.71	10.887	1.661	0.6721	0.1772
11.21	11.473	1.918	0.7092	0.2046
12.71	12.017	2.175	0.7418	0.2319
14.21	12.565	2.431	0.7763	0.2593
16.21	13.009	2.773	0.8037	0.2959
18.21	13.558	3.115	0.8375	0.3323
20.21	13.978	3.458	0.8590	0.3688
23.21	14.301	3.971	0.8829	0.4235
27.21	14.720	4.655	0.9092	0.4965
32.21	15.016	5.511	0.9269	0.5878
38.21	15.373	6.537	0.9489	0.6973
44.21	15.672	7.564	0.9674	0.8068

DEL= 54.80 MM DSTR= 9.27 MM THETA= 5.84 MM
RDEL= 0.4742E+05 RDSTR= 0.8024E+04 RTTA= 0.5058E+04

CURVE | FIT: LOG(FO)= C.1190E+00*LOG(Y/D)+-0.1095E-01

E-7.74-9

0701

UINF= 11.12[illegible] M/S

REX= C.1367E+07 X= 2.323

T= 24.87 DEG.C RHO= C.9734 KG/CU.M

MU= [illegible].1836E-04 KG/MS NU= 0.1887E-04 M**M/S

Y(MM)	U (M/S)	Y/DTA	U/UF	Y/DEL
C.42	6.17E	C+171	C.8819	C.0117
1.12	7.0[illegible]	C+312	C.9315	0.[illegible]225
1.82	7.41C	C+4[illegible]9	C+9[illegible]49	0.0413
2.52	7.695	C+4[illegible]3	0.9788	0.0572
3.22	8.2[illegible]	[illegible].[illegible]16	[illegible].[illegible]826	C.0885
4.62	8.472	1.[illegible]30	C.[illegible]775	0.1[illegible]68
6.02	8.72[illegible]	1.[illegible]60	0.9831	C.1565
8.12	8.[illegible]91	1.930	0.[illegible]78	0.1823
10.22	9.[illegible]1	2.[illegible]99	0.[illegible]13	C.2339
12.32	9.[illegible]75	2.[illegible]69	0.[illegible]164	0.2478
14.42	9.107	3.[illegible]31	0.9896	0.3244
16.52	9.341	3.[illegible]97	0.[illegible]927	0.3810
18.62	9.[illegible]4	3.642	0.[illegible]932	0.4753
20.72	9.[illegible]21	4.[illegible]19	0.[illegible]1C4	0.5497
22.82	10.[illegible]1	4.[illegible]65	0.9781	0.5829
24.92	10.262	5.[illegible]47	0.9827	0.6150
27.02	10.58[illegible]	6.[illegible]34	[illegible].[illegible]9[illegible]6	[illegible].[illegible]6[illegible]6

DEL= 52.73 MM DSTR= [illegible].[illegible]0 MM THETA= 5.12 MM

RDEL= [illegible].[illegible]E+05 RDSTR= [illegible].[illegible]E+04 RTTA= C.3015E+04

SHAPE FACTOR,H= 1.29

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STATION 2

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UINF= 10.[illegible] M/S

REX= [illegible].[illegible]E+07 X= 2.396

T= [illegible].[illegible] DEG.C RHO= [illegible].[illegible]2 KG/CU.M

MU= C.1[illegible]E-04 KG/MS NU= [illegible].[illegible]E-04 M**M/S

Y(MM)	U (M/S)	Y/DTA	U/UF	Y/DEL
[illegible].42	[illegible].[illegible]4	[illegible].[illegible]10	[illegible].[illegible]756	[illegible].[illegible]112
[illegible].12	[illegible].[illegible]3[illegible]	[illegible].[illegible]2[illegible]	[illegible].[illegible]7[illegible]	[illegible].[illegible]213
1.82	[illegible].[illegible]4[illegible]	[illegible].[illegible]3[illegible]	[illegible].[illegible]8[illegible]	[illegible].[illegible]3[illegible]
2.52	[illegible].[illegible]8[illegible]	[illegible].[illegible]4[illegible]	[illegible].[illegible]524	[illegible].[illegible]4[illegible]
3.62	[illegible].[illegible]85	[illegible].[illegible]6[illegible]	[illegible].[illegible]6427	[illegible].[illegible]6[illegible]5
4.62	[illegible].[illegible]7[illegible]	[illegible].[illegible]8[illegible]	[illegible].[illegible]7[illegible]5	[illegible].[illegible]8[illegible]6
5.62	[illegible].[illegible]8[illegible]	1.[illegible]01	[illegible].[illegible]7344	[illegible].[illegible]717
6.62	[illegible].[illegible]63	1.[illegible]3[illegible]	[illegible].[illegible]7571	[illegible].[illegible]1[illegible]8
8.12	[illegible].[illegible]78	1.[illegible]50	[illegible].[illegible]7738	[illegible].[illegible]14[illegible]
9.62	[illegible].[illegible]41	1.[illegible]80	[illegible].[illegible]7[illegible]5	[illegible].[illegible]741
11.12	[illegible].[illegible]7[illegible]	2.[illegible]10	[illegible].[illegible]8[illegible]5	[illegible].[illegible]2[illegible]3
12.62	[illegible].[illegible]8[illegible]	2.[illegible]7[illegible]	[illegible].[illegible]8[illegible]1	[illegible].[illegible]2[illegible]4
14.12	[illegible].[illegible]8[illegible]	2.[illegible]2	[illegible].[illegible]9[illegible]2	[illegible].[illegible]2[illegible]6
15.62	[illegible].[illegible]9[illegible]	3.[illegible]7	[illegible].[illegible]9[illegible]7	[illegible].[illegible]3[illegible]4
17.12	[illegible].[illegible]9[illegible]	3.[illegible]1	[illegible].[illegible]9[illegible]1	[illegible].[illegible]3[illegible]9
18.62	[illegible].[illegible]9[illegible]	[illegible].[illegible]6[illegible]	[illegible].[illegible]9717	[illegible].[illegible]3[illegible]1
20.12	[illegible].[illegible]9[illegible]	4.[illegible]71	[illegible].[illegible]9830	[illegible].[illegible]3[illegible]5
22.62	[illegible].[illegible]9[illegible]	5.[illegible]20	[illegible].[illegible]9921	[illegible].[illegible]4[illegible]0
24.12	[illegible].[illegible]9[illegible]	6.[illegible]82	[illegible].[illegible]9[illegible]2	[illegible].[illegible]5[illegible]4
31.62	[illegible].[illegible]9[illegible]	7.[illegible]44	[illegible].[illegible]9817	[illegible].[illegible]6[illegible]2
36.62	10.[illegible]00	8.[illegible]05	[illegible].[illegible]9[illegible]74	[illegible].[illegible]7[illegible]4
41.62	10.[illegible]61	8.775	[illegible].[illegible]9[illegible]9	[illegible].[illegible]8[illegible]5
45.62	10.[illegible]96			

DEL= 55.24 MM DSTR= [illegible].[illegible]0 MM THETA= 5.20 MM

RDEL= [illegible].[illegible]E+05 RDSTR= [illegible].[illegible]E+04 RTTA= [illegible].[illegible]E+04

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STATION 3

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UINF= 10.[illegible] M/S

REX= [illegible].[illegible]E+07 X= 2.488

T= [illegible].[illegible] DEG.C RHO= 0.9699 KG/CU.M

MU= [illegible].[illegible]E-04 KG/MS NU= 0.1[illegible]9E-04 M**M/S

Y(MM)	U (M/S)	Y/DTA	U/UF	Y/DEL
[illegible].82	[illegible].[illegible]7[illegible]	[illegible].[illegible]13	[illegible].[illegible]8[illegible]	[illegible].[illegible]0[illegible]
1.[illegible]	[illegible].[illegible]4[illegible]	[illegible].[illegible]2[illegible]	[illegible].[illegible]5[illegible]	[illegible].[illegible]1[illegible]
1.74	[illegible].[illegible]0[illegible]	[illegible].[illegible]2[illegible]	[illegible].[illegible]5433	[illegible].[illegible]3[illegible]
2.[illegible]	[illegible].[illegible]8[illegible]	[illegible].[illegible]3[illegible]	[illegible].[illegible]6041	[illegible].[illegible]3[illegible]
3.74	[illegible].[illegible]8[illegible]	[illegible].[illegible]4[illegible]	[illegible].[illegible]6418	[illegible].[illegible]5[illegible]
4.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]5[illegible]	[illegible].[illegible]6742	[illegible].[illegible]6[illegible]
5.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]6[illegible]	[illegible].[illegible]7[illegible]4	[illegible].[illegible]7[illegible]
6.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]7[illegible]	[illegible].[illegible]7415	[illegible].[illegible]9[illegible]
7.[illegible]	[illegible].[illegible]9[illegible]	1.[illegible]4	[illegible].[illegible]7435	[illegible].[illegible]1[illegible]
8.74	[illegible].[illegible]9[illegible]	1.[illegible]7	[illegible].[illegible]7643	[illegible].[illegible]1[illegible]
10.[illegible]	[illegible].[illegible]9[illegible]	1.[illegible]9	[illegible].[illegible]8[illegible]	[illegible].[illegible]1[illegible]
11.74	[illegible].[illegible]9[illegible]	2.[illegible]2	[illegible].[illegible]8[illegible]	[illegible].[illegible]2[illegible]
13.74	[illegible].[illegible]9[illegible]	2.[illegible]5	[illegible].[illegible]8[illegible]	[illegible].[illegible]2[illegible]
15.74	[illegible].[illegible]9[illegible]	2.[illegible]9	[illegible].[illegible]8[illegible]	[illegible].[illegible]3[illegible]
17.74	[illegible].[illegible]9[illegible]	3.[illegible]2	[illegible].[illegible]8[illegible]	[illegible].[illegible]3[illegible]
19.74	[illegible].[illegible]9[illegible]	3.[illegible]6	[illegible].[illegible]8[illegible]	[illegible].[illegible]4[illegible]
21.74	[illegible].[illegible]9[illegible]	4.[illegible]0	[illegible].[illegible]8[illegible]	[illegible].[illegible]4[illegible]
23.74	[illegible].[illegible]9[illegible]	4.[illegible]3	[illegible].[illegible]8[illegible]	[illegible].[illegible]4[illegible]
25.74	[illegible].[illegible]9[illegible]	4.[illegible]7	[illegible].[illegible]8[illegible]	[illegible].[illegible]5[illegible]
27.74	[illegible].[illegible]9[illegible]	5.[illegible]1	[illegible].[illegible]8[illegible]	[illegible].[illegible]5[illegible]
29.74	[illegible].[illegible]9[illegible]	5.[illegible]4	[illegible].[illegible]8[illegible]	[illegible].[illegible]6[illegible]
31.74	[illegible].[illegible]9[illegible]	5.[illegible]8	[illegible].[illegible]8[illegible]	[illegible].[illegible]6[illegible]
33.74	[illegible].[illegible]9[illegible]	6.[illegible]1	[illegible].[illegible]8[illegible]	[illegible].[illegible]6[illegible]
35.74	[illegible].[illegible]9[illegible]	6.[illegible]5	[illegible].[illegible]8[illegible]	[illegible].[illegible]7[illegible]
37.74	[illegible].[illegible]9[illegible]	6.[illegible]8	[illegible].[illegible]8[illegible]	[illegible].[illegible]7[illegible]
39.74	[illegible].[illegible]9[illegible]	7.[illegible]2	[illegible].[illegible]8[illegible]	[illegible].[illegible]8[illegible]
41.74	[illegible].[illegible]9[illegible]	7.[illegible]5	[illegible].[illegible]8[illegible]	[illegible].[illegible]8[illegible]
43.74	[illegible].[illegible]9[illegible]	7.[illegible]9	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
45.74	[illegible].[illegible]9[illegible]	8.[illegible]2	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
47.74	[illegible].[illegible]9[illegible]	8.[illegible]6	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
49.74	[illegible].[illegible]9[illegible]	8.[illegible]9	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
51.74	[illegible].[illegible]9[illegible]	9.[illegible]3	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
53.74	[illegible].[illegible]9[illegible]	9.[illegible]6	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
55.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]0	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
57.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]4	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
59.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]7	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
61.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]1	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
63.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]4	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
65.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]8	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
67.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]1	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
69.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]5	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
71.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]8	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
73.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]2	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
75.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]5	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
77.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]9	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
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89.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]9	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
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95.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]9	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
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325.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]3	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
327.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]6	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
329.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]9	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
331.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]3	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
333.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]6	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
335.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]9	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
337.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]3	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
339.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]6	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
341.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]9	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
343.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]3	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
345.74	[illegible].[illegible]9[illegible]	[illegible].[illegible]6	[illegible].[illegible]8[illegible]	[illegible].[illegible]9[illegible]
347.74	[illegible].[illegible]9[illegible]	[illegible].[ill

E-12.03-9

0501

CURVE 1 FIT: LOG(FD)= 0.1334E+00*LOG(Y/D)+-0.5001E-02

UINF= 12.[illegible] M/S

RTX= 0.1373E+07 X= 2.[illegible]

T= 27.[illegible] DEG.C RHO= 0.[illegible] KG/CU.M

MU= 0.1841E-04 KG/MS NU= 0.1914E-04 M*M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	5.[illegible]	0.117	0.5462	0.0[illegible]
1.75	7.[illegible]21	0.[illegible]	0.[illegible]	0.0[illegible]
2.75	7.[illegible]	0.[illegible]	0.7014	0.0[illegible]
3.75	7.[illegible]13	0.[illegible]	0.7248	0.0[illegible]
5.75	8.[illegible]38	1.[illegible]	0.7[illegible]	0.[illegible]
7.75	8.[illegible]79	1.[illegible]	0.7[illegible]	0.[illegible]
9.75	8.[illegible]	1.[illegible]	0.7[illegible]	0.1[illegible]
11.75	8.[illegible]	2.[illegible]	0.8192	0.[illegible]
13.75	9.[illegible]3	2.[illegible]	0.8[illegible]	0.[illegible]
15.75	9.[illegible]	2.[illegible]	0.8[illegible]	0.[illegible]
18.75	9.[illegible]3	3.[illegible]	0.8[illegible]	0.[illegible]
21.75	9.[illegible]	4.[illegible]	0.8[illegible]	0.[illegible]
25.75	9.[illegible]	4.[illegible]	0.8[illegible]	0.4[illegible]
30.75	9.[illegible]	5.7[illegible]	0.9[illegible]	0.[illegible]
35.75	10.[illegible]	6.7[illegible]	0.9[illegible]	0.6[illegible]
40.75	10.[illegible]53	7.6[illegible]	0.9540	0.7141
45.75	10.[illegible]35	8.0[illegible]	0.9[illegible]	0.8019

DEL= 5[illegible].67 MM DSTR= 6.8[illegible] MM THETA= 5.[illegible] MM

RDEL= 0.7[illegible] RDSTR= 0.[illegible]E+04 RTTA= 0.[illegible]

SHAPE FACTOR.H= 1.[illegible]

STATION 2

UINF= 12.[illegible] M/S

RTX= 0.1383E+07 X= 2.[illegible]

T= 27.[illegible] DEG.C RHO= 0.[illegible] KG/CU.M

MU= 0.1[illegible]E+04 KG/MS NU= 0.[illegible]E-04 M*M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	[illegible]	0.1[illegible]	0.[illegible]	0.[illegible]
1.47	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
2.47	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
3.47	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
4.47	[illegible]	1.[illegible]	0.[illegible]	0.[illegible]
5.47	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
6.97	[illegible]	1.[illegible]	0.7[illegible]	0.1244
8.47	[illegible]	1.[illegible]	0.7[illegible]	0.[illegible]
9.97	[illegible]	1.[illegible]	0.7[illegible]	0.1[illegible]
11.47	[illegible]	2.[illegible]	0.8[illegible]	0.2[illegible]
12.97	[illegible]	2.[illegible]	0.8[illegible]	0.2[illegible]
14.47	[illegible]	2.[illegible]	0.8[illegible]	0.2[illegible]
15.47	[illegible]	2.[illegible]	0.8[illegible]	0.2[illegible]
17.47	[illegible]	2.[illegible]	0.8[illegible]	0.3[illegible]
20.47	[illegible]	3.[illegible]	0.8[illegible]	0.3[illegible]
22.97	[illegible]	4.[illegible]	0.8[illegible]	0.4[illegible]
26.47	[illegible]	4.682	0.8974	0.4726
31.47	[illegible]	5.566	0.9[illegible]	0.5[illegible]
35.47	10.[illegible]	6.450	0.9[illegible]	0.[illegible]
41.47	10.[illegible]	7.334	0.9[illegible]	0.[illegible]
45.47	10.[illegible]39	8.042	0.9616	0.8119

DEL= 5[illegible].01 MM DSTR= 7.[illegible] MM THETA= 5.[illegible] MM

RDEL= 0.32[illegible]E+05 RDSTR= 0.[illegible]266E+04 RTTA= 0.[illegible]E+04

SHAPE FACTOR.H= 1.[illegible]

STATION 3

UINF= 11.[illegible] M/S

RTX= 0.1[illegible]E+07 X= 2.[illegible]

T= 27.[illegible] DEG.C RHO= 0.[illegible] KG/CU.M

MU= 0.1[illegible]E-04 KG/MS NU= 0.1[illegible]E-04 M*M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	3.[illegible]	0.132	0.3441	0.0[illegible]
1.11	4.[illegible]	0.[illegible]	0.3985	0.0[illegible]
2.11	5.[illegible]	0.346	0.4[illegible]	0.0[illegible]
3.11	6.[illegible]	0.510	0.5425	0.0544
4.11	6.[illegible]	0.674	0.5[illegible]	0.0719
5.11	6.[illegible]	0.[illegible]	0.6[illegible]	0.0[illegible]
6.11	7.[illegible]	1.001	0.6517	0.0[illegible]
7.[illegible]	7.719	1.247	0.69[illegible]	0.1[illegible]
9.11	8.[illegible]	1.[illegible]	0.7[illegible]	0.1[illegible]
10.[illegible]	8.[illegible]	1.[illegible]	0.7597	0.1[illegible]
12.[illegible]	8.[illegible]	1.[illegible]	0.7[illegible]	0.2117
14.11	8.[illegible]	2.313	0.8[illegible]	0.2466
16.11	9.[illegible]	2.[illegible]	0.8271	0.2816
18.11	9.[illegible]	2.[illegible]	0.8426	0.3[illegible]
20.11	9.[illegible]	2.[illegible]	[illegible].8514	0.3[illegible]
22.11	9.[illegible]	3.62[illegible]	0.8[illegible]	0.3[illegible]
27.11	9.[illegible]	4.44[illegible]	[illegible].8840	0.4[illegible]
31.11	10.[illegible]	5.263	0.9[illegible]	0.5[illegible]
37.11	10.[illegible]	6.083	0.9[illegible]	0.5[illegible]
42.11	10.[illegible]	6.[illegible]	0.9[illegible]	0.7[illegible]
45.11	10.[illegible]	7.304	0.9541	0.7844

DEL= 57.22 MM DSTR= 8.73 MM THETA= 8.10 MM

RDEL= 0.33[illegible]E+05 RDSTR= 0.50[illegible]E+04 RTTA= 0.3803E+04

SHAPE FACTOR.H= 1.[illegible]

STATION 4

UINF= 11.[illegible] M/S

RTX= 0.1[illegible]E+07 X= 2.674

T= 27.0[illegible] DEG.C RHO= 0.[illegible] KG/CU.M

MU= 0.1[illegible]E-04 KG/MS NU= 0.1937E-04 M*M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.62	3.[illegible]	0.0[illegible]	0.3111	0.0[illegible]
1.52	4.746	0.233	0.4216	0.0[illegible]
2.52	5.[illegible]	0.395	0.4[illegible]	0.0[illegible]
3.52	6.[illegible]	0.552	0.5[illegible]	0.0[illegible]
4.52	6.[illegible]	0.708	0.5638	0.0763
5.52	6.[illegible]	0.865	0.5968	0.0[illegible]
7.00	7.[illegible]	1.097	0.6345	0.1[illegible]
8.52	7.[illegible]	1.335	0.6716	0.1[illegible]
10.02	7.[illegible]	1.570	0.7119	0.1[illegible]
11.52	8.[illegible]	1.805	0.7370	0.1[illegible]
13.52	8.497	2.119	0.7673	0.2[illegible]
15.52	8.[illegible]	2.432	0.7935	0.2[illegible]
17.52	9.[illegible]	2.745	0.8234	0.2[illegible]
20.52	9.[illegible]	3.215	0.8490	0.3[illegible]
23.52	9.[illegible]	3.6[illegible]	0.8668	0.3[illegible]
28.52	9.[illegible]	4.469	0.8922	0.4[illegible]
33.52	10.[illegible]	5.252	0.9115	0.5[illegible]
38.52	10.[illegible]	6.036	0.9304	0.6[illegible]
44.52	10.[illegible]	6.976	0.9506	0.7514

DEL= 59.25 MM DSTR= 9.40 MM THETA= 6.39 MM

RDEL= 0.3[illegible]67E+05 RDSTR= 0.5418E+04 RTTA= 0.3845E+04

C-7.07-17

09N1

CURVE 1 FITS LOG(F0)= 5.1250E+00*LOG(/D)+-8.1343E-02

C-9.28-17

10N1

UINF= 16.374 M/S
REX= 2.181E+07 X= 2.162
TE 27.55 DEGR. RHO= 0.9488 KG/CU.M
MUE 0.1848E-04 KG/MS NUE= 0.1917E-04 M**M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.51	8.646	0.4114	0.5334	0.0174
1.00	10.175	0.8076	0.6277	0.0341
1.50	11.417	1.2038	0.7044	0.0512
2.00	12.424	1.6000	0.7665	0.0683
2.50	13.271	1.9961	0.8187	0.0853
3.00	13.924	2.3923	0.8590	0.1024
3.50	14.465	2.7885	0.8925	0.1195
4.00	14.879	3.1846	0.9181	0.1365
4.50	15.227	3.5808	0.9396	0.1536
5.00	15.480	3.9769	0.9552	0.1707
5.50	15.674	4.3731	0.9672	0.1877
6.00	15.870	4.7693	0.9793	0.2048
6.50	16.009	5.1654	0.9879	0.2219
7.00	16.107	5.5616	0.9939	0.2389
7.50	16.203	5.9577	0.9998	0.2560
8.00	16.203	6.3539	0.9998	0.2731
8.50	16.203	6.7501	0.9998	0.2901
9.00	16.203	7.1462	0.9998	0.3072
9.50	16.203	7.5424	0.9998	0.3243
10.00	16.203	7.9385	0.9998	0.3413
10.50	16.203	8.3347	0.9998	0.3584
11.00	16.203	8.7309	0.9998	0.3755
11.50	16.203	9.1270	0.9998	0.3925
12.00	16.203	9.5232	0.9998	0.4096
12.50	16.203	9.9193	0.9998	0.4267
13.00	16.203	10.3155	0.9998	0.4437
13.50	16.203	10.7116	0.9998	0.4608

DEL= 24.22 MM DSTR= 5.79 MM THETA= 4.49 MM
RDEL= 0.2343E+05 RDSTR= 0.4846E+04 RTTA= 0.3834E+04
SHAPE FACTOR,H= 1.30

STATION 2

UINF= 16.256 M/S
REX= 3.1865E+07 X= 2.235
TE 27.42 DEGR. RHO= 0.9630 KG/CU.M
MUE 0.1851E-04 KG/MS NUE= 0.1921E-04 M**M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.51	5.349	0.112	0.3338	0.0105
1.00	7.000	0.2274	0.4369	0.0211
1.50	8.242	0.3433	0.5144	0.0316
2.00	9.246	0.4593	0.5771	0.0422
2.50	10.093	0.5751	0.6299	0.0527
3.00	10.793	0.6910	0.6736	0.0633
3.50	11.387	0.8068	0.7107	0.0738
4.00	11.893	0.9227	0.7422	0.0844
4.50	12.329	1.0385	0.7694	0.0949
5.00	12.703	1.1544	0.7928	0.1055
5.50	13.029	1.2702	0.8131	0.1160
6.00	13.316	1.3861	0.8310	0.1266
6.50	13.574	1.5019	0.8471	0.1371
7.00	13.810	1.6178	0.8618	0.1477
7.50	14.023	1.7336	0.8751	0.1582
8.00	14.218	1.8495	0.8873	0.1688
8.50	14.396	1.9653	0.8984	0.1793
9.00	14.561	2.0812	0.9087	0.1899
9.50	14.713	2.1970	0.9182	0.2004
10.00	14.853	2.3129	0.9269	0.2110
10.50	14.984	2.4287	0.9351	0.2215
11.00	15.105	2.5446	0.9426	0.2321
11.50	15.219	2.6604	0.9497	0.2426
12.00	15.326	2.7763	0.9564	0.2532
12.50	15.427	2.8921	0.9627	0.2637
13.00	15.523	3.0080	0.9687	0.2743
13.50	15.614	3.1238	0.9744	0.2848
14.00	15.701	3.2397	0.9798	0.2954
14.50	15.784	3.3555	0.9850	0.3059
15.00	15.863	3.4714	0.9899	0.3165
15.50	15.939	3.5872	0.9947	0.3270
16.00	16.012	3.7031	0.9992	0.3376
16.50	16.082	3.8189	1.0036	0.3481
17.00	16.150	3.9348	1.0078	0.3587
17.50	16.215	4.0506	1.0118	0.3692
18.00	16.278	4.1665	1.0158	0.3798
18.50	16.339	4.2823	1.0196	0.3903
19.00	16.398	4.3982	1.0233	0.4009
19.50	16.455	4.5140	1.0269	0.4114
20.00	16.511	4.6299	1.0304	0.4220
20.50	16.565	4.7457	1.0338	0.4325
21.00	16.618	4.8616	1.0371	0.4431
21.50	16.669	4.9774	1.0403	0.4536
22.00	16.719	5.0933	1.0435	0.4642
22.50	16.768	5.2091	1.0465	0.4747
23.00	16.815	5.3250	1.0495	0.4853
23.50	16.862	5.4408	1.0525	0.4958
24.00	16.907	5.5567	1.0553	0.5064
24.50	16.952	5.6725	1.0581	0.5169
25.00	16.995	5.7884	1.0608	0.5275
25.50	17.038	5.9042	1.0635	0.5380
26.00	17.079	6.0201	1.0660	0.5486
26.50	17.120	6.1359	1.0686	0.5591
27.00	17.160	6.2518	1.0710	0.5697
27.50	17.199	6.3676	1.0735	0.5802
28.00	17.237	6.4835	1.0758	0.5908
28.50	17.274	6.5993	1.0781	0.6013
29.00	17.311	6.7152	1.0804	0.6119
29.50	17.347	6.8310	1.0826	0.6224
30.00	17.382	6.9469	1.0848	0.6330
30.50	17.417	7.0627	1.0869	0.6435
31.00	17.451	7.1786	1.0890	0.6541
31.50	17.484	7.2944	1.0911	0.6646
32.00	17.517	7.4103	1.0931	0.6752
32.50	17.549	7.5261	1.0951	0.6857
33.00	17.580	7.6420	1.0970	0.6963
33.50	17.611	7.7578	1.0990	0.7068
34.00	17.641	7.8737	1.1008	0.7174
34.50	17.671	7.9895	1.1027	0.7279
35.00	17.700	8.1054	1.1045	0.7385
35.50	17.729	8.2212	1.1063	0.7490
36.00	17.757	8.3371	1.1080	0.7596
36.50	17.784	8.4529	1.1097	0.7701
37.00	17.811	8.5688	1.1114	0.7807
37.50	17.838	8.6846	1.1131	0.7912
38.00	17.864	8.8005	1.1147	0.8018
38.50	17.890	8.9163	1.1163	0.8123
39.00	17.915	9.0322	1.1179	0.8229
39.50	17.940	9.1480	1.1195	0.8334

DEL= 43.17 MM DSTR= 6.73 MM THETA= 4.58 MM
RDEL= 0.2812E+05 RDSTR= 0.5344E+04 RTTA= 0.3667E+04
SHAPE FACTOR,H= 1.38

STATION 1

UINF= 16.338 M/S
REX= 3.1971E+07 X= 2.227
TE 24.31 DEGR. RHO= 0.9693 KG/CU.M
MUE= 0.1853E-04 KG/MS NUE = 0.1925E-04 M**M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.51	4.739	0.109	0.2966	0.0136
1.00	6.201	0.2180	0.3881	0.0271
1.50	7.336	0.3271	0.4591	0.0407
2.00	8.231	0.4361	0.5151	0.0543
2.50	8.961	0.5451	0.5608	0.0678
3.00	9.613	0.6541	0.6016	0.0814
3.50	10.201	0.7631	0.6384	0.0950
4.00	10.730	0.8721	0.6715	0.1085
4.50	11.208	0.9811	0.7014	0.1221
5.00	11.640	1.0901	0.7285	0.1357
5.50	12.030	1.1991	0.7529	0.1492
6.00	12.385	1.3081	0.7751	0.1628
6.50	12.707	1.4171	0.7953	0.1764
7.00	13.000	1.5261	0.8136	0.1899
7.50	13.268	1.6351	0.8303	0.2035
8.00	13.513	1.7441	0.8457	0.2171
8.50	13.738	1.8531	0.8598	0.2306
9.00	13.945	1.9621	0.8727	0.2442
9.50	14.135	2.0711	0.8846	0.2578
10.00	14.310	2.1801	0.8955	0.2713
10.50	14.472	2.2891	0.9057	0.2849
11.00	14.622	2.3981	0.9151	0.2985
11.50	14.761	2.5071	0.9238	0.3120
12.00	14.890	2.6161	0.9319	0.3256
12.50	15.010	2.7251	0.9394	0.3392
13.00	15.122	2.8341	0.9464	0.3527
13.50	15.227	2.9431	0.9530	0.3663
14.00	15.325	3.0521	0.9591	0.3799
14.50	15.417	3.1611	0.9649	0.3934
15.00	15.504	3.2701	0.9703	0.4070
15.50	15.585	3.3791	0.9754	0.4206
16.00	15.662	3.4881	0.9802	0.4341
16.50	15.735	3.5971	0.9848	0.4477
17.00	15.804	3.7061	0.9891	0.4613
17.50	15.869	3.8151	0.9932	0.4748
18.00	15.931	3.9241	0.9971	0.4884
18.50	15.990	4.0331	1.0008	0.5020
19.00	16.046	4.1421	1.0043	0.5155
19.50	16.100	4.2511	1.0077	0.5291
20.00	16.151	4.3601	1.0109	0.5427
20.50	16.200	4.4691	1.0140	0.5562
21.00	16.247	4.5781	1.0169	0.5698
21.50	16.292	4.6871	1.0197	0.5834
22.00	16.335	4.7961	1.0224	0.5969
22.50	16.377	4.9051	1.0250	0.6105
23.00	16.417	5.0141	1.0275	0.6241
23.50	16.455	5.1231	1.0299	0.6376
24.00	16.492	5.2321	1.0322	0.6512
24.50	16.528	5.3411	1.0345	0.6648
25.00	16.563	5.4501	1.0367	0.6783
25.50	16.597	5.5591	1.0388	0.6919
26.00	16.630	5.6681	1.0409	0.7055
26.50	16.662	5.7771	1.0429	0.7190
27.00	16.693	5.8861	1.0448	0.7326
27.50	16.723	5.9951	1.0467	0.7462
28.00	16.753	6.1041	1.0485	0.7597
28.50	16.782	6.2131	1.0503	0.7733
29.00	16.810	6.3221	1.0521	0.7869
29.50	16.838	6.4311	1.0538	0.8004
30.00	16.865	6.5401	1.0555	0.8140
30.50	16.892	6.6491	1.0572	0.8276
31.00	16.918	6.7581	1.0588	0.8411
31.50	16.944	6.8671	1.0604	0.8547
32.00	16.969	6.9761	1.0619	0.8683
32.50	16.994	7.0851	1.0635	0.8818
33.00	17.018	7.1941	1.0650	0.8954
33.50	17.042	7.3031	1.0664	0.9090
34.00	17.065	7.4121	1.0679	0.9225
34.50	17.088	7.5211	1.0693	0.9361
35.00	17.111	7.6301	1.0707	0.9497
35.50	17.133	7.7391	1.0720	0.9632
36.00	17.155	7.8481	1.0734	0.9768
36.50	17.176	7.9571	1.0747	0.9904
37.00	17.197	8.0661	1.0760	1.0039
37.50	17.218	8.1751	1.0773	1.0175
38.00	17.238	8.2841	1.0785	1.0311
38.50	17.258	8.3931	1.0798	1.0446
39.00	17.278	8.5021	1.0810	1.0582
39.50	17.297	8.6111	1.0822	1.0718

DEL= 40.24 MM DSTR= 7.09 MM THETA= 4.78 MM
RDEL= 0.2610E+05 RDSTR= 0.6002E+04 RTTA= 0.4430E+04
SHAPE FACTOR,H= 1.49

STATION 2

UINF= 16.308 M/S
REX= 3.2072E+07 X= 2.427
TE 24.75 DEGR. RHO= 0.9609 KG/CU.M
MUE= 0.1856E-04 KG/MS NU= 0.1930E-04 M**M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.51	4.433	0.101	0.2712	0.0110
1.00	5.756	0.1990	0.3483	0.0216
1.50	6.799	0.2880	0.4060	0.0312
2.00	7.635	0.3981	0.4580	0.0414
2.50	7.435	0.4770	0.4550	0.0515
3.00	8.057	0.5958	0.5056	0.0627
3.50	8.660	0.7060	0.5304	0.0715
4.00	9.045	0.8051	0.5538	0.0818
4.50	9.439	0.9051	0.5808	0.0914
5.00	10.011	1.0238	0.6129	0.1041
5.50	10.435	1.1225	0.6411	0.1168
6.00	10.887	1.2228	0.6673	0.1295
6.50	11.287	1.3221	0.6911	0.1421
7.00	11.641	1.4214	0.7128	0.1548
7.50	11.954	1.5207	0.7321	0.1675
8.00	12.231	1.6200	0.7491	0.1801
8.50	12.476	1.7193	0.7641	0.1928
9.00	12.693	1.8186	0.7774	0.2055
9.50	12.885	1.9179	0.7892	0.2181
10.00	13.055	2.0172	0.7996	0.2308
10.50	13.207	2.1165	0.8089	0.2435
11.00	13.343	2.2158	0.8172	0.2561
11.50	13.465	2.3151	0.8247	0.2688
12.00	13.576	2.4144	0.8315	0.2815
12.50	13.677	2.5137	0.8377	0.2941
13.00	13.770	2.6130	0.8434	0.3068
13.50	13.856	2.7123	0.8486	0.3195
14.00	13.936	2.8116	0.8535	0.3321
14.50	14.011	2.9109	0.8581	0.3448
15.00	14.082	3.0102	0.8624	0.3575
15.50	14.149	3.1095	0.8665	0.3701
16.00	14.213	3.2088	0.8704	0.3828
16.50	14.274	3.3081	0.8741	0.3955
17.00	14.333	3.4074	0.8777	0.4081
17.50	14.390	3.5067	0.8812	0.4208
18.00	14.445	3.6060	0.8846	0.4335
18.50	14.498	3.7053	0.8879	0.4461
19.00	14.550	3.8046	0.8911	0.4588
19.50	14.600	3.9039	0.8942	0.4715
20.00	14.649	4.0032	0.8972	0.4841
20.50	14.697	4.1025	0.9002	0.4968
21.00	14.744	4.2018	0.9031	0.5095
21.50	14.790	4.3011	0.9059	0.5221
22.00	14.835	4.4004	0.9087	0.5348
22.50	14.879	4.4997	0.9114	0.5475
23.00	14.922	4.5990	0.9140	0.5601
23.50	14.964	4.6983	0.9166	0.5728
24.00	15.006	4.7976	0.9192	0.5855
24.50	15.047	4.8969	0.9217	0.5981
25.00	15.087	4.9962	0.9241	0.6108
25.50	15.127	5.0955	0.9266	0.6235
26.00	15.166	5.1948	0.9289	0.6361
26.50	15.205	5.2941	0.9313	0.6488
27.00	15.243	5.3934	0.9336	0.6615
27.50	15.281	5.4927	0.9359	0.6741
28.00	15.318	5.5920	0.9382	0.6868
28.50	15.355	5.6913	0.9404	0.6995
29.00	15.391	5.7906	0.9426	0.7121
29.50	15.427	5.8899	0.9448	0.7248
30.00	15.462	5.9892	0.9469	0.7375
30.50	15.497	6.0885	0.9490	0.7501
31.00	15.532	6.1878	0.9511	0.7628
31.50	15.566	6.2871	0.9532	0.7755
32.00	15.600	6.3864	0.9552	0.7881
32.50	15.633	6.4857	0.9572	0.8008
33.00	15.666	6.5850	0.9592	0.8135
33.50	15.699	6.6843	0.9612	0.8261
34.00	15.731	6.7836	0.9631	0.8388
34.50	15.763	6.8829	0.9651	0.8515
35.00	15.795	6.9822	0.9670	0.8641
35.50	15.826	7.0815	0.9689	0.8768
36.00	15.857	7.1808	0.9708	0.8895
36.50	15.888	7.2801	0.9727	0.9021
37.00	15.918	7.3794	0.9745	0.9148
37.50	15.948	7.4787	0.9764	0.9275
38.00	15.978	7.5780	0.9782	0.9401
38.50	16.008	7.6773	0.9800	0.9528
39.00	16.037	7.7766	0.9818	0.9655
39.50	16.066	7.8759	0.9836	0.9781

DEL= 40.02 MM DSTR= 8.10 MM THETA= 5.23 MM
RDEL= 0.2613E+05 RDSTR= 0.6030E+04 RTTA= 0.4467E+04
SHAPE FACTOR,H= 1.55

CURVE 1 FIT: LOG(F/Q) = 0.3205E+00*LOG(Y/D) + 1.3278E-02

C-12.02-17

ION2

UINF= 17.034 M/S

REX= 2.1726E+07 X= 1.002

T= 30.00 DEG.C RHO= 0.0967 KG/CU.M

MU= 2.1961E-05 KG/MS NU= 2.1945E-04 M**2/S

Y/DEL	U (M/S)	Y/THETA	U/UE	Y/DEL
0.051	10.197	0.123	0.5981	0.0111
0.254	14.745	0.614	0.8652	0.0554
0.508	15.854	1.228	0.9301	0.1109
0.762	16.238	1.842	0.9526	0.1663
1.016	16.388	2.456	0.9614	0.2218
1.270	16.483	3.070	0.9668	0.2772
1.524	16.548	3.684	0.9706	0.3327
1.778	16.600	4.298	0.9737	0.3881
2.032	16.647	4.912	0.9765	0.4436
2.286	16.686	5.526	0.9788	0.4990
2.540	16.725	6.140	0.9811	0.5545
2.794	16.764	6.754	0.9834	0.6099
3.048	16.803	7.368	0.9857	0.6654
3.302	16.842	7.982	0.9880	0.7208
3.556	16.881	8.596	0.9903	0.7763
3.810	16.920	9.210	0.9926	0.8317
4.064	16.959	9.824	0.9949	0.8872
4.318	16.998	10.438	0.9972	0.9426
4.572	17.037	11.052	0.9995	0.9981

DEL= 42.68 MM DSTR= 5.37 MM THETA= 4.17 MM

RDEL= 0.4730E+05 RDSTR= 5.9436E+04 RTTA= 0.4623E+04

SHAPE FACTOR= 1.29

STATION 2

UINF= 16.765 M/S

REX= 3.1716E+07 X= 1.524

T= 30.00 DEG.C RHO= 0.0951 KG/CU.M

MU= 2.1961E-05 KG/MS NU= 2.3091E-04 M**2/S

Y/DEL	U (M/S)	Y/THETA	U/UE	Y/DEL
0.051	9.561	0.123	0.5703	0.0111
0.254	14.012	0.614	0.8358	0.0554
0.508	15.217	1.228	0.9076	0.1109
0.762	15.683	1.842	0.9355	0.1663
1.016	15.883	2.456	0.9474	0.2218
1.270	15.983	3.070	0.9533	0.2772
1.524	16.043	3.684	0.9569	0.3327
1.778	16.083	4.298	0.9593	0.3881
2.032	16.123	4.912	0.9617	0.4436
2.286	16.163	5.526	0.9641	0.4990
2.540	16.203	6.140	0.9665	0.5545
2.794	16.243	6.754	0.9689	0.6099
3.048	16.283	7.368	0.9713	0.6654
3.302	16.323	7.982	0.9737	0.7208
3.556	16.363	8.596	0.9761	0.7763
3.810	16.403	9.210	0.9785	0.8317
4.064	16.443	9.824	0.9809	0.8872
4.318	16.483	10.438	0.9833	0.9426
4.572	16.523	11.052	0.9857	0.9981

DEL= 48.89 MM DSTR= 7.49 MM THETA= 4.97 MM

RDEL= 0.4337E+05 RDSTR= 6.8715E+04 RTTA= 0.4396E+04

SHAPE FACTOR= 1.51

STATION 3

UINF= 17.749 M/S

REX= 3.3585E+07 X= 2.047

T= 30.00 DEG.C RHO= 0.0958 KG/CU.M

MU= 2.1961E-05 KG/MS NU= 2.2927E-04 M**2/S

Y/DEL	U (M/S)	Y/THETA	U/UE	Y/DEL
0.051	9.400	0.123	0.5295	0.0111
0.254	13.523	0.614	0.7618	0.0554
0.508	14.883	1.228	0.8385	0.1109
0.762	15.383	1.842	0.8667	0.1663
1.016	15.633	2.456	0.8808	0.2218
1.270	15.783	3.070	0.8893	0.2772
1.524	15.883	3.684	0.8949	0.3327
1.778	15.953	4.298	0.8988	0.3881
2.032	16.013	4.912	0.9022	0.4436
2.286	16.063	5.526	0.9050	0.4990
2.540	16.103	6.140	0.9073	0.5545
2.794	16.143	6.754	0.9096	0.6099
3.048	16.183	7.368	0.9119	0.6654
3.302	16.223	7.982	0.9142	0.7208
3.556	16.263	8.596	0.9165	0.7763
3.810	16.303	9.210	0.9188	0.8317
4.064	16.343	9.824	0.9211	0.8872
4.318	16.383	10.438	0.9234	0.9426
4.572	16.423	11.052	0.9257	0.9981

DEL= 51.32 MM DSTR= 8.93 MM THETA= 5.55 MM

RDEL= 0.4730E+05 RDSTR= 0.9136E+04 RTTA= 0.6026E+04

SHAPE FACTOR= 1.61

CURVE 1 FIT: LOG(FC)= 0.1283E+00*LOG(Y/D)+-0.1175E-02

U INF= 12.350 M/S
REX= 0.1271E+07 X= 1.954
T= 26.01 DEG.C RHO= 0.9698 KG/CU.M
MU= 0.1842E-04 KG/MS NU= 0.1899E-04 M*M/S

C-539-13

11N1

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.51	6.[illegible]	0.117	0.5142	[illegible]
0.99	7.[illegible]	0.234	0.6123	[illegible]
1.48	8.[illegible]	0.335	0.6711	[illegible]
1.98	9.[illegible]	0.453	0.7418	[illegible]
2.48	9.[illegible]	0.570	0.7845	[illegible]
2.98	9.[illegible]	0.687	0.8253	[illegible]
3.48	9.[illegible]	0.804	0.8550	[illegible]
3.98	9.[illegible]	0.921	0.8806	[illegible]
4.48	9.[illegible]	1.038	0.9022	[illegible]
4.98	9.[illegible]	1.155	0.9182	[illegible]
5.48	9.[illegible]	1.272	0.9316	[illegible]
5.98	9.[illegible]	1.389	0.9429	[illegible]
6.48	9.[illegible]	1.506	0.9523	[illegible]
6.98	9.[illegible]	1.623	0.9602	[illegible]
7.48	9.[illegible]	1.740	0.9668	[illegible]
7.98	9.[illegible]	1.857	0.9724	[illegible]
8.48	9.[illegible]	1.974	0.9771	[illegible]
8.98	9.[illegible]	2.091	0.9810	[illegible]
9.48	9.[illegible]	2.208	0.9843	[illegible]
9.98	9.[illegible]	2.325	0.9870	[illegible]
10.48	9.[illegible]	2.442	0.9893	[illegible]
10.98	9.[illegible]	2.559	0.9912	[illegible]
11.48	9.[illegible]	2.676	0.9928	[illegible]
11.98	9.[illegible]	2.793	0.9941	[illegible]
12.48	9.[illegible]	2.910	0.9952	[illegible]
12.98	9.[illegible]	3.027	0.9961	[illegible]
13.48	9.[illegible]	3.144	0.9969	[illegible]
13.98	9.[illegible]	3.261	0.9975	[illegible]
14.48	9.[illegible]	3.378	0.9980	[illegible]
14.98	9.[illegible]	3.495	0.9984	[illegible]
15.48	9.[illegible]	3.612	0.9988	[illegible]
15.98	9.[illegible]	3.729	0.9991	[illegible]
16.48	9.[illegible]	3.846	0.9993	[illegible]
16.98	9.[illegible]	3.963	0.9995	[illegible]
17.48	9.[illegible]	4.080	0.9997	[illegible]
17.98	9.[illegible]	4.197	0.9998	[illegible]
18.48	9.[illegible]	4.314	0.9999	[illegible]
18.98	9.[illegible]	4.431	0.9999	[illegible]
19.48	9.[illegible]	4.548	1.0000	[illegible]
19.98	9.[illegible]	4.665	1.0000	[illegible]
20.48	9.[illegible]	4.782	1.0000	[illegible]
20.98	9.[illegible]	4.899	1.0000	[illegible]
21.48	9.[illegible]	5.016	1.0000	[illegible]
21.98	9.[illegible]	5.133	1.0000	[illegible]
22.48	9.[illegible]	5.250	1.0000	[illegible]
22.98	9.[illegible]	5.367	1.0000	[illegible]
23.48	9.[illegible]	5.484	1.0000	[illegible]
23.98	9.[illegible]	5.601	1.0000	[illegible]
24.48	9.[illegible]	5.718	1.0000	[illegible]
24.98	9.[illegible]	5.835	1.0000	[illegible]
25.48	9.[illegible]	5.952	1.0000	[illegible]
25.98	9.[illegible]	6.069	1.0000	[illegible]
26.48	9.[illegible]	6.186	1.0000	[illegible]
26.98	9.[illegible]	6.303	1.0000	[illegible]
27.48	9.[illegible]	6.420	1.0000	[illegible]
27.98	9.[illegible]	6.537	1.0000	[illegible]
28.48	9.[illegible]	6.654	1.0000	[illegible]
28.98	9.[illegible]	6.771	1.0000	[illegible]
29.48	9.[illegible]	6.888	1.0000	[illegible]
29.98	9.[illegible]	7.005	1.0000	[illegible]
30.48	9.[illegible]	7.122	1.0000	[illegible]
30.98	9.[illegible]	7.239	1.0000	[illegible]
31.48	9.[illegible]	7.356	1.0000	[illegible]
31.98	9.[illegible]	7.473	1.0000	[illegible]
32.48	9.[illegible]	7.590	1.0000	[illegible]
32.98	9.[illegible]	7.707	1.0000	[illegible]
33.48	9.[illegible]	7.824	1.0000	[illegible]
33.98	9.[illegible]	7.941	1.0000	[illegible]
34.48	9.[illegible]	8.058	1.0000	[illegible]
34.98	9.[illegible]	8.175	1.0000	[illegible]
35.48	9.[illegible]	8.292	1.0000	[illegible]
35.98	9.[illegible]	8.409	1.0000	[illegible]
36.48	9.[illegible]	8.526	1.0000	[illegible]
36.98	9.[illegible]	8.643	1.0000	[illegible]
37.48	9.[illegible]	8.760	1.0000	[illegible]
37.98	9.[illegible]	8.877	1.0000	[illegible]
38.48	9.[illegible]	8.994	1.0000	[illegible]
38.98	9.[illegible]	9.111	1.0000	[illegible]
39.48	9.[illegible]	9.228	1.0000	[illegible]
39.98	9.[illegible]	9.345	1.0000	[illegible]

DEL= 60.02 MM DSTR= 5.67 MM THETA= 4.37 MM
RDEL= 0.2327E+05 RDSTR= 0.2198E+04 RTTA= 0.2843E+04
SHAPE FACTOR= 1.30

STATION 2

U INF= 12.336 M/S
REX= 0.1310E+07 X= 2.030
T= 26.32 DEG.C RHO= 0.9687 KG/CU.M
MU= 0.1836E-04 KG/MS NU= 0.1896E-04 M*M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.51	[illegible]	[illegible]	0.3370	[illegible]
0.99	[illegible]	[illegible]	[illegible]	[illegible]
1.49	[illegible]	[illegible]	[illegible]	[illegible]
2.00	[illegible]	[illegible]	[illegible]	[illegible]
2.75	[illegible]	[illegible]	[illegible]	[illegible]
3.55	[illegible]	[illegible]	[illegible]	[illegible]
4.35	[illegible]	[illegible]	[illegible]	[illegible]
5.15	[illegible]	[illegible]	[illegible]	[illegible]
5.95	[illegible]	[illegible]	[illegible]	[illegible]
6.75	[illegible]	[illegible]	[illegible]	[illegible]
7.55	[illegible]	[illegible]	[illegible]	[illegible]
8.35	[illegible]	[illegible]	[illegible]	[illegible]
9.15	[illegible]	[illegible]	[illegible]	[illegible]
9.95	[illegible]	[illegible]	[illegible]	[illegible]
10.75	[illegible]	[illegible]	[illegible]	[illegible]
11.55	[illegible]	[illegible]	[illegible]	[illegible]
12.35	[illegible]	[illegible]	[illegible]	[illegible]
13.15	[illegible]	[illegible]	[illegible]	[illegible]
13.95	[illegible]	[illegible]	[illegible]	[illegible]
14.75	[illegible]	[illegible]	[illegible]	[illegible]
15.55	[illegible]	[illegible]	[illegible]	[illegible]
16.35	[illegible]	[illegible]	[illegible]	[illegible]
17.15	[illegible]	[illegible]	[illegible]	[illegible]
17.95	[illegible]	[illegible]	[illegible]	[illegible]
18.75	[illegible]	[illegible]	[illegible]	[illegible]
19.55	[illegible]	[illegible]	[illegible]	[illegible]
20.35	[illegible]	[illegible]	[illegible]	[illegible]
21.15	[illegible]	[illegible]	[illegible]	[illegible]
21.95	[illegible]	[illegible]	[illegible]	[illegible]
22.75	[illegible]	[illegible]	[illegible]	[illegible]
23.55	[illegible]	[illegible]	[illegible]	[illegible]
24.35	[illegible]	[illegible]	[illegible]	[illegible]
25.15	[illegible]	[illegible]	[illegible]	[illegible]
25.95	[illegible]	[illegible]	[illegible]	[illegible]
26.75	[illegible]	[illegible]	[illegible]	[illegible]
27.55	[illegible]	[illegible]	[illegible]	[illegible]

DEL= 45.91 MM DSTR= 6.17 MM THETA= 4.48 MM
RDEL= 0.2970E+05 RDSTR= 0.3991E+04 RTTA= 0.2971E+04
SHAPE FACTOR= 1.39

STATION 3

U INF= 12.350 M/S
REX= 0.1373E+07 X= 2.119
T= 26.70 DEG.C RHO= 0.9675 KG/CU.M
MU= 0.1845E-04 KG/MS NU= 0.1907E-04 M*M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.51	[illegible]	[illegible]	0.2846	[illegible]
1.02	[illegible]	[illegible]	[illegible]	[illegible]
1.52	[illegible]	[illegible]	[illegible]	[illegible]
2.37	[illegible]	[illegible]	[illegible]	[illegible]
3.37	[illegible]	[illegible]	[illegible]	[illegible]
4.37	[illegible]	[illegible]	[illegible]	[illegible]
5.37	[illegible]	[illegible]	[illegible]	[illegible]
6.37	[illegible]	[illegible]	[illegible]	[illegible]
7.37	[illegible]	[illegible]	[illegible]	[illegible]
8.37	[illegible]	[illegible]	[illegible]	[illegible]
9.37	[illegible]	[illegible]	[illegible]	[illegible]
10.37	[illegible]	[illegible]	[illegible]	[illegible]
12.37	[illegible]	[illegible]	[illegible]	[illegible]
14.37	[illegible]	[illegible]	[illegible]	[illegible]
16.37	[illegible]	[illegible]	[illegible]	[illegible]
18.37	[illegible]	[illegible]	[illegible]	[illegible]
20.37	[illegible]	[illegible]	[illegible]	[illegible]
22.37	[illegible]	[illegible]	[illegible]	[illegible]
24.37	[illegible]	[illegible]	[illegible]	[illegible]
26.37	[illegible]	[illegible]	[illegible]	[illegible]
28.37	[illegible]	[illegible]	[illegible]	[illegible]
30.37	[illegible]	[illegible]	[illegible]	[illegible]
32.37	[illegible]	[illegible]	[illegible]	[illegible]
34.37	[illegible]	[illegible]	[illegible]	[illegible]
36.37	[illegible]	[illegible]	[illegible]	[illegible]
38.37	[illegible]	[illegible]	[illegible]	[illegible]

DEL= 58.84 MM DSTR= 7.47 MM THETA= 5.13 MM
RDEL= 0.3792E+05 RDSTR= 0.4931E+04 RTTA= 0.3318E+04
SHAPE FACTOR= 1.45

STATION 4

U INF= 12.424 M/S
REX= 0.1481E+07 X= 2.219
T= 27.16 DEG.C RHO= 0.9660 KG/CU.M
MU= 0.1847E-04 KG/MS NU= 0.1912E-04 M*M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.51	3.435	0.092	0.2791	0.0096
0.99	[illegible]	0.180	0.3605	0.0188
1.49	5.187	0.271	0.4217	0.0279
1.99	5.578	0.362	0.4535	0.0373
2.69	6.057	0.489	0.4925	0.0509
3.69	6.577	0.671	0.5348	0.0698
4.69	6.947	0.852	0.5648	0.0887
5.69	[illegible]	1.034	0.6027	0.1077
6.69	[illegible]	1.216	0.6407	0.1266
7.69	[illegible]	1.397	0.6684	0.1455
8.69	8.303	1.579	0.6913	0.1644
10.19	8.743	1.852	0.7271	0.1911
11.69	9.335	2.124	0.7656	0.2193
13.69	9.780	2.488	0.7936	0.2568
15.69	10.183	2.851	0.8283	0.2943
18.69	10.592	3.396	0.8533	0.3506
22.69	10.994	4.123	0.8857	0.4256
27.69	11.232	5.032	0.9132	0.5194
32.69	11.523	5.940	0.9368	0.6132
38.69	11.749	7.031	0.9552	0.7258

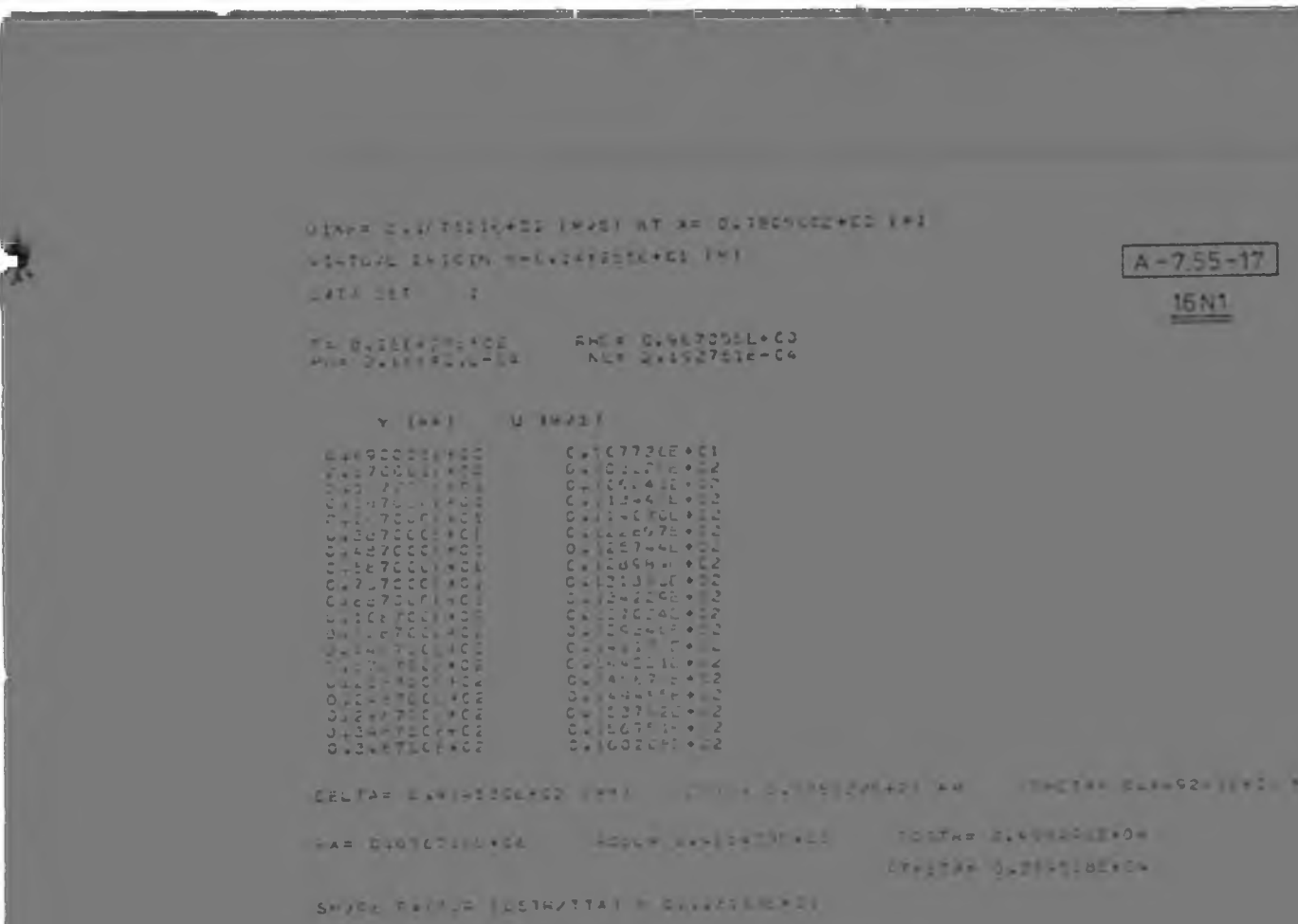
DEL= 53.31 MM DSTR= 8.28 MM THETA= 5.50 MM
RDEL= 0.3463E+05 RDSTR= 0.5381E+04 RTTA= 0.3575E+04
SHAPE FACTOR= 1.51

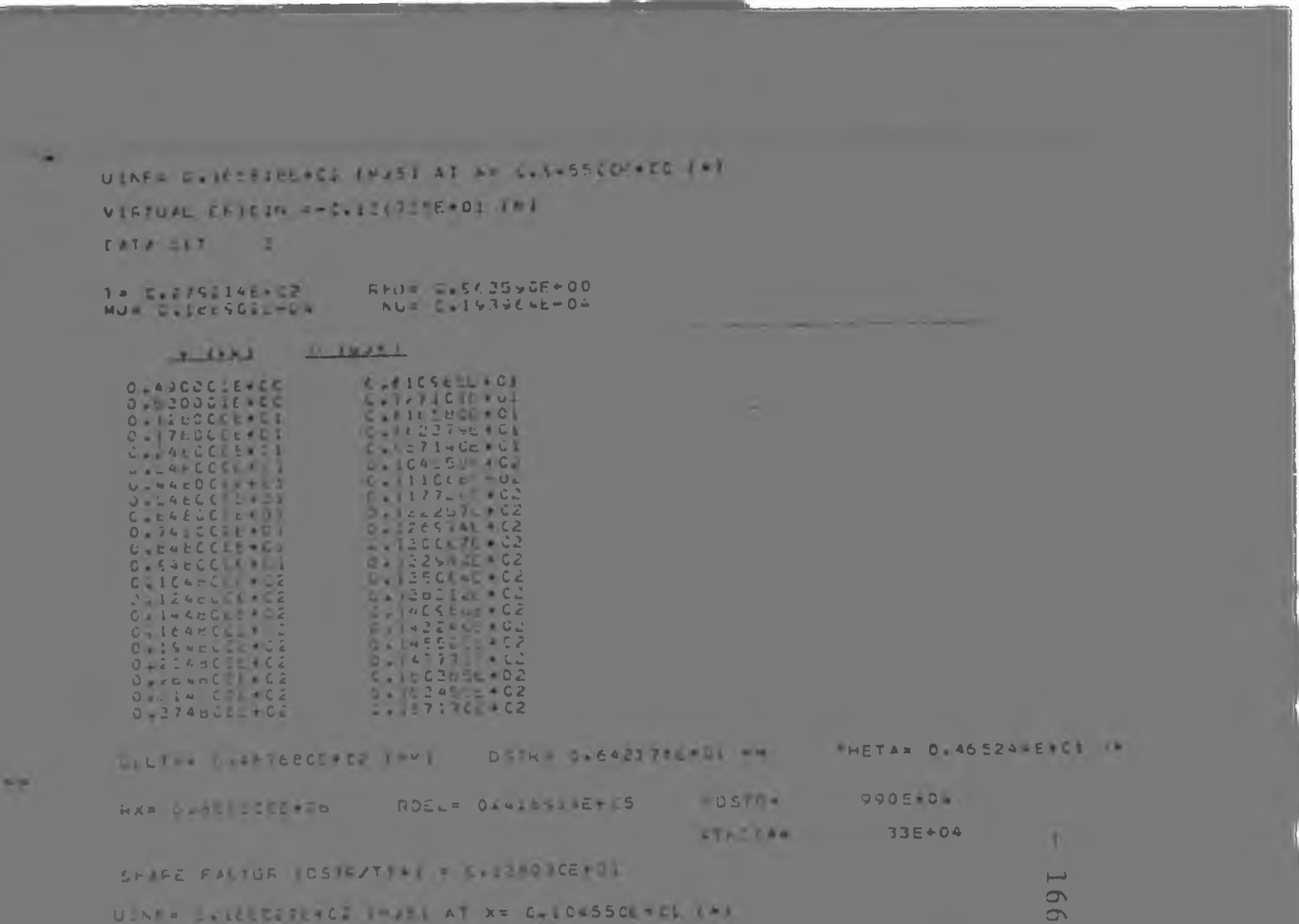
C-12,22-13

11N2

A-7.55-17

16N1





CURVE) FIT: LOG(FO)= 0.1192E+00*LOG(Y/D1)-0.9503E-02

E-7.27-17

23N1

50% Blocked

UINF= 16.685 M/S
REX= [illegible]E+07 X= 2.424
T= 24.73 DEG.C RHO= 0.9752 KG/CU.M
MU= 0.1832E-04 KG/MS NU= 0.1877E-04 M**M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
[illegible]	[illegible]	0.132	[illegible]	[illegible]
1.00	[illegible]	0.265	0.4205	[illegible]
1.50	[illegible]	[illegible]	0.4618	[illegible]
2.00	[illegible]	0.530	0.6831	0.0382
2.50	[illegible]	0.663	0.7089	0.0573
3.00	[illegible]	[illegible]	0.7345	0.0764
4.00	[illegible]	[illegible]	0.7513	0.1055
5.00	[illegible]	1.326	0.7662	0.1146
6.00	[illegible]	1.591	0.7844	0.1432
7.50	[illegible]	1.989	0.7989	0.1719
9.00	[illegible]	2.387	0.8131	0.2101
11.00	[illegible]	2.918	0.8313	0.2484
13.00	[illegible]	3.448	0.8412	0.2865
15.00	[illegible]	3.979	0.8518	0.3438
18.00	[illegible]	4.775	0.8661	0.4212
21.00	[illegible]	5.571	0.8801	0.5157
27.00	[illegible]	6.958	0.9017	0.6112
33.00	[illegible]	7.787	0.9518	0.7258

DEL= [illegible] MM DSTR= 6.26 MM THETA= 4.88 MM
RDEL= [illegible]E+05 RDSTR= 0.5564E+04 RTTA= 0.4198E+04
SHAPE FACTOR,H= 1.28
POWER LAW, N= 7.68

STATION 2

UINF= 16.647 M/S
REX= 0.2242E+07 X= 2.500
T= 24.83 DEG.C RHO= 0.9740 KG/CU.M
MU= 0.1834E-04 KG/MS NU= 0.1882E-04 M**M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.52	7.[illegible]	[illegible]	0.4266	0.0102
[illegible]	7.[illegible]	[illegible]	0.4797	0.0167
1.22	[illegible]	[illegible]	0.5284	0.0249
1.72	9.617	0.352	0.5714	0.0351
2.32	10.135	0.488	0.6150	0.0477
3.22	11.179	0.699	0.6783	0.0677
4.32	11.921	0.933	0.7221	0.0881
5.32	12.364	1.119	0.7512	0.1085
6.32	12.728	1.330	0.7722	0.1289
7.32	13.064	1.539	0.7865	0.1493
8.82	13.372	1.854	0.8053	0.1799
10.32	13.687	2.170	0.8183	0.2105
12.32	13.778	2.590	0.8337	0.2513
14.32	13.994	3.010	0.8482	0.2921
16.82	14.212	3.538	0.8623	0.3431
19.32	14.448	4.062	0.8784	0.3941
23.32	14.717	4.902	0.8923	0.4553
27.32	15.037	5.743	0.9124	0.5572
33.32	15.423	7.005	0.9358	0.6796
39.32	15.827	8.266	0.9603	0.8020

DEL= 49.[illegible] MM DSTR= 6.35 MM THETA= 4.76 MM
RDEL= [illegible]E+05 RDSTR= 0.5615E+04 RTTA= 0.4209E+04
SHAPE FACTOR,H= 1.33

STATION 3

UINF= 16.963 M/S
REX= [illegible]E+07 X= 2.589
T= 24.73 DEG.C RHO= 0.9739 KG/CU.M
MU= 0.1836E-04 KG/MS NU= 0.1885E-04 M**M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.50	5.993	0.095	0.3573	0.0069
[illegible]	[illegible]	0.151	[illegible]	0.0159
1.19	7.[illegible]	[illegible]	0.4291	0.0276
1.79	8.112	0.341	0.4835	0.0448
2.39	8.722	0.456	0.5200	0.0656
3.09	9.406	0.589	0.5608	0.0907
4.09	[illegible]	0.780	0.6111	0.0777
5.09	[illegible]	0.971	0.6589	0.2967
6.09	[illegible]	1.161	0.6872	0.1157
7.09	[illegible]	1.352	0.7331	0.1347
8.59	[illegible]	1.638	0.7809	0.1631
10.09	[illegible]	1.924	0.7865	0.1916
12.09	[illegible]	2.305	0.8126	0.2296
14.[illegible]	[illegible]	2.687	0.8345	0.2678
17.09	14.[illegible]	3.259	0.8555	0.3240
21.09	14.753	4.022	0.8796	0.4004
26.09	15.138	4.975	0.9026	0.4955
32.09	15.573	6.119	0.9285	0.6095
38.09	16.023	7.263	0.9494	0.7234

DEL= 50.[illegible] MM DSTR= 7.42 MM THETA= 5.24 MM
RDEL= [illegible]E+05 RDSTR= 0.6672E+04 RTTA= 0.4713E+04
SHAPE FACTOR,H= 1.42
POWER LAW, N= 8.81

STATION 4

UINF= 17.356 M/S
REX= [illegible]E+07 X= 2.689
T= 24.95 DEG.C RHO= 0.9732 KG/CU.M
MU= 0.1837E-04 KG/MS NU= 0.1887E-04 M**M/S

Y(MM)	U (M/S)	Y/THETA	U/UE	Y/DEL
0.50	5.444	0.090	0.3169	0.0098
[illegible]	[illegible]	0.161	0.3728	0.0174
1.29	7.[illegible]	0.233	0.4099	0.0252
1.89	7.495	0.335	0.4362	0.0330
2.19	7.992	0.336	0.4651	0.0427
2.89	8.655	0.522	0.5037	0.0564
3.89	9.299	0.667	0.5412	0.0720
4.89	9.845	0.847	0.5709	0.0915
5.89	10.502	1.028	0.6112	0.1110
7.89	11.[illegible]	1.208	0.6443	0.1306
7.89	11.665	1.389	0.6789	0.1501
9.19	12.241	1.650	0.7182	0.1793
10.89	12.856	1.931	0.7482	0.2086
12.89	13.479	2.292	0.7845	0.2477
14.89	14.[illegible]	2.653	0.8140	0.2867
15.89	14.[illegible]	3.015	0.8396	0.3257
19.89	14.847	3.556	0.8641	0.3843
23.89	15.304	4.279	0.8907	0.4623
28.89	15.666	5.182	0.9117	0.5599
33.89	15.904	6.085	0.9309	0.6575
38.69	16.132	6.988	0.9505	0.7551

DEL= 51.24 MM DSTR= 8.22 MM THETA= 5.54 MM
RDEL= [illegible]E+05 RDSTR= 0.7558E+04 RTTA= 0.5091E+04
SHAPE FACTOR,H= 1.48

CURVE FIT: LOG(F'D)= 3.1264E+00*LOG(Y/D)+-3.135ME-01

E-120-1"

23N2

50% Blocked

UINF= 16.450 M/S
REX= 0.2[illegible]E+07
T= 25.[illegible] DEG.C
MU= 0.18[illegible]E-04 KG/MS

X= 2.359
RHO= 0.9730 KG/CU.M
NU= 0.1888E-04 M*M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
[illegible]	[illegible]	[illegible]	[illegible]	0.[illegible]

CURVE 1 FIT: LOG(FD)= 0.1135E+00*LOG(Y/D)+-0.3739E-02

E-1451-17

24N1

50% Blocked

UINF= 15.578 M/S
REX= 0.1688E+07
T= 26.70 DEG.C
MU= 0.1846E-04 KG/MS

X= 2.062
RHO= 0.9574 KG/CU.M
NU= 0.1908E-04 M*M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.52	8.806	0.519	0.5713	0.0106
0.79	9.645	0.197	0.6257	0.0175
1.09	10.206	0.312	0.6623	0.0277
1.36	10.763	0.427	0.6972	0.0379
1.86	10.983	0.579	0.7125	0.0479
2.36	11.281	0.656	0.7315	0.0583
2.86	11.526	0.770	0.7462	0.0685
3.36	11.636	1.000	0.7574	0.0889
4.36	12.077	1.299	0.7829	0.1093
5.36	12.283	1.453	0.7964	0.1296
6.36	12.530	1.852	0.8125	0.1602
7.86	12.722	2.146	0.8249	0.1908
9.36	12.955	2.605	0.8400	0.2316
11.36	13.223	3.293	0.8574	0.2927
14.36	13.476	3.981	0.8738	0.3539
17.36	13.815	4.809	0.8955	0.4354
21.36	14.132	6.044	0.9163	0.5373
26.36	14.516	7.420	0.9412	0.6594
32.36	14.850	9.255	0.9694	0.8227

DEL= 44.95 MM DSTR= 5.54 MM THETA= 4.36 MM
RDEL= 0.3766E+05 RDSTR= 0.4529E+04 RTTA= 0.3561E+04
SHAPE FACTOR,H= 1.27
POWER LAW, N= 7.37

STATION 2

UINF= 15.139 M/S
REX= 0.1698E+07
T= 26.89 DEG.C
MU= 0.1846E-04 KG/MS

X= 2.138
RHO= 0.9559 KG/CU.M
NU= 0.1909E-04 M*M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.52	4.628	0.102	0.3093	0.0101
0.79	5.369	0.154	0.3584	0.0153
1.09	5.985	0.213	0.3995	0.0211
1.59	6.701	0.311	0.4540	0.0307
2.09	7.525	0.408	0.5024	0.0404
2.69	8.276	0.525	0.5525	0.0520
3.29	9.005	0.643	0.6014	0.0636
4.29	9.994	0.838	0.6672	0.0830
5.29	10.733	1.033	0.7165	0.1023
6.29	11.198	1.229	0.7475	0.1216
7.29	11.547	1.424	0.7709	0.1410
8.29	11.755	1.619	0.7848	0.1603
9.79	11.964	1.912	0.7987	0.1893
11.29	12.163	2.205	0.8123	0.2183
13.29	12.391	2.596	0.8272	0.2570
15.29	12.594	3.182	0.8475	0.3150
19.29	12.972	3.768	0.8663	0.3730
22.29	13.215	4.354	0.8823	0.4310
28.29	13.605	5.526	0.9083	0.5470
34.29	14.032	6.608	0.9368	0.6631
40.29	14.356	7.870	0.9585	0.7791

DEL= 51.71 MM DSTR= 7.20 MM THETA= 5.12 MM
RDEL= 0.4096E+05 RDSTR= 0.5705E+04 RTTA= 0.4056E+04
SHAPE FACTOR,H= 1.41
POWER LAW, N= 4.92

STATION 3

UINF= 15.404 M/S
REX= 0.1795E+07
T= 27.01 DEG.C
MU= 0.1847E-04 KG/MS

X= 2.227
RHO= 0.9555 KG/CU.M
NU= 0.1911E-04 M*M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.52	2.562	0.092	0.1680	0.0099
0.88	3.462	0.155	0.2270	0.0167
1.38	4.330	0.243	0.2839	0.0262
1.88	4.978	0.332	0.3265	0.0357
2.38	5.491	0.420	0.3601	0.0452
3.18	6.203	0.561	0.4068	0.0605
4.18	7.023	0.737	0.4605	0.0795
5.18	7.810	0.914	0.5121	0.0985
6.18	8.567	1.090	0.5615	0.1175
7.18	9.234	1.267	0.6055	0.1365
8.18	9.844	1.443	0.6455	0.1555
9.18	10.438	1.619	0.6844	0.1745
10.18	10.954	1.796	0.7184	0.1935
11.18	11.396	1.972	0.7473	0.2125
12.68	11.949	2.237	0.7835	0.2411
14.18	12.336	2.501	0.8089	0.2696
16.18	12.760	2.854	0.8361	0.3076
19.18	13.182	3.383	0.8644	0.3646
23.18	13.432	4.089	0.8809	0.4407
28.18	13.782	4.971	0.9019	0.5357
33.18	14.058	5.853	0.9219	0.6308
39.18	14.426	6.911	0.9460	0.7448

DEL= 52.60 MM DSTR= 9.86 MM THETA= 5.67 MM
RDEL= 0.4240E+05 RDSTR= 0.7855E+04 RTTA= 0.4570E+04
SHAPE FACTOR,H= 1.63
POWER LAW, N= 3.18

STATION 1

UINF= 15.123 M/S
REX= 0.1951E+07
T= 27.24 DEG.C
MU= 0.1848E-04 KG/MS

X= 2.327
RHO= 0.9553 KG CU.M
NU= 0.1913E-04 M*M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.51	2.735	0.092	0.1714	0.0097
0.78	3.299	0.126	0.2067	0.0149
1.28	4.104	0.207	0.2571	0.0244
1.88	4.745	0.304	0.2973	0.0359
2.68	5.433	0.433	0.3404	0.0511
3.68	6.116	0.595	0.3831	0.0702
4.68	6.797	0.757	0.4259	0.0893
5.68	7.423	0.918	0.4651	0.1084
6.68	7.966	1.080	0.4990	0.1275
8.18	8.801	1.323	0.5514	0.1561
9.68	9.420	1.565	0.5902	0.1847
11.68	10.425	1.888	0.6531	0.2229
13.68	11.224	2.212	0.7032	0.2611
15.68	11.846	2.535	0.7547	0.2992
18.68	12.933	3.020	0.8103	0.3565
21.68	13.506	3.505	0.8461	0.4138
24.68	14.044	3.990	0.8799	0.4710
29.68	14.492	4.799	0.9079	0.5664
34.68	14.840	5.607	0.9297	0.6619
39.68	15.156	6.415	0.9496	0.7573

DEL= 52.40 MM DSTR= 10.79 MM THETA= 6.19 MM
RDEL= 0.4415E+05 RDSTR= 0.9093E+04 RTTA= 0.5212E+04
SHAPE FACTOR,H= 1.74

E-904-17

28N1

57% Blocked

CURVE 1 FITS LOG(FD)= 0.1[illegible]*LOG(Y/DIA-0.6[illegible]

UINF= 14.633 M/S
REX= 0.1[illegible]
T= 27.0 DEG.C
MU= 0.1[illegible]

X= 2.129
RHO= 0.0647 KG/CU.M
NU= 0.1[illegible] M**M/S

Y(MM)	U (M/S)	Y/THETA	U/UF	Y/DEL
0.62	6.[illegible]	0.[illegible]	0.5662	0.0[illegible]
0.70	6.[illegible]	0.[illegible]	0.6[illegible]	0.0[illegible]
1.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
1.75	[illegible]	0.[illegible]	0.6[illegible]	0.[illegible]
2.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
2.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
3.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
3.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
4.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
4.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
5.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
5.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
6.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
6.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
7.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
7.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
8.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
8.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
9.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
9.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
10.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
10.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
11.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
11.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
12.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
12.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
13.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
13.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
14.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
14.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
15.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
15.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
16.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
16.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
17.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
17.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
18.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
18.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
19.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
19.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
20.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
20.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
21.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
21.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
22.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
22.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
23.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
23.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
24.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
24.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
25.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
25.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
26.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
26.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
27.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
27.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
28.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
28.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
29.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
29.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
30.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
30.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
31.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
31.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
32.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
32.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
33.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
33.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
34.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
34.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
35.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
35.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
36.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
36.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
37.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
37.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
38.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
38.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
39.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
39.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
40.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
40.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
41.26	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
41.76	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]

DEL= [illegible] MM DSTR= 6.70 MM THETA= 4.16 MM
RDEL= [illegible] RDSTR= 0.5[illegible]E+04 RTTA= 0.42[illegible]E+04
SHAPE FACTOR,H= 1.[illegible]
POWER LAW, N= 5.26

STATION 2

UINF= 14.[illegible] M/S
REX= 0.1[illegible]
T= 27.4[illegible] DEG.C
MU= 0.1[illegible] KG/MS

X= 2.265
RHO= [illegible] KG/CU.M
NU= 0.1[illegible] M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UF	Y/DEL
0.[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
0.[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
1.[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
1.[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
2.[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]

DEL= [illegible] MM DSTR= 6.70 MM THETA= 4.16 MM
RDEL= [illegible] RDSTR= 0.5[illegible]E+04 RTTA= 0.42[illegible]E+04
SHAPE FACTOR,H= 1.[illegible]
POWER LAW, N= 5.26

STATION 3

UINF= 14.[illegible] M/S
REX= 0.1[illegible]
T= 27.[illegible] DEG.C
MU= 0.1[illegible] KG/MS

X= 2.[illegible]
RHO= 0.0[illegible] KG/CU.M
NU= 0.1[illegible] M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UF	Y/DEL
0.[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
0.[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
1.[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
1.[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
2.[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.[illegible]

DEL= [illegible] MM DSTR= 7.59 MM THETA= 5.20 MM
RDEL= 0.4[illegible]E+05 RDSTR= 0.6588E+04 RTTA= 0.4512E+04
SHAPE FACTOR,H= 1.46
POWER LAW, N= 8.75

STATION 4

UINF= 13.[illegible] M/S
REX= 0.2[illegible]
T= 27.[illegible] DEG.C
MU= 0.1[illegible] KG/MS

X= 2.794
RHO= 0.0639 KG/CU.M
NU= 0.1[illegible] M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UF	Y/DEL
0.62	4.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
0.62	5.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
1.[illegible]	6.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
1.[illegible]	7.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
2.62	7.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
3.62	8.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
4.62	8.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
5.62	9.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
6.62	[illegible]	1.[illegible]	0.[illegible]	0.[illegible]
7.62	[illegible]	1.[illegible]	0.[illegible]	0.[illegible]
8.62	[illegible]	1.[illegible]	0.[illegible]	0.[illegible]
10.62	[illegible]	1.[illegible]	0.[illegible]	0.[illegible]
12.62	[illegible]	2.[illegible]	0.[illegible]	0.[illegible]
14.62	[illegible]	2.[illegible]	0.[illegible]	0.[illegible]
16.62	[illegible]	2.[illegible]	0.[illegible]	0.[illegible]
18.62	[illegible]	3.[illegible]	0.[illegible]	0.[illegible]
20.62	[illegible]	3.[illegible]	0.[illegible]	0.[illegible]
22.62	[illegible]	4.[illegible]	0.[illegible]	0.[illegible]
24.62	[illegible]	4.[illegible]	0.[illegible]	0.[illegible]
26.62	[illegible]	5.[illegible]	0.[illegible]	0.[illegible]
28.62	[illegible]	5.[illegible]	0.[illegible]	0.[illegible]
30.62	[illegible]	6.[illegible]	0.[illegible]	0.[illegible]
32.62	[illegible]	6.[illegible]	0.[illegible]	0.[illegible]
34.62	[illegible]	6.[illegible]	0.[illegible]	0.[illegible]
36.62	[illegible]	7.[illegible]	0.[illegible]	0.[illegible]
38.62	[illegible]	7.[illegible]	0.[illegible]	0.[illegible]
40.62	[illegible]	7.[illegible]	0.[illegible]	0.[illegible]
42.62	[illegible]	8.[illegible]	0.[illegible]	0.[illegible]

DEL= [illegible] MM DSTR= 8.01 MM THETA= 5.88 MM
RDEL= 0.4[illegible]E+05 RDSTR= 0.75[illegible]E+04 RTTA= 0.51[illegible]E+04
SHAPE FACTOR,H= 1.53
POWER LAW, N= 9.76

CURVE 1 FIT LOG(FD)= 0.1200E+00*LOG(Y/D)+-0.5631E-02

E-11,77-17

29N1

67% Blocked

UINF= 16.000 M/S
REX= 0.1893E+07
T= 20.90 DEG.C
MU= 0.1842E-04 KG/MS

X= 2.154
RHO= 0.9699 KG/CU.M
NU= 0.1899E-04 M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.00	0.000	0.000	0.0000	0.0000
0.50	0.175	0.112	0.0587	0.0183
1.00	0.535	0.193	0.1779	0.0316
1.50	1.721	0.262	0.4227	0.0429
2.00	3.143	0.324	0.6784	0.0531
2.50	4.418	0.380	0.8982	0.0624
3.00	5.509	0.433	1.0870	0.0718
3.50	6.486	0.483	1.2553	0.0792
4.00	7.443	0.533	1.4277	0.0868
4.50	8.324	0.582	1.5796	0.0954
5.00	9.124	0.632	1.7187	0.1034
5.50	9.845	0.683	1.8503	0.1112
6.00	10.475	0.733	1.9682	0.1212
6.50	11.079	0.784	2.0847	0.1324
7.00	11.579	0.836	2.1826	0.1435
7.50	12.021	0.887	2.2673	0.1535
8.00	12.423	0.939	2.3429	0.1637
8.50	12.784	0.991	2.4107	0.1741
9.00	13.085	1.042	2.4676	0.1844
9.50	13.375	1.093	2.5227	0.1945
10.00	13.629	1.145	2.5707	0.2048
10.50	13.879	1.196	2.6179	0.2150
11.00	14.121	1.248	2.6635	0.2253
11.50	14.342	1.299	2.7053	0.2357
12.00	14.539	1.350	2.7423	0.2460
12.50	14.727	1.402	2.7778	0.2564
13.00	14.877	1.453	2.8062	0.2667
13.50	15.038	1.504	2.8366	0.2769
14.00	15.213	1.556	2.8697	0.2873
14.50	15.376	1.607	2.9004	0.2976
15.00	15.516	1.659	2.9268	0.3080
15.50	15.647	1.710	2.9515	0.3183
DEL= 5.87 MM		DSTR= 2.72 MM		THETA= 0.46 MM
RDEL= 0.6432E+05		RDSTR= 0.2997E+04		RTTA= 0.3892E+04
SHAPE FACTOR,H= 1.28				
POWER LAW, N= 7.05				

STATION 2

UINF= 16.758 M/S
REX= 0.1947E+07
T= 20.83 DEG.C
MU= 0.1847E-04 KG/MS

X= 2.240
RHO= 0.9694 KG/CU.M
NU= 0.1906E-04 M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.00	0.000	0.000	0.0000	0.0000
0.50	5.546	0.106	0.3375	0.0101
0.90	6.592	0.183	0.4010	0.0174
1.40	7.345	0.267	0.4470	0.0254
1.90	8.228	0.376	0.5007	0.0355
2.40	9.206	0.524	0.5602	0.0497
2.90	10.166	0.735	0.6186	0.0699
3.40	11.201	0.947	0.6815	0.0901
3.90	11.971	1.159	0.7285	0.1102
4.40	12.650	1.371	0.7699	0.1304
4.90	12.739	1.584	0.7753	0.1506
5.40	13.133	1.796	0.7992	0.1708
5.90	13.434	2.008	0.8176	0.1910
6.40	13.705	2.221	0.8341	0.2112
6.90	14.062	2.445	0.8558	0.2316
7.40	14.300	2.682	0.8703	0.3122
7.90	14.479	3.919	0.8812	0.3727
8.40	14.708	4.708	0.8954	0.4505
8.90	15.012	5.617	0.9138	0.5343
9.40	15.295	6.679	0.9309	0.6352
9.90	15.716	7.740	0.9564	0.7362
10.40	15.990	8.802	0.9731	0.8371
DEL= 49.53 MM		DSTR= 6.58 MM		THETA= 4.71 MM
RDEL= 0.4235E+05		RDSTR= 0.5749E+04		RTTA= 0.4113E+04
SHAPE FACTOR,H= 1.40				
POWER LAW, N= 5.03				

STATION 3

UINF= 17.131 M/S
REX= 0.2089E+07
T= 20.18 DEG.C
MU= 0.1843E-04 KG/MS

X= 2.319
RHO= 0.9692 KG/CU.M
NU= 0.1901E-04 M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.00	0.000	0.000	0.0000	0.0000
0.50	4.159	0.080	0.2470	0.0091
0.82	5.017	0.147	0.2958	0.0150
1.42	5.740	0.210	0.3381	0.0223
1.92	6.481	0.300	0.3821	0.0314
2.42	7.103	0.399	0.4184	0.0406
2.92	7.782	0.525	0.4571	0.0534
3.42	8.484	0.668	0.4992	0.0680
4.42	9.284	0.884	0.5467	0.0883
5.42	9.959	1.128	0.5872	0.1046
6.42	10.698	1.387	0.6267	0.1228
7.42	11.228	1.656	0.6620	0.1411
8.42	11.805	2.016	0.7126	0.1655
9.42	12.318	2.375	0.7593	0.2051
10.42	12.664	2.734	0.7967	0.2410
12.42	13.351	3.094	0.8482	0.3114
15.42	14.021	3.633	0.8888	0.3696
17.42	14.351	4.351	0.9043	0.4427
20.42	14.775	5.240	0.9157	0.5241
22.42	15.181	6.227	0.9356	0.6438
24.42	15.490	7.303	0.9582	0.7534
26.42	15.695	8.380	0.9712	0.8630
DEL= 54.71 MM		DSTR= 8.57 MM		THETA= 5.67 MM
RDEL= 0.4602E+05		RDSTR= 0.7722E+04		RTTA= 0.4768E+04
SHAPE FACTOR,H= 1.54				
POWER LAW, N= 3.71				

STATION 4

UINF= 17.493 M/S
REX= .2217E+07
T= 20.82 DEG.C
MU= 0.1846E-04 KG/MS

X= 2.419
RHO= 0.9671 KG/CU.M
NU= 0.1909E-04 M**M/S

Y(MM)	U (M/S)	Y/TTA	U/UE	Y/DEL
0.00	4.159	0.085	0.2418	0.0095
0.70	4.866	0.128	0.2830	0.0144
1.20	5.628	0.211	0.3250	0.0239
1.70	6.509	0.331	0.3759	0.0371
2.20	7.172	0.467	0.4141	0.0523
2.70	8.067	0.636	0.4658	0.0712
3.20	8.699	0.805	0.5023	0.0901
3.70	9.648	1.058	0.5569	0.1185
4.20	10.488	1.312	0.6056	0.1469
4.70	11.174	1.565	0.6453	0.1753
5.20	11.731	1.903	0.7005	0.2132
5.70	12.257	2.411	0.7655	0.2700
6.20	12.754	2.918	0.8173	0.3268
6.70	13.159	3.425	0.8523	0.3836
7.20	13.438	4.270	0.8915	0.4782
7.70	13.661	5.115	0.9159	0.5729
8.20	13.833	5.961	0.9374	0.6675
8.70	13.942	6.806	0.9552	0.7622
DEL= 52.82 MM		DSTR= 8.51 MM		THETA= 5.92 MM
RDEL= 0.4841E+05		RDSTR= 0.8713E+04		RTTA= 0.5422E+04
SHAPE FACTOR,H= 1.61				
POWER LAW, N= 3.30				

E-8.56-17

30°

80% Blocked

E-11.66-17

0101

80% Blocked

STATION 1

UINF= 18.533 M/S
REX= 0.2766E+ 7 X= 0.714
T= 23.14 DEG.C RHO= 0.9791 KG/CU.M
MU= 0.1852E-04 KG/MS NU= 0.1867E-04 M**2/S

Y(MM)	U (M/S)	Y/THTA	U/UE	Y/DEL
0.63	5.386	0.710	0.2906	0.0267
0.83	6.017	0.937	0.3246	0.0352
1.03	6.744	1.235	0.3639	0.0443
1.43	7.651	1.634	0.4129	0.0614
2.03	8.900	2.231	0.4803	0.0870
3.03	10.869	3.228	0.5865	0.1298
4.03	12.269	4.225	0.6620	0.1725
5.03	13.127	5.222	0.7083	0.2152
6.03	13.807	6.219	0.7450	0.2579
7.03	14.311	7.216	0.7722	0.3006
8.03	14.736	8.213	0.7951	0.3433
11.03	15.747	11.202	0.8496	0.4716
13.03	16.147	13.196	0.8712	0.5569
16.03	16.677	16.190	0.8998	0.6853
23.03	17.446	23.178	0.9413	0.9853
28.03	17.762	28.167	0.9583	1.1993
34.03	17.972	34.157	0.9697	1.4560
40.03	17.597	40.147	0.9494	1.7127

DEL= 53.65 MM DSTR= 6.60 MM THETA= 5.65 MM
RDEL= 0.5271E+05 RDSTR= 0.3562E+04 RTTA= 0.3648E+04
SHAPE FACTOR,H= 1.50
POWER LAW, N= 3.86

STATION 2

UINF= 18.903 M/S
REX= 0.2766E+ 7 X= 2.515
T= 23.14 DEG.C RHO= 0.9791 KG/CU.M
MU= 0.1852E-04 KG/MS NU= 0.1867E-04 M**2/S

Y(MM)	U (M/S)	Y/THTA	U/UE	Y/DEL
0.50	5.768	0.698	0.3171	0.0194
0.70	6.605	0.965	0.3631	0.0271
1.10	8.134	1.496	0.4473	0.0421
1.50	9.345	2.027	0.5139	0.0572
2.10	10.804	2.824	0.5941	0.0813
3.10	12.507	4.152	0.6877	0.1204
4.10	13.664	5.480	0.7513	0.1596
5.10	14.511	6.807	0.7978	0.1987
6.10	15.134	8.135	0.8321	0.2378
9.10	16.350	12.117	0.8990	0.3528
11.10	16.880	14.780	0.9281	0.4319
14.10	17.374	18.762	0.9553	0.5486
19.10	17.678	25.417	0.9720	0.7431
25.10	17.479	33.399	0.9610	0.9764

DEL= 80.71 MM DSTR= 7.10 MM THETA= 5.11 MM
RDEL= 0.7932E+05 RDSTR= 0.7346E+04 RTTA= 0.5102E+04
SHAPE FACTOR,H= 1.41
POWER LAW, N= 4.03

STATION 4

UINF= 18.903 M/S
REX= 0.2766E+ 7 X= 3.714
T= 23.14 DEG.C RHO= 0.9788 KG/CU.M
MU= 0.1852E-04 KG/MS NU= 0.1868E-04 M**2/S

Y(MM)	U (M/S)	Y/THTA	U/UE	Y/DEL
0.63	5.386	0.710	0.2906	0.0267
0.83	6.017	0.937	0.3246	0.0352
1.23	6.744	1.235	0.3639	0.0443
1.63	7.651	1.634	0.4129	0.0614
2.23	8.900	2.231	0.4803	0.0870
3.23	10.869	3.228	0.5865	0.1298
4.23	12.269	4.225	0.6620	0.1725
5.23	13.127	5.222	0.7083	0.2152
6.23	13.807	6.219	0.7450	0.2579
7.23	14.311	7.216	0.7722	0.3006
8.23	14.736	8.213	0.7951	0.3433
11.23	15.747	11.202	0.8496	0.4716
13.23	16.147	13.196	0.8712	0.5569
16.23	16.677	16.190	0.8998	0.6853
23.23	17.446	23.178	0.9413	0.9853
28.23	17.762	28.167	0.9583	1.1993
34.23	17.972	34.157	0.9697	1.4560
40.23	17.597	40.147	0.9494	1.7127

DEL= 53.65 MM DSTR= 6.60 MM THETA= 5.65 MM
RDEL= 0.5271E+05 RDSTR= 0.3562E+04 RTTA= 0.3648E+04
SHAPE FACTOR,H= 1.50
POWER LAW, N= 3.86

Y(MM)	U (M/S)	Y/THTA	U/UE	Y/DEL
1.61	3.[illegible]	0.[illegible]	0.2[illegible]	0.[illegible]
3.05	4.027	0.[illegible]	0.2[illegible]	0.0152
1.75	5.051	0.[illegible]	0.2[illegible]	0.[illegible]
4.05	6.733	0.917	0.3[illegible]	0.[illegible]
2.55	7.776	0.[illegible]	0.[illegible]	0.[illegible]
3.55	8.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
4.55	8.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
5.55	9.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
6.55	10.351	1.[illegible]	0.[illegible]	0.[illegible]
7.55	10.[illegible]	1.[illegible]	0.[illegible]	0.[illegible]
9.55	11.[illegible]	1.[illegible]	0.[illegible]	0.[illegible]
10.55	12.567	1.717	0.6715	0.[illegible]
12.55	13.416	2.[illegible]	0.[illegible]	0.[illegible]
14.55	14.213	2.[illegible]	0.[illegible]	0.[illegible]
17.55	15.151	2.[illegible]	0.[illegible]	0.[illegible]
21.55	16.[illegible]	3.[illegible]	0.[illegible]	0.[illegible]
24.55	16.[illegible]	3.[illegible]	0.[illegible]	0.[illegible]
30.55	17.[illegible]	4.[illegible]	0.[illegible]	0.[illegible]
34.55	17.[illegible]	5.[illegible]	0.[illegible]	0.[illegible]
40.55	17.76[illegible]	5.503	0.9495	0.7262

DEL= 55.02 MM DSTR= 5.01 MM THETA= 5.15 MM
RDEL= 0.5659E+05 RDSTR= 0.1300E+05 RTTA= 0.6319E+04
SHAPE FACTOR,H= 1.62
POWER LAW, N= 3.22

APPENDIX E

E1 Accuracy of Experimental Equipment

Table E1.1 lists the equipment used, and the errors involved.

TABLE E1.1

INSTRUMENT, MAKE & MODEL	ACCURACY OR ERROR
Cambridge potentiometer, type 44228	± 0,01 millivolt
Doric DVM, type DS-100	± 0,001 volt
Riken Denshi X-Y Recorder, type F-3D	Within ± 0,3%
Positioning of hot-wire	± 0,5 mm
Water U-tubes	± 0,4 mm H_2O
Van Essen manometer, model 6750	± 0,002" H_2O
Fortin barometer	± 0,001 mm Hg
Disa anemometer, type 55D01	Output read on DVM
Disa lineariser, type 55D10	Output read on DVM
Disa RMS voltmeter type 55D35	Output read on DVM
Disa Auxilliary Unit, type 55D25	Output read on DVM
Hewlett-Packard Spectrum analyser, type 3580 A	Output plotted by the X-Y recorder

TABLE E1.1 (cont.)

INSTRUMENT, MAKE & MODEL	ACCURACY OR ERROR
Hewlett-Packard Log Voltmeter/ Converter, type 7562	Output plotted by the X-Y recorder
Tektronix oscilloscope model with Polaroid camera	-

The values presented in Table E1.1 are the maximum errors expected.

When using the Van Essen manometer with the nozzle unit of the hot-wire calibration rig, the error in velocity may be estimated from :-

$$\frac{dV}{V} = \frac{1}{2}\left(\frac{dh}{h} - \frac{\delta\rho}{\rho}\right) \qquad \ldots\ldots\ldots [E1.1]$$

Assuming no error in ρ,

V(m/s)	h("H_2O)	% error
2,2	0,01	10
5,0	0,05	2
16,0	0,50	0,2

Clearly, the expected error at low velocities is very large. A linear regression analysis was used to fit a curve to the calibration values, and an error of 0,1 m/s was typical.

The error in measuring the transpiration flow rate was estimated as follows (using an ordinary water manometer) :-

Basic error for orifice plate : 2,3% (BS 1042)

$$\frac{dQ}{Q} = \tfrac{1}{2}\left[\frac{dh}{h} + \frac{dv_1}{v_1} + \frac{dT}{T}\right] + 2\frac{dl}{d} \qquad \text{..... [E1.2]}$$

$$\frac{dQ}{Q} = \tfrac{1}{2}\left[\frac{0,5}{20} + \frac{0,5}{8534} + (0,01 + 0,004)\right] + 2\frac{0,01}{38}$$

$$\frac{dQ}{Q} = 2\% + \text{basic error}$$

$$\frac{dQ}{Q} = 4,3\%$$

As v_w was directly proportional to Q,

$$\frac{dv_w}{v_w} = 4,3\%$$

This could be even greater if an error had been made in calculating the surface area of the porous plate, However, as h increased, the large term, dh/h, in E1.2 decreased.

In measuring the power spectrum, the emphasis was on the shape of the curve, and the occurrence of any peaks. The exact frequency and power of these peaks was not required to be known, and therefore an error analysis was not attempted for these measurements.

The main stream velocities measured with the anemometer did not drop below 5 m/s, which was within 2% and considered acceptable.

APPENDIX F

F1 Some Details Pertaining to the Programme

F1.1 The pressure gradient term

A pressure gradient would clearly alter the main stream velocity, and therefore u_e, β and p^+. It would, however, also affect the ξ grid spacing, even if constant x spacing was used in the physical plane. As a preliminary test, a constant pressure gradient was assumed. It was thought that the small increase in U_∞ caused by the growth of the boundary layer in an enclosed flow situation could be fitted with a straight line.

Then $$du_e/dx = c \qquad \ldots\ldots\ldots [F1.1]$$

This changes the x-axis transformation :

$$\int_0^{\xi} d\xi = \mu\rho \int_0^{\bar{x}} (xo + u_{e_o})\, dx \qquad \ldots\ldots\ldots [F1.2]$$

For condition [F1.1],

$$\beta = 1 - \left(\frac{u_{e_o}}{u_e}\right), \qquad \ldots\ldots\ldots [F1.3]$$

where $u_{e_o} = 0{,}99 \times U_o$

With injection, assumption [F1.1] proved inadequate.

F1.2 Numerical Integration

Certain quantities were obtained by integrating. δ^* was obtained as follows.

$$\delta^* = -\left(\frac{2\xi}{\rho u_e}\right)^{\frac{1}{2}} \int_0^{\eta_\infty} \phi'(\xi,\eta)\, d\eta$$

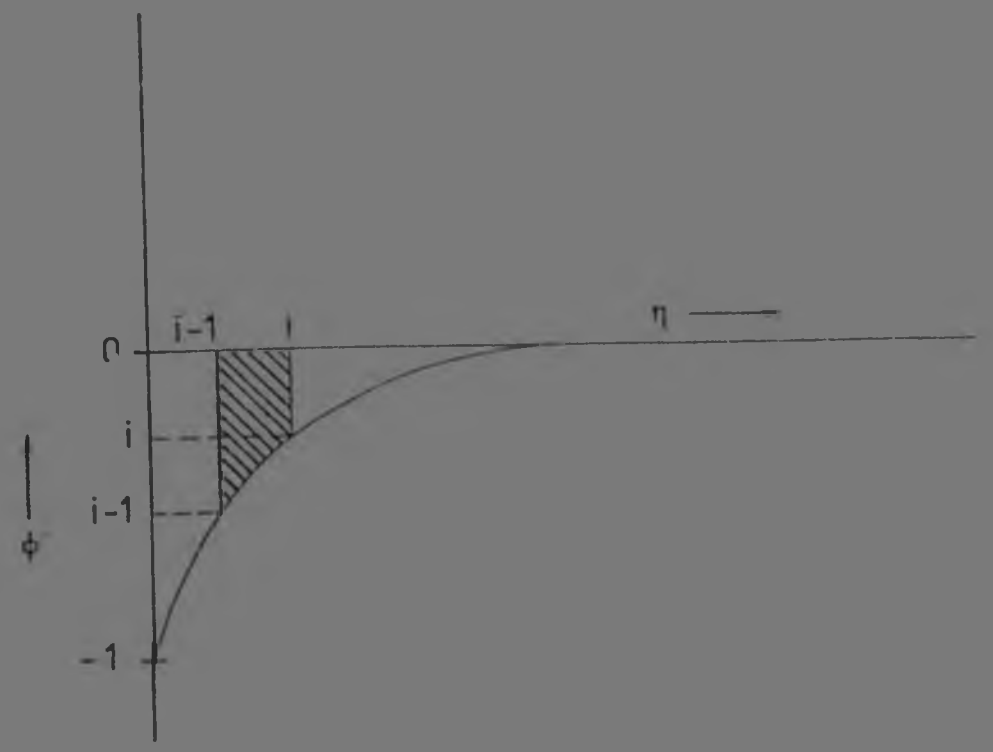


FIG F1.1 : SKETCH SHOWING TRAPEZOIDAL RULE

$$\text{Integral} = \sum_{i=2}^{N} (\phi'_i + \phi_{i-1}) \times (\eta_i - \eta_{i-1}) \times \tfrac{1}{2} \quad \ldots \quad [F1.4]$$

F2 Initial Computer Runs

A few trial runs were attempted without transpiration. A laminar profile was generated near the point of transition, assumed to occur at $Re_x = 3{,}2 \times 10^5$. From this point $\varepsilon^+ \neq 0$, and the programme marched into the transition region. The result obtained is shown in Fig F2.1. The uninjected laminar boundary layer with a small, linear pressure gradient ($du/dx = 10^{1/5}$) was attempted next. The profiles, shown in Fig F2.2, varied slightly from the first profile in Fig F2.1 (laminar, zero pressure gradient). Finally, a series of turbulent profiles were generated by the programme, starting at $Re_x = 3{,}24 \times 10^5$ with fully turbulent profiles. Values of c_f were not in satisfactory agreement with theory, thus the forward difference equation for ϕ_w'' was altered.

TABLE F2.1 Results of Initial Computer Runs

x (m)	ξ x 10^4	A^+	Re_xx10^{-5}	Re_θ	θ (mm)	H	δ (mm)	c_fx10^3
MHKTRANS L-0-10 (x_{trip} = 0,591 m)								
0,588	1,0578	26,0	3,185	330	0,609	2,56	5,04	1,41
0,597	1,0740	26,0	3,233	328	0,606	2,15	5,08	2,35
0,606	1,0902	26,0	3,232	333	0,616	1,90	5,23	4,18
0,615	1,1064	26,0	3,331	343	0,633	1,81	5,63	4,46
MHKPUX10 L-0-10								
0,076	0,1420	28,99	0,443	125	0,214	2,48	1,85	4,23
0,085	0,1595	29,27	0,500	132	0,224	2,47	1,96	4,01
0,094	0,1771	29,43	0,557	138	0,233	2,47	2,05	3,87
0,103	0,1949	29,55	0,616	144	0,242	2,45	2,13	3,75
MHKFLOW1 T-0-10								
0,598	1,0758	26,0	3,239	881	1,627	1,41	18,20	5,06
0,607	1,0920	26,0	3,287	893	1,649	1,41	18,70	5,16
0,616	1,1082	26,0	3,336	905	1,670	1,41	19,21	5,15
0,625	1,1244	26,0	3,385	916	1,691	1,41	19,35	5,11

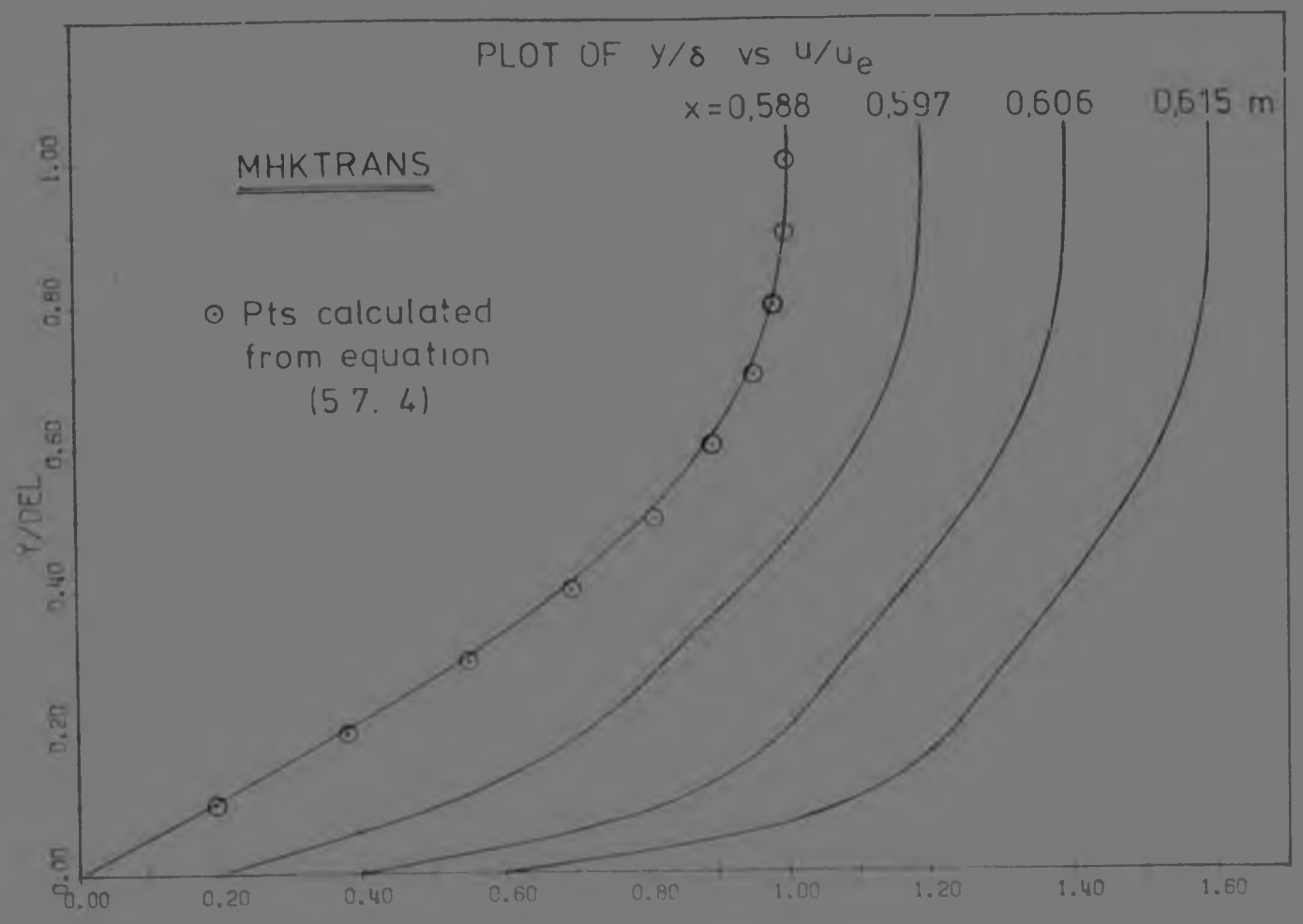


FIG F2.1 : LAMINAR PROFILES BEFORE AND DURING TRANSITION

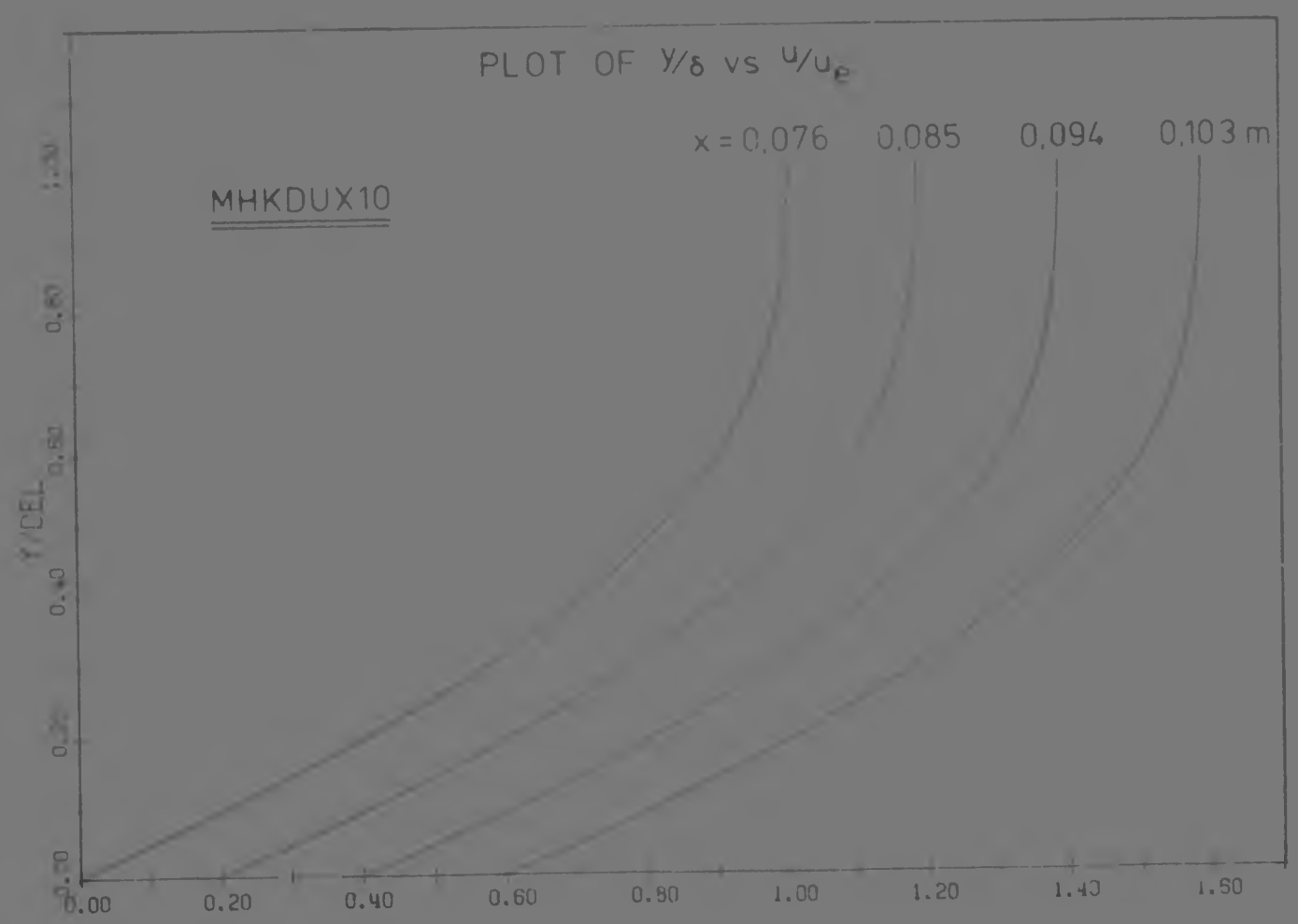


FIG F2.2 : LAMINAR PROFILES WITH PRESSURE GRADIENT

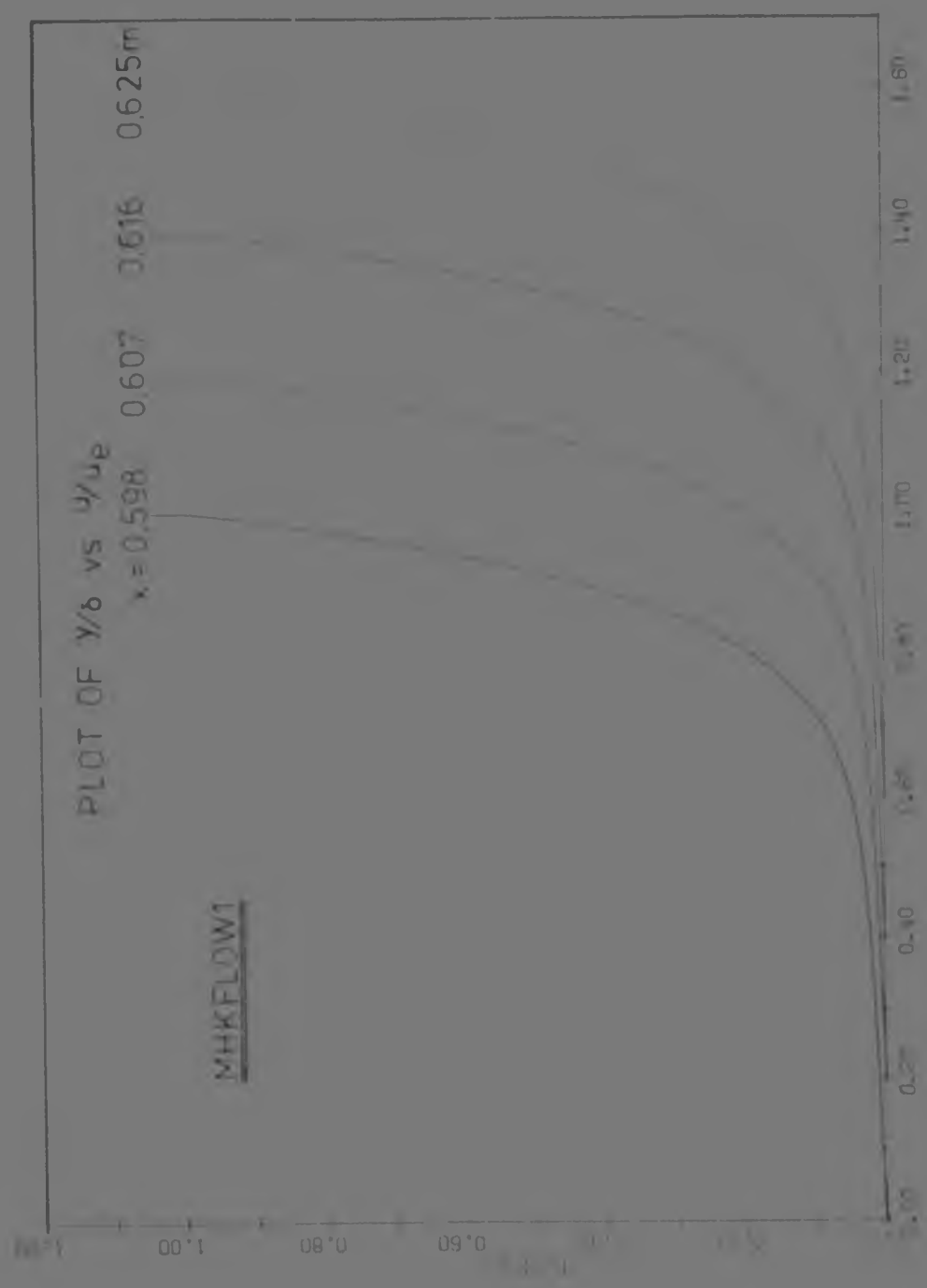


FIG F2.3 : TURBULENT INPUT PROFILES

F3 Results of Main Computer Runs

TABLE F3.1

Station	A^+	Re_θ	t (mm)	H	δ (mm)	$c_f \times 10^3$
MHKIJO01 T-1-17						
3	26,00	1812	1,97	1,33	23,14	4,085
10	23,11	1894	2,06	1,34	25,01	5,120
20	23,03	2019	2,19	1,36	26,48	4,818
30	22,95	2139	2,32	1,38	27,23	4,560
40	22,89	2257	2,45	1,39	28,74	4,357
50	22,83	2372	2,58	1,39	29,47	4,190
60	22,78	2486	2,70	1,40	31,03	4,049
MHKIJO02 T-2-17						
3	26,00	1812	1,97	1,33	23,14	4,085
10	20,93	1910	2,07	1,34	25,01	6,054
20	20,76	2065	2,24	1,37	26,48	5,580
30	20,59	2216	2,41	1,39	27,99	5,197
40	20,44	2364	2,57	1,41	28,74	4,896
50	20,31	2509	2,72	1,42	30,30	4,648
60	20,19	2652	2,88	1,43	31,89	4,438
MHKIJO03 T-3-17						
3	26,00	1811	1,97	1,33	23,53	4,088
10	19,15	1925	2,09	1,35	24,73	6,845
20	18,89	2109	2,29	1,38	26,92	6,229
30	18,64	2288	2,49	1,41	28,46	5,743
40	18,42	2465	2,68	1,43	29,22	5,361
50	18,22	2639	2,87	1,44	30,80	5,046
60	18,05	2812	3,05	1,45	32,42	4,779

Station	A^+	Re_θ	θ (mm)	H	δ (mm)	$c_f \times 10^3$
MHKIJ005 T-5-17						
3	26,00	1811	1,97	1,33	23,53	4,088
10	16,47	1953	2,12	1,35	24,73	8,507
20	16,09	2189	2,38	1,40	26,92	7,652
30	15,72	2421	2,63	1,43	28,46	6,980
40	15,40	2653	2,88	1,46	30,04	6,446
50	15,11	2883	3,13	1,48	31,66	6,003
60	14,84	3114	3,38	1,50	33,33	5,626
MHKIJ007 T-7-17						
3	26,00	1811	1,97	1,33	23,25	4,091
10	14,38	1978	2,15	1,36	25,13	9,909
20	13,94	2260	2,45	1,41	27,37	8,897
30	13,52	2542	2,76	1,46	28,93	8,085
40	13,14	28 25	3,07	1,49	31,39	7,432
50	12,79	3109	3,38	1,52	33,08	6,886
60	12,47	3394	3,69	1,54	34,84	6,420
MHKIJ009 T-9-17						
3	26,00	1811	1,97	1,33	23,25	4,091
10	12,81	2000	2,17	1,36	25,13	11,501
20	12,39	2322	2,52	1,42	27,37	10,390
30	11,94	2646	2,87	1,47	29,74	9,450
40	11,55	2975	3,23	1,51	32,27	8,683
50	11,18	3307	3,59	1,54	34,00	8,034
60	10,84	3643	3,96	1,57	36,77	7,476
MHKIJ010 T-10-17						
3	26,00	1811	1,97	1,33	23,15	4,095
10	11,97	2010	2,18	1,36	25,74	11,853
20	11,56	2353	2,56	1,43	28,03	10,727
30	11,11	2700	2,93	1,48	29,63	9,761
40	10,70	3052	3,31	1,52	32,15	8,969
50	10,33	3409	3,70	1,56	34,82	8,298
60	9,98	3771	4,10	1,58	36,65	7,719

Station	A^+	Re_θ	θ (mm)	H	δ (mm)	$c_f \times 10^3$
MHKIJO12 T-12-17						
3	26,00	1811	1,97	1,33	23,33	4,096
10	10,78	2029	2,20	1,36	25,23	13,279
20	10,42	2403	2,61	1,43	28,25	12,142
30	9,98	2786	3,03	1,48	30,70	11,092
40	9,58	3177	3,45	1,53	33,30	10,216
50	9,22	3576	3,88	1,56	35,09	9,467
60	8,88	3982	4,32	1,60	37,96	8,817
MHKIJO15 T-15-17						
3	26,00	1810	1,97	1,33	23,70	4,098
10	9,34	2051	2,23	1,35	25,62	15,419
20	9,07	2461	2,67	1,42	27,90	14,318
30	8,66	2886	3,13	1,47	31,18	13,155
40	8,29	3325	3,61	1,52	33,82	12,162
50	7,94	3776	4,10	1,56	36,63	11,301
60	7,61	4239	4,60	1,59	39,61	10,547
MHKIJO17 T-17-17						
3	26,00	1810	1,97	1,33	23,22	4,100
10	9,27	2052	2.23	1,35	25,82	15,201
20	8,99	2464	2,68	1,42	28,12	14,105
30	8,59	2891	3,14	1,47	30,56	12,957
40	8,21	3332	3,62	1,52	34,08	11,977
50	7,87	3785	4,11	1,56	36,91	11,129
60	7,54	4249	4,61	1,59	39,92	10,386

TABLE F3.2 Turbulent Shear Layer with Injection and Pressure Gradient

Test run MHKDUX003, $du/dx = 10^{1/3}$, F = 0,003, XTR = 0,8 m

x(m)	$Re_x \times 10^{-6}$	δ(mm)	θ(mm)	Re_θ	H	$p^+ \times 10^3$	A^+	$c_f \times 10^3$
0,790	1,069	22,05	1,78	2406	1,31	3,49	26,55	3,842
0,825	1,132	22,32	1,80	2464	1,31	1,81	21,03	6,003
0,875	1,224	23,30	1,84	2578	,33	1,89	21,00	5,584
0,925	1,320	23,63	1,88	2685	1,34	2,00	20,95	5,250
0,975	1,418	24,61	1,92	2788	1,35	2,09	20,93	4,979
1,025	1,518	24,91	1,95	2888	1,36	2,16	20,91	4,759
1,075	1,622	25,19	1,98	2986	1,36	2,21	20,91	4,573

TABLE F3.3 Computer runs with XTR small, U_∞ = 17 m/s, $du/dx = 0^{1/3}$

x(m)	$Re_x \times 10^{-5}$	δ(mm)	θ	Re_θ	H	A^+	$c_f \times 10^3$
MHKLONG3 T-3 XTR = 0,312 m							
0,254	2,325	8,27	0,73	665	1,46	26,00	5,001
0,359	3,286	10,79	1,02	934	1,40	21,97	22,759
0,509	4,659	14,52	1,45	1328	1,43	21,23	15,222
0,659	6,032	18,08	1,92	1755	1,46	20,52	11,231
0,809	7,405	21,89	2,40	2200	1,47	19,94	8,978
0,959	8,778	26,02	2,89	2644	1,48	19,45	7,542
1,109	10,151	30,52	3,38	3095	1,49		6,550
MHKLONG5 T-4,765-17 XTR = 0,312 m							
0,254	3,325	8,27	0,73	665	1,46	26,00	5,001
0,359	3,286	10,80	1,01	925	1,35	20,72	31,735
0,509	4,659	14,53	1,43	1313	1,37	19,75	20,820
0,659	6,032	18,65	1,95	1786	1,42	18,78	14,980
0,809	7,405	23,26	2,51	2300	1,45	17,97	11,685
0,959	8,778	27,64	3,10	2841	1,48	17,29	9,594
1,109	10,151	32,41	3,71	3398	1,49	16,70	8,156

F4 Input Data for the Programme

NX, the number of $\xi(x)$ stations, including the first two

DX, the ξ step length $\Delta\xi$, for equal steps (as noted before, these steps need not be equal)

X(1), the value of x at the first ξ station, in m

XTR, the value of x at the start of the porous section for injected flow

IY, the number of η grid points

K, the ratio of adjacent η step lengths. If K = 1, equal step length results

H, the first η step length

UINF, mainstream velocity, in m/s

DUDX, a pressure gradient term, in s^{-1}

PSTAT, static pressure, in Pa

T, temperature of mainstream, in ^{0}C

VW, injection velocity, in m/s

IJOB, 0 - no plot output
1 - plot velocity profile } For IJOB = 1, the JCL had to set up another job

EQUIVALENT NOTATION USED IN PROGRAMME

ROMAN

$A+$	AP	U_{CL}	UCL
c_f	CF	U_e	UE
du_e/dx	DUDX	u_w^*, u_τ	USTR
f''	FDD	$u+$	UP
h	H	U_∞	UINF
H	H12	v_w	VW, VW1
K	K	v_w+	VWP
$p+$	PP	x	X
Re_x	REX	y	Y
Re_{δ^*}	RDSTR	$y+$	YP
Re_θ	RTTA	y/θ	YOTTA
u	U	y/δ	YODEL

GREEK

β	BETA	μ	MU
δ	DEL	ν	NU
δ^*	DSTR	ξ	XI
$\varepsilon+$	EP	ρ	RHO
ε_i+	EPI	τ	
η	ETA	ϕ	P
θ	TTA	ϕ'	PD
κ	KL	ϕ''	PDD

```
                                                                                                                                    
VEL 2.2  (SEPT 76)                          OS/360  FORTRAN H EXTENDED            DATE 78.027/16.00.41        PAGE   1
REQUESTED OPTIONS:
TIONS IN EFFECT: NAME(MAIN) OPT(2) LINECNT(60) SIZE(MAX) AUTODBL(NONE)
                 SOURCE EXPDIC NOLIST NODECK OBJECT NOMAP NOPRINT NOGOSTMT NOXREF NOALC NOAGGR TERM FLAG(I)
                 C
                 C     PROGRAMME TO SOLVE THE MOMENTUM EQUATION FOR
                 C     INCOMPRESSIBLE LAMINAR OR TURBULENT BOUNDARY
                 C     LAYER FLOW,WITH SUCTION OR INJECTION AT THE
                 C     WALL,AND PRESSURE GRADIENT.
                 C
                 C     AN EDDY-VISCOSITY FORMULATION IS USED FOR THE
                 C     REYNOLDS STRESS
                 C
ISN 0002               REAL*8 KL,KX,KA1,PTAMP,KP1,F=3.412
ISN 0003               REAL*8 A(90,5),B(90,1)
ISN 0004               REAL*8 X(100),ETA(100),VDEL(100),VDETA(100)
ISN 0005               REAL*8 P(4,100),PD(4,100),PDD(4,100),UV(100),FD(100)
ISN 0006               REAL*8 FP(100)
ISN 0007               REAL*8 X(90),XI(90)
ISN 0008               REAL*8 K,H,DX,DXI,MU,RHO
ISN 0009               REAL*8 DST8(4)
ISN 0010               REAL*8 DSL,THL,CF,USTR,UL,UEO,UINF,TAU,PP,AP
ISN 0011               REAL*8 PET,DUDX,TTA,RX,RDEL,RETA,PSTAT
ISN 0012               REAL*8 T,VW,VBU,VWI,VWP,FDD
ISN 0013               REAL*8 DISI,DIS2
ISN 0014               REAL*8 A1,H1,C1,D1,E1,F1,G1,H1,I1,J1,K1,J2,K2
ISN 0015               REAL*8 X1,X2,X3,X4,X5,X6,XITR,XTR
                 C     DATA
ISN 0016               XTR=2.29700
ISN 0017               IY=100
ISN 0018               NX=3
ISN 0019               DX=0.0100
ISN 0020               H=0.04500
ISN 0021               X(1)= 0.9000
ISN 0022               K=1.01000
ISN 0023               UINF=17.6000
ISN 0024               DUDX=0.000
ISN 0025               T=22.000
ISN 0026               PSTAT=5.000
ISN 0027               VW1=0.12900
ISN 0028               KL=0.400
ISN 0029               NC=1
ISN 0030               ICOU=0
ISN 0031               JOBP=0
                 C     IF JOBP=0 PLOT IS SUPPRESSED; JOBP=1 ALLOWS PLOT
                 C
ISN 0032               VBU=VW1/UINF
ISN 0033               UEO=UINF*0.9900
                 C
ISN 0034               WRITE(6,1000) UINF,DUDX,VBU
ISN 0035          1000 FORMAT(/////T10,'UINF=',D13.6,'  M/S',//T10,'DU/DX=',D13.6,'  1/S'
                    *,//T10,'VW/UINF=',D13.6)
ISN 0036               T=T+273.1600
ISN 0037               RHO=(PSTAT*3513.600)*9.80900/(237.100*T)
                 C
                 C     CALCULATE MU
                 C
ISN 0038               MU=(((T-275.01/25.)*0.121+1.723)*1.0D-5



VEL 2.2  (SEPT 76)          MAIN            OS/360  FORTRAN H EXTENDED            DATE 78.027/16.00.41        PAGE   2
                 C
                 C     CALCULATE TAU
                 C
ISN 0039               TAU=TAUF(RHO,MU,X,DUDX,UEO,NC)
                 C
ISN 0040               WRITE(6,911) TAU,RHO,MU
ISN 0041          911  FORMAT(//T5,'TAU=',D13.6,5X,'RHO=',D13.6,/X,'MU=',D13.6)
                 C
                 C     DEFINE PARAMETERS FOR SUBROUTINE LEQT1B
ISN 0042               N=IY-4
                 C
                 C
ISN 0043               DO 1 I=2,NX
ISN 0044               X(I)=X(I-1)+DX
ISN 0045          1    CONTINUE
ISN 0046               DO 2 J=1,NX
ISN 0047               XI(J)=MU*RHO*X(J)*(X(J)*DUDX/2.000+UEO)
ISN 0048          2    CONTINUE
ISN 0049               XITR=MU*RHO*XTR*(XTR*DUDX/2.0+UEO)
                 C     GENERATE ETA POINTS
ISN 0050               CALL MKC01(H,K,IY,ETA)
                 C
                 C     CALCULATE CONSTANTS FOR MATRIX A
ISN 0051               CALL MK002(H,K,A1,B1,C1,D1,F1,F1,X1,X2,X3,X4,X5,X6)
                 C
ISN 0052               NC=1
ISN 0053          85   CALL MK003(X,DUDX,UEO,UE,ETA,NC,PP,AP,TAU,RHO,MU,VW1,USTR,VBU,VW)
ISN 0054               IF(X(NC) .LT. 0.039D0) GO TO 1000
ISN 0055               IF(NC .EQ. 1) GO TO 18
ISN 0056               GO TO 19
ISN 0057          18   FDD=TAU*(2.000*XI(NC))**0.5D0/(RHO*UE*UE*MU)
ISN 0058          19   CONTINUE
                 C
ISN 0059               CALL MK004(ETA,TAU,F1,MU,RHO,P,PD,IY,DUDX,VW,NC,FDD,NDEL,UE,PP,
                    *AP,XI,UETA,DSTA,EDEL,DEL)
                 C
ISN 0060               CALL MK005(ETA,PD,F,4,IY,NC,ETA)
ISN 0061               IF(NC .EQ. 2) GO TO 82
ISN 0062               NC=NC+1
ISN 0063               TAU=TAUF(RHO,MU,X,DUDX,UEO,NC)
ISN 0064               FDD=TAU*DSQRT(2.0*XI(NC))/(RHO*UE*MU)
ISN 0065               GO TO 85
ISN 0066          3000 CONTINUE
ISN 0067               CALL MKC01(ETA,X,XI,NC,IY,MU,RHO,P,PD,PDD,DUDX,DEL,UE,UINF,V
                    *W,NDEL,VBU)
ISN 0068               IF(NC .EQ. 2) GO TO 82
ISN 0069               NC=NC+1
ISN 0070               TAU=TAUF(RHO,MU,X,DUDX,UEO,NC)
ISN 0071               GO TO 85
ISN 0072          82   CONTINUE
                 C
                 C
                 C     SET UP DO LOOP IN X DIRECTION
ISN 0073               I=IY-4
ISN 0074               GPM=0
ISN 0075               NAT=NX+1
ISN 0076          95   NITR=0
ISN 0077               NC=NC+1
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FVFL 2.2  (SEPT 76)          MAIN          OS/360  FORTRAN H EXTENDED          DATE 78.027/16.00.41       PAGE   7

ISN 0092                IF(NC .EQ. NX1) STOP
ISN 0094                NCA=NC-3*GE
ISN 0095                NX1=NC-NCA
ISN 0096                IF(NCA-1) 3,4,5
ISN 0097            3   NCA1=2
ISN 0098                NCA2=1
ISN 0099                GO TO 6
ISN 0100            4   NCA1=1
ISN 0101                NCA2=1
ISN 0102                GO TO 6
ISN 0103            5   NCA1=3
ISN 0104                NCA2=2
ISN 0105            6   CONTINUE
ISN 0106                IF(NCA .NE. 3) GO TO 17
ISN 0107                GR=GR+1
ISN 0108           17   CONTINUE
                C       CALCULATE UE,BETA,P+ AND A+
                C
                C       CALCULATE TAU FOR NC+ X STATION
                C
ISN 0109                EX1=2.000*X1(NC)
ISN 0110                EXP=DSQRT(EX1)
ISN 0111                NAT=NCA
ISN 0112                IF(NITER .EQ. 0) NAT=NCA1
ISN 0113                TAU=RHO*RMU*UE*UE*PDD(NAT,1)/EX
                D
ISN 0114                CALL MK003(X,DUDX,UEO,UC,BETA,NC,PP,AP,TAU,RHO,MU,VM1,USTR,VEP,VM)
                E
                E       CALCULATE BOUNDARY CONDITIONS
ISN 0115                P(4,1)=-(V*P1UC*MU)*(EXP(EC1-A1)*1/EX
ISN 0116                KP1=K+1.0
ISN 0117                PTAYP=P(4,1)*A*(KP1+1.0)*P(NCA1,3)-K*H*KP1
ISN 0118                P(4,2)=P(4,1)*H*(KP1+1.0)
ISN 0119                WRITE(6,9991) P(4,1),P(4,2),PTAYP
ISN 0120           9991 FORMAT(///5X,'P(4,1)=',D13.5,5X,'P(4,2)=',D13.5,5X,
                C       CALCULATE EPS1
ISN 0121           90   CALL MK004(X1,ETA,PDD,RHO,MU,AP,DEL,EP,NC,NCA,DSTR,KL,NCA1,NCA2,
               #UE,NITER,IY,X)
ISN 0122           910  FORMAT(/5D,'NITER=',I3,3X,'NCA=',I3,3X,'NCA1=',I3,3X,'NCA2=',I3)
ISN 0123                IF(NITER .GT. 10) GO TO 8
                C
                C       CALCULATE EPS1 DASH
                C
                C       GENERATE A
ISN 0124                CALL MK005(A,A1,H1,C1,PP,C1P1,H3,AP,EP,EP,EP,X6,X1,NC,K,IY,P,
               #PP,PDD,NCA,NCA1,DIFEP,DIFEA,ET*EM)
                C       GENERATE B
ISN 0125                CALL MK009(X1,P,PD,PDD,NCA,NCA1,NCA2,NC,IY,NITER,B)
                C
                C       MODIFY A AND B
ISN 0126                B(1,1)=B(3,1)-A(1,1)*P(4,1)-A(1,2)*P(4,2)
ISN 0127                B(2,1)=B(4,1)-A(2,1)*P(4,1)-A(2,2)*P(4,2)
ISN 0128                A(3,3)=A(3,3)-A(3,1)*P(1,3)-1.0
ISN 0129                A(3,4)=A(3,4)-A(3,2)*P(1,3)
ISN 0130                A(4,3)=A(4,3)-A(4,1)*P(1,3)-A(4,2)*P(2,3)
ISN 0131                A(4,4)=A(4,4)-A(4,1)*P(1,4)-A(4,2)*P(2,4)
ISN 0132                P(1,1)=0.000
ISN 0133                P(2,1)=0.000
ISN 0134                P(1,2)=0.000
ISN 0135                P(1,4)=0.000
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VFL 2.2  (SEPT 76)          MAIN          OS/360  FORTRAN H EXTENDED          DATE 78.027/16.00.41       PAGE   8

ISN 0137                A(3,3)=0.000
ISN 0138                A(3,4)=0.000
ISN 0139                CALL A21=(A,B,N)
                C       CONVERT B TO ONE DIM
ISN 0140                CALL MK010(B,B1)
ISN 0141                CALL MK011(P,PD,K,M,NIE)
ISN 0142                CALL MK012(P,ETA,PD,PDO,K,M,ETA
ISN 0143                IF(ITER .EQ. 1) GO TO 2000
                C
                C       ESTABLISH EDGE OF BOUNDARY LAYER
ISN 0144                CALL MK013(PD,NDEL,ETA, EDEL,IY)
                C       CALCULATE DEL STAR
ISN 0145                CALL MK014(PD,A1,RHO,UE,NDEL,K,M,DSTR,NC,ETA)
                C
                C       TEST FOR CONVERGENCE
ISN 0146                NTI=NCA
ISN 0147                IF(NITER .EQ. 0) NTI=NCA1
                C
                C
ISN 0148           51   DIFS1=PDD(4,1)-P(NTI,1)
ISN 0149                DIFS2=DSTR(4)-DSTR(NTI)
ISN 0150                DIFS1=DABS(DIFS1)
ISN 0151                DIFS2=DABS(DIFS2)
ISN 0152           7    WRITE(6,7777) DIFS1,DIFS2,NTI,NCA,ITE
ISN 0153                CALL MK015(PDD,P,DSTR,NCA,ITE)
ISN 0154                WRITE(6,7777) DIFS1,DIFS2,NTI,NCA,ITE
ISN 0155           7777 FORMAT(///5X,'DIFS1=',D13.6,5X,'DIFS2=',D13.6,5X,'NTI=',I3,5X,'NCA=',I3,5X,'ITE=',I3)
               #,'ITE=',I3)
ISN 0156                IF(DIFS1 .LT. 0.0500 .AND. DIFS2 .LT. 0.0100) GO TO 8
ISN 0157                NITER = NITER+1
ISN 0158                GO TO 50
ISN 0159           8    CONTINUE
                C
                C       THE SOLUTION HAS NOW CONVERGED
                C
                C       CALCULATE PHYSICAL QUANTITIES
ISN 0160                CALL MK016(PD,ET,A,X1,C,NC,NDEL,K,M,DSTR,ITE,EC,ETA,NCA)
                C       SUBROUTINE TO CALCULATE THE VARIABLES REQUIRED FOR PRINTING
ISN 0161                CALL MK017(PD,P,ETA,PDD,NCA,NCA1,NCA2,NC,IY,X1,RHO,MU,DSTR,
               #ROP,VP,ETA,VP,PDD,VM,NDEL,ET*EM,ITE)
ISN 0162                H12=DSTR(NCA)/ETA
ISN 0163                  WRITE(6,1001)
ISN 0164                  WRITE(6,1001) NC
ISN 0165           1001 FORMAT(1H1,///T10,'STATION',I4,/T10,11('*'),//)
ISN 0166                  WRITE(6,1010) X(NC)
ISN 0167           1010 FORMAT(///5X,'X=',F13.6)
ISN 0168                  WRITE(6,1011) H12(NC)
ISN 0169           1011 FORMAT(///5X,'H12=',D13.6)
ISN 0170                  WRITE(6,1012) DSTR(NC)
ISN 0171           1012 FORMAT(///5X,'DSTR=',D13.6)
ISN 0172                  WRITE(6,1002) (ETA(J),P(J,1),P(J,2),P(J,3),J=1,IY)
ISN 0173           1002 FORMAT(///5X,'ETA',5X,'F',5X,'F1',5X,'F2'//(4D13.6))
ISN 0174                  WRITE(6,1003) (ETA(J),PDD(J,1),PDD(J,2),PDD(J,3),J=1,IY)
ISN 0175           1003 FORMAT(///5X,'ETA',5X,'F',5X,'F1',5X,'F2'//(4D13.6))
ISN 0176                  WRITE(6,1004) (ETA(J),VP(J),VM(J),J=1,IY)
ISN 0177           1004 FORMAT(///5X,'ETA',5X,'VP',5X,'VM'//(3D13.6))
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FVFL 2.2  (SEPT 76)          MAIN          OS/360  FORTRAN H EXTENDED          DATE 78.027/16.00.41       PAGE   5

 ISN 0170                WRITE(6,1005) ID
 ISN 0171          1005  FORMAT(//////1 ,'ID=',013,6,' M/S')
 ISN 0172          1006  FORMAT(1H1,7X,'Y(N)',124,'P',T40,'PD',T55,'PDD',T69,'U/UL',
                        *1H4,'Y/YTA',T90,'CP',/)
 ISN 0173          1007  FORMAT(7(3X,013.6))
                         C
                         C
                         C
 ISN 0174                IF(IDD .EQ. 0) GO TO 2003
 ISN 0175                IF(NC .EQ. 3) GO TO 1505
 ISN 0176                WRITE(10,1004)
 ISN 0177                IF(N1 .EQ. 0) GO TO 2002
 ISN 0181                GO TO 2003
 ISN 0182          2002  CONTINUE
 ISN 0183                ICOU=ICOU+1
 ISN 0184                WRITE(6,1006)
 ISN 0185                DO 1250 I=1,10
 ISN 0186                WRITE(6,1007)Y(I),P(NCA,I),PD(NCA,I),PDD(NCA,I),
                        *FD(I),YOTTA(I),EP(I)
 ISN 0187          1250  CONTINUE
 ISN 0188                DO 1251 I=11,NN,5
 ISN 0189                WRITE(6,1007)Y(I),P(NCA,I),PD(NCA,I),PDD(NCA,I),
                        *FD(I),YOTTA(I),EP(I)
 ISN 0190          1251  CONTINUE
 ISN 0191                DO 1 43 I=1,NP
 ISN 0192                IF(      ) .LT.  0.0) WRITE(6,1501)
 ISN 0193                I F(      ) .LT.  0.0) STOP
 ISN 0194                IF(FD(      .GT. 1.2) WRITE(6,1502)
 ISN 0195                IF(FD(I) .GT. 1.2) STOP
 ISN 0200                WRITE(10,10400) YOTTA(I),FD(I)
 ISN 0201          1243  CONTINUE
 ISN 0202                DO 1252 I=11,NN,5
 ISN 0203                WRITE(10,10400) YOTTA(I),FD(I)
 ISN 0204          1252  CONTINUE
 ISN 0205                DO 1253 I=50,NN,5
 ISN 0206                WRITE(10,10400) YOTTA(I),FD(I)
 ISN 0207          1253  CONTINUE
 ISN 0208                IF(NC .EQ. 3) WRITE(10,10500)
 ISN 0209                IF(NC .GT. 3) WRITE(10,10501)
 ISN 0210                IF(NC .EQ. 3) WRITE(10,10000)
 ISN 0212                IF(NC .EQ. 10)WRITE(10,10001)
 ISN 0214                IF(NC .EQ. 20)WRITE(10,10002)
 ISN 0216                IF(NC .EQ. 30)WRITE(10,10003)
 ISN 0218                IF(NC .EQ. 40)WRITE(10,10004)
 ISN 0220                IF(NC .EQ. 50)WRITE(10,10005)
 ISN 0222                IF(NC .EQ. 60)WRITE(10,10006)
 ISN 0224                WRITE(10,10600)
 ISN 0226                WRITE(10,10700)
 ISN 0227                IF(NC .EQ. NX) GO TO 1505
 ISN 0228                GO TO 2003
 ISN 0230          1505  DO 1245 I=1,NN,5
 ISN 0231                WRITE(10,10800) YOTTA(I),EP(I)
 ISN 0232          1245  CONTINUE
 ISN 0233                WRITE(10,10900)
 ISN 0234                WRITE(10,10001)
 ISN 0235                WRITE(10,11000)
 ISN 0236                WRITE(10,12000)
 ISN 0237                IF(ICOU .GT. 6) GO TO 2003
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VEL 2.2  (SEPT 76)          MAIN          OS/360  FORTRAN H EXTENDED          DATE 78.027/16.00.41       PAGE   6

 ISN 0241                IF(NC .EQ. NX) GO TO 2003
 ISN 0242                GO TO 2002
 ISN 0243          1501  FORMAT(//////,T10,'PROGRAMME STOPPED BECAUSE AN NEGATIVE',/)
 ISN 0244          1502  FORMAT(//////,T10,'PROGRAMME STOPPED BECAUSE FD AT I=',I3,/)
 ISN 0245          10400 FORMAT(6X,8F9.4)
 ISN 0246          10500 FORMAT('$ COMO',/,'$ TITLE="U/UL VS Y/YTA" XTITLE=
                        *'Y/YTA',/,'$ YTITLE="U/UL"',/)
 ISN 0247          10501 FORMAT('$ COMO',/,'$ XMAX=13, YMAX=1.2 LAB NO=33 ',/
 ISN 0248          10600 FORMAT('$ MINC=0, XINC=.1 YINC=.05 YLEN=10.0 ',/
 ISN 0249          10700 FORMAT('$ XINC=.2 YINC=.05 YLEN=10.0 ',/
 ISN 0250          10800 FORMAT('$ XMAX=1.2 XINC=.2 YLEN=10.0 ',/
 ISN 0251          10900 FORMAT('$ XMAX=1.2 XINC=.2 YLEN=10.0 ',/
 ISN 0252          11000 FORMAT('$ XMAX=1.2 XINC=.2 YLEN=10.0 ',/
 ISN 0253          11100 FORMAT('$ XMAX=1.2 XINC=.2 YLEN=10.0 ',/
 ISN 0254          12000 FORMAT('$ XMAX=1.2 XINC=.2 YLEN=10.0 ',/
 ISN 0255          10000 FORMAT('LABEL=',I2,'*')
 ISN 0256          10001 FORMAT('LABEL=',I2,'*')
 ISN 0257          10002 FORMAT('LABEL=',I2,'*')
 ISN 0258          10003 FORMAT('LABEL=',I2,'*')
 ISN 0259          10004 FORMAT('LABEL=',I2,'*')
 ISN 0260          10005 FORMAT('LABEL=',I2,'*')
 ISN 0261          10006 FORMAT('LABEL=',I2,'*')
                         C     STEP TO NEXT X STATION
                         C
 ISN 0262          2003  CONTINUE
 ISN 0263                GO TO 99
 ISN 0264          2000  WRITE(6,2001)
 ISN 0265          2001  FORMAT(//'0',T,'PROGRAMME STOPPED BECAUSE IER=',I2,/)
 ISN 0266                STOP
 ISN 0267                END

PTIONS IN EFFECT*NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)

PTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOREMAP NOCOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

TATISTICS*      SOURCE STATEMENTS =      265,  PROGRAM SIZE =     21056,  SUBPROGRAM NAME =  MAIN

TATISTICS*  NO  DIAGNOSTICS GENERATED

**** END OF COMPILATION ******                                  315K BYTES OF CORE NOT USED
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*VEL 2.2  (SEPT 76)                    OS/360  FORTRAN H EXTENDED            DATE 78.027/16.01.21       PAGE   3

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(0K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOLOGPRT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

                C
                C     ***************************************************
                C     SUBROUTINE MAPPELEETA(ETA,KK,NC,IT,MU,UINF,RHO,PRO,DNOR,DEL,VC,UINF,
      ISN 0002       *PF,PDOTF,NPTS)
                C     ***************************************************
                C     PROGRAMMED TO CALCULATE INITIAL PROFILES FOR LAMINAR FLOW.
                C     DEL IS ESTABLISHED FROM AN EQUATION AND FROM THE PROFILE
                C     AN ITERATIVE PROCESS IS USED
                C
                C
                C
      ISN 0003        REAL*8 F(101),F1(101),FPP(101),YDEL(1001)
      ISN 0004        REAL*8 ETA(101),ETA1(101),PD(4,100),PDD(4,100),FD(100)
      ISN 0005        REAL*8 YP,DYDX(1),Y(1)
      ISN 0006        REAL*8 EPS1,EPS2,EPS3,EPS,ET2
      ISN 0007        REAL*8 DEL,DELI,DIFS1,DIFS2,DIFS3,DIFS,DEL1,DEL2,DEL3
      ISN 0008        REAL*8 FA1,AF,CF,CF1,DEL1,FA,GA,E2
      ISN 0009        REAL*8 F4,DIF21,DIFS2,AL,AC(4),AF(4)
      ISN 0010        REAL*8 DSTR(4)
                C
      ISN 0011    11  AF(2,DDD*A(I)+C)
      ISN 0012        NEIF=0
      ISN 0013        FXI=DSQRT(AF)
                C
      ISN 0014        DEL2=DS.COS*MU*(1.DD/E2/(RHO*UINF))
      ISN 0015        DEL=DSQRT(DEL2)
      ISN 0016    6   A4=DEL2*DD3*(RHO/MU)
      ISN 0017        DF=FXI/(DDD*DEL)
      ISN 0018        DO 1 I=1,IT
      ISN 0019        ETD(I)=ETA(I)*DF
      ISN 0020    1   CONTINUE
      ISN 0021        NITER=NITER+1
      ISN 0022        WRITE(6,103) NITER,NC,DEL
      ISN 0023   103   FORMAT(/T5,'NITER=',I4,6X,'NC=',I4,5X,'DEL=',D13.6,/)
                C
      ISN 0024        DO 2 I=1,IT
      ISN 0025        E2=ETD(I)*ETD(I)
      ISN 0026         E3=E2*ETD(I)
      ISN 0027        FA=ETD(I)*(2.DDD-2.DDD*E2+E3)
      ISN 0028        GA=ETD(I)*(1.DDD-.6D*ETD(I)*(1.DDD*E2-E3))
      ISN 0029        FD(I)=FA*LAM*GA*A.DDD
      ISN 0030    2   CONTINUE
                C
                C     DETERMINE EDGE OF B.L.
      ISN 0031        NDEL=0
      ISN 0032    4   NDEL=NDEL+1
      ISN 0033         DIFS1=1.DDD-FD(NDEL)
      ISN 0034        DIFS1=DABS(DIFS1)
      ISN 0035        IF(DIFS1 .LT. 0.0001D0) GO TO 3
      ISN 0036        IF(NDEL .EQ. IT) GO TO 3
      ISN 0037        GO TO 4
      ISN 0038    3   EDEL=ETA(NDEL)
      ISN 0039        DELI=FXI*EDEL/(RHO*UE)
      ISN 0040        DIFS2=DEL-DELI
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*VEL 2.2  (SEPT 76)          MK001L          OS/360  FORTRAN H EXTENDED            DATE 78.027/16.01.21       PAGE   4

      ISN 0041        DIFS3=DABS(DIFS2)
      ISN 0042        DEL=DELI
      ISN 0043        DEL1=NDEL*DEL
      ISN 0044        IF(DIFS2 .LT. 0.0001D0) GO TO 5
      ISN 0045        IF(NITER .GT. 8) GO TO 5
      ISN 0046        GO TO 6
                C
      ISN 0047    5   CONTINUE
      ISN 0048        DO 15 J=NDEL,IT
      ISN 0049        FD(J)=1.000
      ISN 0050   15    CONTINUE
      ISN 0051        AF1=(F1(NDEL)*DD*DEL
      ISN 0052        DO 17 J=NDEL,IT
      ISN 0053        YDOT(J)=AF1*(ETA(J)
      ISN 0054   17    CONTINUE
      ISN 0055        F(1)=0.000
      ISN 0056        DO 7 J=2,IT
      ISN 0057        JJ=J-1
      ISN 0058        F(J)=F(JJ)+FD(JJ)*(ETA(J)-ETA(JJ))/2.000+F(JJ)
      ISN 0059    7   CONTINUE
      ISN 0060        A1=-K**3.000/(H*(1.000+K))
      ISN 0061        A2=(K-1.0001*K/H
      ISN 0062        A3=K/(H*(1.000*K))
      ISN 0063        IYM1=IY-1
      ISN 0064        DO 8 I=2,IYM1
      ISN 0065        FDD(I)=(A1*F(I+1)-(1+A2*FD(I)+A3*FD(I-1))/(K**2)
      ISN 0066    8   CONTINUE
      ISN 0067        FDD(1)=0.0
      ISN 0068        FDD(IY)=FDD(IYM1)
      ISN 0069        IYM2=IY-2
      ISN 0070        KF=K+1.0
      ISN 0071         FDD(IY)=(FD(IY)-FD(IYM1))/(KF*H)
      ISN 0072        DO 9 I=1,IT
      ISN 0073        PENC,I)=F(I)-ETA(I)
      ISN 0074        PD(NC,I)=FD(I)-1.DD
      ISN 0075        PDD(NC,I)=FDD(I)
      ISN 0076    9   CONTINUE
      ISN 0077        VV=0.000
                C
      ISN 0078        DMC
      ISN 0079        TE=0.000
      ISN 0080        DO 11 J=2,NPTS
      ISN 0081        JJ=J-1
      ISN 0082        TE=TE+(FD(I,J)+FD(I,JJ))*(ETA(J)-ETA(JJ))/2.000
      ISN 0083   11    CONTINUE
      ISN 0084        DSTR(1)=(1.0000-TE)*DEL
      ISN 0085        RETURN
      ISN 0086        END

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(0K) AUTODBL(NONE)

OPTIONS IN EFFECT: SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOLOGPRT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

STATISTICS*     SOURCE STATEMENTS =      91, PROGRAM SIZE =     ####  SUBPROGRAM NAME =MK001L

STATISTICS*  NO DIAGNOSTICS GENERATED
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VEL 2.2  (SEPT 76)                    OS/360  FORTRAN H EXTENDED            DATE 78.027/16.01.18       PAGE   1
QUESTED OPTIONS:
IONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

                C
                C     ***************************************************
                C       FUNCTION TO CALCULATE TAU FOR MAIN
                C     ***************************************************
ISN 0002                FUNCTION TAUF(PHO,MU,X,[illegible],UE0,NC)
ISN 0003                REAL*8 UE,UE0,PHO,MU,X(60),DUDX,RA,TAUF
ISN 0004                UE=X(NC)*DUDX+UE0
ISN 0005                RA=(0.5*UE*X(NC)/MU
ISN 0006                RA=RA**0.70
ISN 0007                TAUF=0.[illegible]*RA**0.70/RA
ISN 0008                RETURN
ISN 0009                END

VEL 2.2  (SEPT 76)                    OS/360  FORTRAN H EXTENDED            DATE 78.027/16.01.30       PAGE   1
QUESTED OPTIONS:
IONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

                C     ***************************************************
ISN 0002              SUBROUTINE MAKE1(M,K,ETA)
                C     ***************************************************
                C     PROGRAMME TO CALCULATE ETA FOR MAIN
ISN 0003              REAL*8 M,K,KM1,KS
ISN 0004              REAL*8 ETA(100)
ISN 0005              KM1=K-1.000
ISN 0006              ETA(1)=0.000
ISN 0007              IF(K .EQ. 1.0000) GO TO 20
ISN 0008              DO 1 I=2,IY
ISN 0009              J=I-1
ISN 0010              KS=K**J-1.000
ISN 0011              ETA(I)=M*KS/KM1
ISN 0012         1    CONTINUE
ISN 0013              GO TO 30
ISN 0014         20   DO 40 I=2,IY
ISN 0015              J=I-1
ISN 0016              ETA(I)=ETA(J)+M
ISN 0017         40   CONTINUE
ISN 0018         30   CONTINUE
ISN 0019              RETURN
ISN 0020              END

VEL 2.2  (SEPT 76)                    OS/360  FORTRAN H EXTENDED            DATE 78.027/16.01.35       PAGE   1
QUESTED OPTIONS:
IONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

ISN 0002              SUBROUTINE MK002(M,K,A1,B1,C1,D1,E1,F1,X1,X2,X3,X4,X5,X6)
                C     PROGRAMME TO CALCULATE THE CONSTANTS REQUIRED IN SETTING UP
                C     THE MATRIX A
ISN 0003              REAL*8 M,K,A1,B1,C1,D1,E1,F1,G1,H1,I1,J1,K1M,KP1,K2,M2,M3
ISN 0004              REAL*8 X1,X2,X3,X4,X5,X6
                C
ISN 0005              K1M=1.000-K
ISN 0006              KP1=1.000+K
ISN 0007              K2=K**2.000
ISN 0008              M2=M**2.000
ISN 0009              M3=M**3.000
                C
ISN 0010              A1=-K**3.000/(M*KP1)
ISN 0011              B1=-K1M*K/M
ISN 0012              C1=K/(M*KP1)
                C
ISN 0013              D1=[illegible].000*(K**4.000)/(M2*KP1)
ISN 0014              E1=-2.000*(K**3.000)/M2
ISN 0015              F1=2.000*(K**3.000)/(M2*KP1)
                C
ISN 0016              G1=-2.000*K**[illegible].000/(M3*K2)
ISN 0017              H1=2.000*(K**3.000*K-1.[illegible])*K**5.000/(M3*KP1)
ISN 0018              I1=-K**[illegible].000/K2*K*[illegible]*1.000/K2
ISN 0019              I1=2.0[illegible]*K**3.000/M3
ISN 0020              J1=[illegible].000*(-K1M*K**2.000-1.000)*K**2.000/(M3*KP1)
ISN 0021              K1=2.000*K**2.000/(M2*K2)
ISN 0022              X1=2.000*K**6.000/(M2*KP1)
ISN 0023              X2=-2.000*K**[illegible].000/M2
ISN 0024              X3=2.000*K**5.000/(M2*KP1)
ISN 0025              X4=2.000*K**[illegible]/(M2*KP1)
ISN 0026              X5=-2.000*K/M2
ISN 0027              X6=-2.000*K/(M2*KP1)
ISN 0028              RETURN
ISN 0029              END

VEL 2.2  (SEPT 76)                    OS/360  FORTRAN H EXTENDED            DATE 78.027/16.01.44       PAGE   1
QUESTED OPTIONS:
IONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

ISN 0002              SUBROUTINE MK003(K,DUDX,UE0,UE,BETA,NC,PP,AP,TAU,RHO,MU,V01,USTR,
                     #V0P,V01)
                C     PROGRAMME TO CALCULATE UE,BETA,V0,PP,AP,USTR,AND V0P
                C
ISN 0003              REAL*8 DUDX,UE0,UE,BETA,PP,AP,TAU,RHO,MU,V01,V0,USTR,MU,USTR3,
                     #V0P,DFW
ISN 0004              REAL*8 X(60)
ISN 0005              REAL*8 AP1,AP2
ISN 0006              UE=X(NC)*DUDX+UE0
ISN 0007              BETA=1.000-(U[illegible]U)**2
ISN 0008              USTR=(TAU/[illegible])**0.5[illegible]
ISN 0009              PP=UE*DUDX*MU/(RHO[illegible]**3)
ISN 0010              IF((NC) .GE. 2.2[illegible] .AND. X(NC) .LT. 2.700) GO TO 1
ISN 0012              V0=0.000
ISN 0013              AP1=1.6[illegible]-11.[illegible]*P
ISN 0014              AP=24.000/DSQRT(A[illegible])
ISN 0015              WRITE(6,100) NC,PP,AP,USTR,UE
ISN 0016         100  FORMAT(/[illegible],'AP',14.2X,'[illegible]',13.6,2X,'UE0=',E13.6,2X,'USTR=',
                     #E13.6,2X,'UE=',E13.6,/[illegible],'FROM MK003',/)
ISN 0017              GO TO 2
ISN 0018         1    V0=V01
ISN 0019              V0P=V0/USTR
ISN 0020              PI=DATAN(1.0)*4.0
ISN 0021              AP2=-SQRT(DFW-1.000)/V0P**DFW
ISN 0022              AP=24.000/DSQRT(A[illegible])
ISN 0023         2    RETURN
ISN 0024              END
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IONS IN EFFECT: NAME(MAIN) OPT(1) SIZE(131072) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOOPTIONS NOREF NOALC NOANSI IBM FLAG(I)

ISN 0002              SUBROUTINE PROPS( IA,IAD,KL,KU,KHD,PHD,IY,DUDX,VR,NC,FDD,NDEL,
                     #UL,PP,AP,AI,UTR,DSTR,FDEL,DEL)
                C
                C     PROGRAMME TO GENERATE INITIAL VELOCITY PROFILES.
                C
ISN 0003              REAL*4 SR4
ISN 0004              REAL*4 IAD,KL,KU,KHD,DUDX,VR,USTR,UE,PP,AP,AU,AI(60),SR2,SR1,
                     #SR3,USE,PHD,DSTR(4),DIF(101),HD,FDEL
ISN 0005              REAL*8 ETA(100),YP(100),UP(100),FD(100),P(4,100),PD(4,100),
                     #G(100),X(100)
ISN 0006              REAL*4 X
ISN 0007              REAL*4 PLW
ISN 0008              REAL*8 DEL
                C
ISN 0009              USTR=VR*PDD*UE*UE*0.500*(2.000/AI(NC))**0.500
ISN 0010              UST=0USTR**0.400
ISN 0011              NU=MU/RHO
ISN 0012              FAI=(2.000*AI(NC))**0.500
ISN 0013              AFX=FAI*USTR/(NU*UE)
ISN 0014              DO 1 I=1,IY
ISN 0015              YP(I)=AFX*ETA(I)
ISN 0016           1  CONTINUE
                E
ISN 0017              G(1)=1.000
ISN 0018              DO 2 I=2,IY
ISN 0019              SR2=YP(I)/AP
ISN 0020              IF(SR2 .LT. 0.0100) GO TO 300
ISN 0022                PLW=0.000
ISN 0023                IF(SR2 .LT. 100) PLW=1.000/DEXP(SR2)
ISN 0025              SR4=1.000-PLW
ISN 0026              GO TO 301
ISN 0027          300 SR4=0.000
ISN 0028          301 SR1=2.000*XL*YP(I)*SR4
ISN 0029              SR3=SR1**2.000
ISN 0030              G(I)=2.000/(1.000+DSQRT(1.000+SR3))
ISN 0031           2  CONTINUE
                C
                C     INTEGRATION
ISN 0032              UP(1)=0.000
ISN 0033              DO 3 I=2,IY
ISN 0034              J=I-1
ISN 0035              UP(I)=(G(I)+G(J))*(YP(I)-YP(J))/2.000+UP(J)
ISN 0036           3  CONTINUE
ISN 0037              USE=USTR/UE
ISN 0038              DO 4 I=1,IY
ISN 0039              FD(I)=UP(I)/USE
ISN 0040           4  CONTINUE
                C     DETERMINE EDGE OF BOUNDARY LAYER
ISN 0041              NDEL=0
ISN 0042           8  NDEL=NDEL + 1
ISN 0043              DIF(I)=1.000-FD(NDEL)
ISN 0044              IF(DIFSI .LT. 0.000100) GO TO 9
ISN 0046              IF(NDEL .EQ. IY) GO TO 9

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ISN 0048              GO TO 8
ISN 0049           9  ND2=NDEL
ISN 0050              DO 41 I=ND2,IY
ISN 0051              FD(I)=1.000
ISN 0052          41  CONTINUE
                E
                C     INTEGRATE TO OBTAIN P
ISN 0053              P(1)=0.000
ISN 0054              DO 5 I=2,IY
ISN 0055              J=I-1
ISN 0056              P(I)=(FD(I)+FD(J))*(ETA(I)-ETA(J))/2.000**(J)
ISN 0057           5  CONTINUE
                A
                C     GENERATE P AND PD
ISN 0058              DO 6 I=1,IY
ISN 0059              P(NC,I)=P(I)-ETA(I)
ISN 0060           6  CONTINUE
ISN 0061              DO 7 I=1,IY
ISN 0062              PD(NC,I)=FD(I)-1.000
ISN 0063           7  CONTINUE
                L
                C     CALCULATE DSTR
ISN 0064              TEMP=0.000
ISN 0065              DO 10 I=2,NDEL
ISN 0066              J=I-1
ISN 0067              TEMP=TEMP+(PD(NC,I)+PD(NC,J))*(ETA(I)-ETA(J))/2.000
ISN 0068          10  CONTINUE
ISN 0069              DSTR(NC)=FAI*TEMP/(RHO*UE)
ISN 0070              FDEL=ETA(NDEL)
ISN 0071              DEL=FAI*DEL/(RHO*UE)
ISN 0072              RETURN
ISN 0073              END

IONS IN EFFECT: NAME(MAIN) OPT(1) SIZE(131072) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOOPTIONS NOREF NOALC NOANSI IBM FLAG(I)

ISN 0002              SUBROUTINE MPODS(G,GD,K,M,IY,NC,ETA)
                C     GENERAL DIFFERENTIATING PROGRAM
ISN 0003              REAL*8 G(4,100),GD(4,100),K
ISN 0004              REAL*8 ETA(100)
ISN 0005              REAL*8 H,KP1,KP1,AS,BS,CS
                C
ISN 0006              N1=NC
ISN 0007              K1M=1.0D0-K
ISN 0008              KP1=K+1.0D0
ISN 0009              IYM1=IY-1
ISN 0010              AS=-(K+1.0D0)/(H**K1)
ISN 0011              BS=-K1**K/H
ISN 0012              CS=K/(H**KP1)
                C
ISN 0013              DO 1 I=2,IYM1
ISN 0014              GD(N1,I)=(AS*G(N1,I-1)+BS*G(N1,I)+CS*G(N1,I+1))**K
ISN 0015           1  CONTINUE
                C     TO OBTAIN GD(N1,1) AND GD(N1,IY), A FIRST ORDER POLYNOMIAL FIT
                C     IS USED
                C
ISN 0016              GD(N1,1)=-G(N1,1)**K*((K+2.0)*G(N1,2)*KP1**KP1-G(N1,3)
ISN 0017              GD(N1,1)=GD(N1,1)/(6.0**KP1)
                C
ISN 0018              IYM2=IY-2
ISN 0019              GD(N1,IY)=KP1*G(N1,IYM1)**K-G(N1,IYM2)
                C
ISN 0020              RETURN
ISN 0021              END
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IEMS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                SOURCE EXPDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

ISN 0002            SUBROUTINE MK006(A,AI,DH,C1,D1,E1,F1,X1,X2,X3,X4,X5,X6,X7,NC,NC
                   &1A,P,PD,PDD,NCA,NCA1,NIT(R,BETA,ETA,EP)
                C
                C   PROGRAMME TO CALCULATE THE COEFFICIENT MATRIX A
ISN 0003            REAL*8 X1(60)
ISN 0004            REAL*8 A1,DH,C1,D1,E1,F1,AI,X2,X3,X4,X5,X6
ISN 0005            REAL*8 A(60,61),P(4,100),PD(4,100),PDD(4,100),EP(100)
ISN 0006            REAL*8 NN,PHI,DH2
ISN 0007            REAL*8 R
ISN 0008            REAL*8 Z1,Z2,Z3,Z4,Z5,Z6,Z7
ISN 0009            REAL*8 ETA(100)
ISN 0010            REAL*8 BETA
                C
                C
ISN 0011            DH1=X1(NC-1)-X1(NC-2)
ISN 0012            DH2=X1(NC)-X1(NC-1)
ISN 0013            NN=(DH1*.000*DH2)/(DH2*(DH1+DH2))
ISN 0014            N1=NCA
ISN 0015            IF(N1)15,.GT. .0) GO TO 10
ISN 0017            N1=NCA1
ISN 0018         10 IE=IY-4
ISN 0019            DO 1 J=1,IE
ISN 0020            I=J+2
ISN 0021            I3=I+1
ISN 0022            A(J,I)=A1*X1*(1.000+EP(I-1))/K**13
ISN 0023         1  CONTINUE
ISN 0024            DO 2 J=1,IE
ISN 0025            I=J+2
ISN 0026            I3=I+1
ISN 0027            I2=I+1
ISN 00.8            Z1=A1*X2*(1.000+EP(I-1))/K**13
ISN 0029            Z2=D1*D1*(1.000+EP(I))/K**13
ISN 0030            Z3=D1*(1.000)*ETA(I))/K**12
ISN 0031            Z4=D1*A*A1*(PD(NT,1)+2.000)/K**1
ISN 0032            Z5=2.000*X1(NC)*NN*Z1*(PD(NT,I)+1.000)/K**1
ISN 0033            A(J,2)=Z1+Z2+Z3 Z4-Z5
ISN 0034         2  CONTINUE
ISN 0035            DO 3 J=1,IE
ISN 0036            I=J+2
ISN 0037            I3=I+1
ISN 0038            I2=I+1
ISN 0039            Z1=A1*X3*(1.000+EP(I-1))/K**13
ISN 0040            Z2=D1*E1*(1.000+EP(I))/K**11
ISN 0041            Z3=C1*X4*(1.000+EP(I+1))/K**13
ISN 0042            Z4=D1*(P(NT,I)*ETA(I))/K**12
ISN 0043            Z5=D1*A*D1*(PD(NT,I)+2.000)/K**1
ISN 0044            Z6=2.000*X1(NC)*(PD(NT,I)+1.000)*NN*D1/K**1
ISN 0045            Z7=2.000*X1(NC)*PDD(NT,I)*NN
ISN 0046            A(J,3)=Z1+Z2+Z3+Z4-Z5-Z6+Z7
ISN 0047         3  CONTINUE
ISN 0048            DO 4 J=1,IE
ISN 0049            I=J+2
ISN 0050            I3=I+1

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ISN 0051            I2=I+1
ISN 0052            Z1=D1*E1*(1.000+EP(I))/K**13
ISN 0053            Z2=C1*X5*(1.000+EP(I+1))/K**11
ISN 0054            Z3=E1*(P(NT,I)*ETA(I))/K**12
ISN 0055            Z4=BETA*C1*(PD(NT,I)+2.000)/K**1
ISN 0056            Z5=2.000*X1(NC)*C1*NN*(PD(NT,I)+1.000)/K**1
ISN 0057            A(J,4)=Z1+Z2+Z3-Z4-Z5
ISN 00.8         4  CONTINUE
ISN 0059            DO 5 J=1,IE
ISN 0060            I=J+2
ISN 0061            I3=I+1
ISN 0062            A(J,5)=X6*(1.000+EP(I+1))/K**13
ISN 0063         5  CONTINUE
ISN 0064            RETURN
ISN 0065            END
IEMS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                SOURCE EXPDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

ISN 0002            SUBROUTINE MK006(X1,ETA,PDD,RHO,MU,AP,DEL,FF,NC,NCA,DSTR,KL,NCA1,
                   &NEAP,IE,NIT(P,IY,X)
                C   PROGRAMME TO CALCULATE EPSI THROUGHOUT ETA RANGE
                C
ISN 0033            REAL*8 KL
ISN 0034            REAL*8 X(60)
ISN 0035            REAL*8 DFXI
ISN 0036            REAL*8 EPSI
ISN 0037            REAL*8 X1(60)
ISN 0038            REAL*8 ETA(100),P(4,100),EP(100),PP(100)
ISN 0039            REAL*8 RHO,MU,AP,DEL,DSTR(4),UF T1,DIFSI,FXI,T2
ISN 0040            NT=NCA
ISN 0010            FXI=(2.000*X1(NC))**0.500
ISN 0011            IF(NIT(P .GT. 0) GO TO 1
ISN 0012            NT=NCA1
ISN 0014         1    (P*1*RHO*UF*DEL/FXI
ISN 0015            IF(X(NC) .LT. 0.0C9(0) GO TO 300
ISN 0016            DO 2 I=1,IY
ISN 0017            IF(ETA(I) .LE. 0.000001001 GO TO 400
ISN 0018            T1=1.000+5.500*(ETA(I)/DEL)**6
ISN 0022            GO TO 401
ISN 0023         400  T1=1.000
ISN 0024         401 EP(I)=(10.0)6800*UF*DSTR(NT))/T1)*(RHO*FXI
ISN 0025         2  CONTINUE
ISN 0026            PP(1)=0.000
ISN 0027            DFXI=((FXI*PDD(NT,1)/MU)**0.500)/AP
ISN 0028            I=1
ISN 0029         3  I=I+1
ISN 0030            T1=-ETA(I)*DFXI
ISN 0031               T2=1.000
ISN 0032               IF(T1 .GT. -50.0)T2=1.000-DEXP(T1)
ISN 0034            PP(I)=(VEL**TA(I)*12)**2*FXI*PDD(NT,I)/MU
ISN 0035            DIFSI=PP(I)-EP(I)
ISN 0036            IF(DIFSI .LT. 0.000) GO TO 4
ISN 0038            IF(I .EQ. IY) GO TO 4
ISN 0040            GO TO 3
ISN 0041         4  DO 5 J=1,I
ISN  042            EP(J)=PP(J)
ISN 0043         5  CONTINUE
ISN 0044            WRITE(6,10000) I
ISN 0045         10000 FORMAT(//1(,'THE MATCHING POINT F 10 EPSI WAS AT ',14,//)
ISN 0046            GO TO 301
ISN 0047         300 DO 6 I=1,IY
ISN 0048            EP(I)=0.000
ISN 0049         6  CONTINUE
ISN 0050         301   CONTINUE
ISN 0051            RETURN
ISN 0052            END
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EVEL 2.2  (SEPT 76)                    OS/360  FORTRAN H EXTENDED              DATE 78.027/16.02.10        PAGE    1
QUESTED OPTIONS:
TIONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                 SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

 ISN 0002                SUBROUTINE MK009(X1,P,PD,PDD,NCA,NCA1,NCA2,NC,IY,NITER,D)
                  C      PROGRAMME TO CALCULATE VECTOR B
                  C
 ISN 0003                REAL*8 LL,MM,DH1,DH2,T1,T2,T3,FX,T4
 ISN 0004                REAL*8 X1(2)
 ISN 0005                REAL*8 P(4,100),PD(4,100),PDD(4,100),D(96,1)
 ISN 0006                FX=2.000*X1(NC)
 ISN 0007                NT=96
 ISN 0008                IF(NITER .GT. 0) GO TO 10
 ISN 0010                NT=NCA1
 ISN 0011           10   IE=IY-4
 ISN 0012                DH1=X1(NC-1)-X1(NC-2)
 ISN 0013                DH2=X1(NC)-X1(NC-1)
 ISN 0014                LL=DH2/(DH1*(DH1+DH2))
 ISN 0015                MM=-(DH1+DH2)/(DH1*DH2)
 ISN 0016                DO 1 J=1,IE
 ISN 0017                I=J+2
 ISN 0018                T1=LL*PD(NCA2,I)+MM*PD(NCA1,I)
 ISN 0019                T2=(PD(NT,I)+1.000)*I
 ISN 0020                T3=LL*P(NCA2,I)+MM*P(NCA1,I)
 ISN 0021                T4=PDD(1,I)*T3
 ISN 0022                D(J,1)=FX*(T2-T4)
 ISN 0023           1    CONTINUE
 ISN 0024                RETURN
 ISN 0025                END

EVEL 2.2  (SEPT 76)                    OS/360  FORTRAN H EXTENDED              DATE 78.027/16.02.14        PAGE    1
QUESTED OPTIONS:
TIONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                 SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

 ISN 0002                SUBROUTINE MK010(D,P,IY)
                  C      PROGRAMME TO WRITE D AS P
 ISN 0003                REAL*8 D(96,1),P(4,100)
 ISN 0004                IE=IY-4
 ISN 0005                DO 1 J=1,IE
 ISN 0006                I=J+2
 ISN 0007                 P(4,I)=D(J,1)
 ISN 0008           1    CONTINUE
                  C
                  C      FIND P(4,IY-1) AND P(4,IY)
 ISN 0009                P(4,IY-1)=P(4,IY-2)
 ISN 0010                P(4,IY)=P(4,IY-2)
                  C
 ISN 0011                 RETURN
 ISN 0012                END

EVEL 2.2  (SEPT 76)                    OS/360  FORTRAN H EXTENDED              DATE 78.027/16.02.19        PAGE    1
QUESTED OPTIONS:
TIONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                 SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

 ISN 0002                SUBROUTINE MK011(P,PD,K,IY)
                  C      PROGRAMME TO CALCULATE PD, WITH BOUNDARY CONDITIONS
 ISN 0003                REAL*8 P(4,100),PD(4,100)
 ISN 0004                REAL*8 K,H,TA,TB,TC,K1,KP1,K1M
 ISN 0005                PD(4,1)= 1.000
 ISN 0006                KP1=K+1.000
 ISN 0007                K1M=1.000-K
 ISN 0008                IYM1=IY-1
 ISN 0009                TA=-K*3.000/(H*KP1)
 ISN 0010                TB=-K1M*K/H
 ISN 0011                TC=K/(H*KP1)
 ISN 0012                DO 1 I=2,IYM1
 ISN 0013                P1PK**I
 ISN 0014                PD(4,I)=P(4,I-1)*TA/K1+P(4,I)*TB/K+P(4,I+1)*TC/K1
 ISN 0015           1    CONTINUE
 ISN 0016                PD(4,IY)=0.000
 ISN 0017                RETURN
 ISN 0018                END

EVEL 2.2  (SEPT 76)                    OS/360  FORTRAN H EXTENDED              DATE 78.027/16.02.24        PAGE    1
QUESTED OPTIONS:
TIONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                 SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

 ISN 0002                SUBROUTINE MK012(P,PTA,PD,P[illegible],MP[illegible])
                  C      PROGRAMME TO CALCULATE PDD FROM P
                  C
 ISN 0003                REAL*8 PTA(100),MP,M1,M2,[illegible]
 ISN 0004                REAL*8 P(4,100),PDD(4,100),DTA(100),D
 ISN 0005                REAL*8 H,T1A,T2A,T3A,K1,KP
 ISN 0006                REAL*8 KP1,K1M
 ISN 0007                IYM1=IY-1
 ISN 0008                KP1=K+1.000
 ISN 0009                K1M=1.0-K
 ISN 0010                T1A=-K*3.000/(H*KP1)
 ISN 0011                T2A=-K1M*K/H
 ISN 0012                T3A=K/(H*KP1)
 ISN 0013                DO 1 I=2,IYM1
 ISN 0014                K1=K**I
 ISN 0015                PDD(4,I)=(PD(4,I-1)*T1A+PD(4,I)*T2A+PD(4,I+1)*T3A)/K1
 ISN 0016           1    CONTINUE
 ISN 0017                D1=(PD(4,2)-PD(4,1))/(DTA(2)-DTA(1))
 ISN 0018                D2=(PD(4,3)-PD(4,2))/(DTA(3)-DTA(2))
 ISN 0019                D3=(D2-D1)/(DTA(3)-DTA(1))
 ISN 0020                PDD(4,1)=D1+D3*(DTA(1)-DTA(2))
 ISN 0021                IYM1=IY-2
 ISN 0022                K1=K**IYM1
 ISN 0023                PDD(4,IY)=(PD(4,IY)-PD(4,IYM1))/(K1*D)
 ISN 0024                RETURN
 ISN 0025                END
```

```
TIONS IN EFFECT:  NAME(MAIN) OPTIMIZE(3) LINECOUNT(60) SIZE(MAXINT) NOALC NOANSF TERM FLAG(I)
                  SOURCE ESCDIC NOLIST NODECK OBJECT NOMAP NOOFFSET NOXREF NOALC NOANSF TERM FLAG(I)

ISN 0002          SUBROUTINE MAIN(IPD,PD,DSTR,NCA,ATP,FXI,NUEL,ETA,IPRINT,DT,NT)
                  DIMENSION PD(4,100),DSTR(4),ATP(4),FXI(4),ETA(100)
                  NUEL=0
                  NPL=0
                  IF(IPRINT.EQ.1) IPRINT=0.0001*NT
                  IF(IPRINT.EQ.1) GO TO 2
                  GO TO 1
                2 IDEL=IFIX(1.0/DT+0.5)
                1 WRITE(6,100) NUEL,NPL
                  FORMAT(1H1,'PRINT MK013, TIME=',F8.3,' NUEL=',I4,' NPL=',I4/)
                  RETURN
                  END

TIONS IN EFFECT:  NAME(MAIN) OPTIMIZE(3) LINECOUNT(60) SIZE(MAXINT) NOALC NOANSF TERM FLAG(I)
                  SOURCE ESCDIC NOLIST NODECK OBJECT NOMAP NOOFFSET NOXREF NOALC NOANSF TERM FLAG(I)

ISN 0002          SUBROUTINE MK013(IPD,PD,DSTR,NCA,ATP,FXI,NUEL,ETA,IPRINT,DT,NT)
                  PROGRAMME TO WRITE THE PRESENT STATION
                  REAL*8 PD(4,100),PD(4,100),PD(4,100),DSTR(4),ATP(4),FXI(4),ETA(100)
                  DO 1 I=1,4
                  PINCA(I)=0.0
                  CONTINUE
                  DO 2 I=1,4
                  PDINCA(I)=PD(4,I)
                  CONTINUE
                  DO 3 I=1,4
                  PDDINCA(I)=PD(4,I)
                  CONTINUE
                  DSTR(4)=DSTR(4)
                  RETURN
                  END

TIONS IN EFFECT:  NAME(MAIN) OPTIMIZE(3) LINECOUNT(60) SIZE(MAXINT) NOALC NOANSF TERM FLAG(I)
                  SOURCE ESCDIC NOLIST NODECK OBJECT NOMAP NOOFFSET NOXREF NOALC NOANSF TERM FLAG(I)

ISN 0002          SUBROUTINE MK014(PD,DSTR,NCA,ATP,FXI,NUEL,ETA,IPRINT,DT,NT)
                  PROGRAMME TO CALCULATE THE FA
                  REAL*8 PD(4,100),PD(4,100),PD(4,100),DSTR(4),ATP(4),FXI(4),ETA(100)
                  REAL*8 PINCA(4),PDINCA(4),PDDINCA(4)
                  ATP=0.000
                  DO 1 I=1,NUEL
                  J=I
                  TI=PINCA(J)+(1.000+PDINCA(J))
                  T2=PDINCA(J)+(ETA(I)-ETA(J))/2.000
                  ATP=ATP+(T1+T2)*(ETA(I)-ETA(J))/2.000
                  CONTINUE
                  FAI=(1.0/NC)*2.000)**0.500
                  T1=FAI*ATP/FXI(I)
                  RETURN
                  END

TIONS IN EFFECT:  NAME(MAIN) OPTIMIZE(3) LINECOUNT(60) SIZE(MAXINT) NOALC NOANSF TERM FLAG(I)
                  SOURCE ESCDIC NOLIST NODECK OBJECT NOMAP NOOFFSET NOXREF NOALC NOANSF TERM FLAG(I)

ISN 0002          SUBROUTINE MK015(PD,DSTR,NCA,ATP,FXI,NUEL,ETA,IPRINT,DT,NT)
                  PROGRAMME TO CALCULATE VARIANCE
                  REAL*8 PD(4,100),PD(4,100),PD(4,100),DSTR(4),ATP(4),FXI(4),ETA(100)
                  REAL*8 TAU(100),VAR(100),SIGMA(100),ETA(100),
                  DO 1 I=1,NUEL
                  TAU(I)=2.000*(ETA(I)-ETA(1))
                  SIGMA(I)=0.500*PDINCA(I)*TAU(I)**0.500
                  VAR(I)=SIGMA(I)**2.000
                  CONTINUE
                  DELVAR=0.0
                  DO 2 I=1,NUEL
                  DELVAR=VAR(I)-DELVAR
                  CONTINUE
                  UVAR=DELVAR
                  CONTINUE
                  DO 3 I=1,NUEL
                  IF(UVAR.LT.(0.1D-5)) GO TO 4
                  CONTINUE
                  DO 4 I=1,NUEL
                  PDDINCA(I)=PDDINCA(I)/UVAR
                  CONTINUE
                  DO 5 I=1,NUEL
                  PDINCA(I)=PDINCA(I)/UVAR
                  CONTINUE
                  RETURN
                  END
```

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EVEL 2.2  (SEPT 76)                    OS/360  FORTRAN H EXTENDED              DATE 78.027/16.02.54        PAGE  1
IJUSTED OPTIONS:
TIONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
                 SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)

 ISN 0002            SUBROUTINE AAZM(AA,B,N)
 ISN 0003             IMPLICIT REAL*8 (A-H,O-Z)
 ISN 0004            DIMENSION A(96,97),X(96),AA(96,5),B(96,1)
 ISN 0005            JJ1=N+1
 ISN 0006            NP1=N+1
 ISN 0007            DO 1 J=1,N
 ISN 0008            DO 2 I=1,N
 ISN 0009                 A(I,J)=0.0D0
 ISN 0010          2 CONTINUE
 ISN 0011          1 CONTINUE
 ISN 0012            J=3
 ISN 0013            DO 1000 I=1,3
 ISN 0014                    A(I,1)=AA(I,J)
 ISN 0015                         J=J-1
 ISN 0016      1000  CONTINUE
               C
 ISN 0017            J=4
 ISN 0018            DO 1001 I=1,4
 ISN 0019                    A(I,2)=AA(I,J)
 ISN 0020                         J=J-1
 ISN 0021      1001  CONTINUE
               C
 ISN 0022            NM4=N-4
 ISN 0023            DO 1002 IS=1,NM4
 ISN 0024                     J=5
 ISN 0025                    JJ=IS+2
 ISN 0026                    IT=IS+4
 ISN 0027                    DO 1003 I=IS,IT
 ISN 0028                            A(I,JJ)=AA(I,J)
 ISN 0029                                 J=J-1
 ISN 0030      1003  CONTINUE
 ISN 0031      1002  CONTINUE
               C
 ISN 0032            J=5
 ISN 0033            NM3=N-3
 ISN 0034            NM1=N-1
 ISN 0035            DO 1004 I=NM3,N
 ISN 0036                    A(I,NM1)=AA(I,J)
 ISN 0037                         J=J-1
 ISN 0038      1004  CONTINUE
 ISN 0039            J=5
 ISN 0040            NM2=N-2
 ISN 0041            DO 1005 I=NM2,N
 ISN 0042                    A(I,N)=AA(I,J)
 ISN 0043                   J=J-1
 ISN 0044      1005  CONTINUE
 ISN 0045            DO 1006 I=1,N
 ISN 0046                   A(I,NP1)=B(I,1)
 ISN 0047      1006  CONTINUE
 ISN 0048            M7=1
 ISN 0049            N=JJ1-1
 ISN 0050            IF(N.LE.0)STOP
 ISN 0052            DET=1.
```

```
EVEL 2.2  (SEPT 76)          AAZM          OS/360  FORTRAN H EXTENDED              DATE 78.027/16.02.54        PAGE  2
 ISN 0053            L=N-1
 ISN 0054            NP=N+1
 ISN 0055            DO 36 K=1,L
 ISN 0056            M=K+1
 ISN 0057            ADD=DABS(A(K,K))
 ISN 0058            IR=K
 ISN 0059            DO 38 I=M,N
 ISN 0060            ATT=DABS(A(I,K))
 ISN 0061            IF(ADD-ATT)37,38,38
 ISN 0062      37    ADD=ATT
 ISN 0063            IR=I
 ISN 0064      38    CONTINUE
 ISN 0065            IF(IR-K)39,41,39
 ISN 0066      39    DET=-DET
 ISN 0067            DO 40 J=K,NP
 ISN 0068            S=A(IR,J)
 ISN 0069            A(IR,J)=A(K,J)
 ISN 0070      40    A(K,J)=S
 ISN 0071      41    DO 36 I=M,N
 ISN 0072            IF(A(I,K).EQ.0.0)GO1
 ISN 0074            S=A(I,K)/A(K,K)
 ISN 0075            DO 36 J=M,NP
 ISN 0076            A(I,J)=A(I,J)-S*A(K,J)
 ISN 0077      36    CONTINUE
 ISN 0078            X(N)=A(N,NP)/A(N,N)
 ISN 0079            DO 43 I=1,L
 ISN 0080            K=N-I
 ISN 0081            M=K+1
 ISN 0082            S=0.
 ISN 0083            DO 42 J=M,N
 ISN 0084      42    S=S+A(K,J)*X(J)
 ISN 0085            X(K)=(A(K,NP)-S)/A(K,K)
 ISN 0086      43    CONTINUE
 ISN 0087            IF(M7.LE.0)GOTO 30
 ISN 0089      30    CONTINUE
 ISN 0090            DO 1007 I=1,N
 ISN 0091                   B(I,1)=X(I)
 ISN 0092      1007  CONTINUE
 ISN 0093            RETURN
 ISN 0094            END
PTIONS IN EFFECT:NAME(MAIN) OPTIMIZE(1) LINECOUNT(60) SIZE(MAX) AUTODBL(NONE)
PTIONS IN EFFECT:SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT NOGOSTMT NOXREF NOALC NOANSF TERM FLAG(I)
TATISTICS:     SOURCE STATEMENTS =       93, PROGRAM SIZE =     76.[illegible], SUBPROGRAM NAME =  AAZM
TATISTICS:  NO  DIAGNOSTICS GENERATED
**** END OF COMPILATION ******                                          375K BYTES OF CORE NOT USED
TATISTICS:  NO  DIAGNOSTICS THIS STEP
```

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A D D E N D U M

The ratio of displacement thickness to momentum thickness, H, numerically quantifies the shape of the boundary layer. The "fuller" the profile, the smaller H.

The following admittedly over-simplified analysis suggests the trend discussed. A consideration of the following sketches indicates the typical values of H, and its relationship with other properties of the boundary layer.



ie. as H increases, τ decreases.

Thus $H = f(1/\tau)$

From Reynolds Analogy, and experimental results for heat transfer,

$St = c_f/2$ (Bird, Stewart and Lightfoot, 1960)

And with injection :-

$St = c_f/2 \times 1,16 \quad F = 0,004$ (Moffat and Kays, 1968)

Thus $St = f(1/H)$

However, c_f decreases with injection ratio, as does St (see Moffat and Kays, 1968).

Thus, as H increases, St decreases. From Fig 7.13, it is clear that H increased with F, and for the restricted flow case, H was higher for a given x station and injection ratio, for fixed primary and secondary flow rates.

By definition, $St = \frac{h}{\rho_\infty V_\infty}$ h = heat transfer coefficient

Heat transfer, $Q = h(t_e - t_w)$

If St decreases, so does h, and for hypothetically constant Q and t_e, t_w must decrease. Hence a lower wall temperature results, which is the desired effect.

Considering the injection velocity profile with blockage shown in Fig 7.14, leads to comparing it with the turbulent velocity, varying in space rather than with time. Although the average injected momentum is unaltered for a fixed secondary flowrate, it may be more meaningful to use some form of root mean square value for v_j with blockage. The greater penetration of y momentum clearly has a greater decellerating effect on the boundary layer - it may also decrease the heat transfer coefficient. However, only extensive experimentation can conclusively verify this qualitative speculation.

Author Krieg M
Name of thesis An investigation into practical aspects of transplantation flows 1978

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