TURBULENCE MEASUREMENTS
IN A
STRAIGHT CONICAL DIFFUSER

by

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ABSTRACT.

The turbulence parameters in a straight conical diffuser with a total included angle of $8^{\circ}\,8'$ were investigated. Quantity flow through the diffuser was kept constant and inlet boundary layer thicknesses were varied by introducing straight pipes of varying lengths before the diffuser. Measurements of turbulence parameters were made along various traverses at eleven stations in the diffuser. Some of the results obtained agreed with the findings of other workers in the field, and other of the results differed considerably. The turbulence intensities, cross correlation coefficients, and turbulent kinetic energies were calculated for each measuring point.

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I. INTRODUCTION

In 1966 the fluid mechanics section of the Mechanical Engineering Department at the University of Manitoba initiated a long term study of air flow in three - dimensional diffusers. It was hoped that this study would extend the work of H.Sprenger who completed an experimental analysis of the flow through a series of diffusers in 1959.

Sprenger was primarily concerned with determining the effects of the boundary layer on the incompressible flow in channels with adverse pressure gradients. He tested various straight and curved diffusers with circular entry and outlet cross - sections, and several straight and curved diffusers with circular entry cross - sections and elliptical outlet cross - sections. (Sprenger, 1959).

Sprenger found that a straight circular diffuser with an outlet to inlet area ratio of 4 : 1 and a total cone angle of 8° produced the best pressure conversion for all boundary layer thicknesses entering the diffuser. Later work by Cockrell and Markland (1963) and Mc Donald and Fox (1965) confirmed that conical diffusers with included angles of 4° to 10° had better pressure recovery characteristics than diffusers which were not in this angle range.

As a result of Sprenger's findings, R. Lipka of the University of Manitoba initiated plans to test a straight conical diffuser with an 8° included angle and an outlet to inlet area ratio of 4 : 1. It was hoped that Sprenger's

results could be repeated and that the conical diffuser could be used as a reference diffuser whose characteristics could be compared to the characteristics of circular - curved and elliptical - curved diffusers.

Unfortunately, discrepancies between Lipka's findings (Lipka, 1968) and Sprenger's results necessitated the repetition of the experiments in more detail. Since Lipka had not made any turbulence measurements and Sprenger had recommended that any extension of his work should include turbulence measurements inside the diffuser, it was decided that the turbulence intensities and the turbulent shear stresses within the diffuser would be measured during the new series of tests. This thesis deals with these turbulence measurements.

The Mechanical Engineering Department of the University of Manitoba intends to study the flow within the reference diffuser in detail and to extend this study to provide a generalized mathematical model for flow in three - dimensional diffusers of all shapes - particularly those shapes which are of use in fans, compressors, and turbines.

The next chapter shall deal with the equations of turbulent motion and the theory of operation of turbulence measuring equipment.

II THEORY

2.1. Introduction.

The purpose of this chapter is to introduce the concepts of turbulent flow and turbulent flow measurement.

Following the method of Hinze(1959) it will be shown how the equations of motion and energy for turbulent flows can be derived by a perturbation method. It will also be shown how this perturbation method can be used to arrive at a theory of measurement for turbulent flows.

In order to arrive at the equations for turbulent flow it is first necessary to note the method by which turbulent flows are characterized.

Usually a turbulent flow is considered to consist of two parts - an 'average' or 'mean' velocity $\bar{U}$, and an instantaneous velocity fluctuation, u. Consequently the instantaneous value of the total velocity U, is considered to be the sum of the 'mean' velocity plus the instantaneous velocity fluctuation or, $\bar{U} + u$. $\bar{U}$ is defined as $\lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} U\,dt$, where T and t both signify time, and U is the overall velocity. In practice a satisfactory $\bar{U}$ is obtained if $\partial\bar{U}/\partial t$ is zero, or is negligibly small. The violence, or intensity of the turbulence fluctuations is taken as the root mean square value of the time averaged instantaneous velocity fluctuations and is usually termed u'.

That is , $u' = \sqrt{\overline{u^2}}$. The overscore here denotes an average.

In the following text all averaging procedures will be denoted by overscores. Since it will be necessary to carry out averaging procedures on products of quantities as well as single quantities the properties of these overscores must be defined.

Given : $A = \overline{A} + a$

$B = \overline{B} + b$

where A and B can be any fluctuating quantities.

Then : $\overline{A} = \overline{\overline{A} + a} = \overline{\overline{A}} + \overline{a} = \overline{A} + \overline{a}$

from which $\overline{a} = 0$

Also : $\overline{\overline{A}\,\overline{B}} = \overline{\overline{A}}\,\overline{\overline{B}} = \overline{A}\,\overline{B}$

and : $\overline{\overline{A}\,b} = \overline{\overline{A}}\,\overline{b} = 0$

because $\overline{b} = 0$

Similarly: $\overline{\overline{B}\,a} = \overline{\overline{B}}\,\overline{a} = 0$

because $\overline{a} = 0$

Finally : $\overline{A\,B} = \overline{(\overline{A} + a)(\overline{B} + b)}$

$= \overline{\overline{A}\,\overline{B}} + \overline{\overline{A}\,b} + \overline{\overline{B}\,a} + \overline{a\,b}$

$= \overline{A}\,\overline{B} + \overline{a\,b}$

As an example of how these averaging procedures are applied to the equations of turbulent flow consider the continuity equation for compressible flow.

$$\frac{\partial e}{\partial t} + \frac{\partial}{\partial x_i}(e U_i) = 0 \qquad 2.1.1$$

where $i = 1, 2, 3$

ρ = density

x_i represents a standard cartesian coordinate system.

U_i = velocity along the three cartesian directions.

The continuity equation must be true at any instant in turbulent flows. It must also hold on the average.

Now, let $\rho = \overline{\rho} + \tilde{\rho}$

$U_i = \overline{U}_i + u_i$

where $\tilde{\rho}$ and u are instantaneous fluctuations and $\overline{U}_i$ and $\overline{\rho}$ are mean values.

Substituting these values in equation 2. 1. 1 , and applying an averaging procedure the following is obtained:

$$\frac{\partial}{\partial t}\overline{(\overline{\rho}+\tilde{\rho})} + \frac{\partial}{\partial x_i}\overline{(\overline{\rho}+\tilde{\rho})(\overline{U}_i + u_i)} = 0$$

Applying the given properties of overscores this becomes:

$$\frac{\partial \overline{\rho}}{\partial t} + \frac{\partial}{\partial x_i}(\overline{\rho}\,\overline{U}_i + \overline{\tilde{\rho} u_i}) = 0 \qquad 2.\ 1.\ 2$$

It can be seen that one extra term, $\overline{\tilde{\rho} u_i}$, has been added to the continuity equation as a result of the turbulent fluctuations.

2.2 Equations of Turbulent Motion for Incompressible Flows.

In a manner similar to the foregoing the equations of motion for turbulent flow can be derived from the Navier - Stokes equations.

The Navier - Stokes equations for an incompressible fluid of constant viscosity are:

$$\rho \frac{\partial U_i}{\partial t} + \rho U_j \frac{\partial U_i}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \mu \nabla^2 U_i \qquad 2.2.0.$$

$i = 1, 2, 3$
$j = 1, 2, 3$

Where:

$p =$ static pressure

$\mu =$ dynamic viscosity

$x_{i,j} =$ cartesian coordinates

$\nabla^2 =$ Laplace's operator

Introducing:

$$U_j = \bar{U}_j + u_j$$

$$U_i = \bar{U}_i + u_i$$

$$p = \bar{p} + \tilde{p}$$

Equations 2.2.0. become

$$\frac{\partial}{\partial t}(\bar{U}_i + u_i) + (\bar{U}_j + u_j)\frac{\partial}{\partial x_j}(\bar{U}_i + u_i)$$

$$= \frac{\partial}{\partial x_i}(\bar{p} + \tilde{p}) \cdot \frac{1}{\rho} + \nu \nabla^2 (\bar{U}_i + u_i) \qquad 2.2.1.$$

Where:

$$\nu = \frac{\mu}{\rho} = \text{kinematic viscosity}$$

The equation of continuity for incompressible turbulent flow is:

$$\frac{\partial}{\partial x_i}(\bar{U}_i + u_i) = 0 \qquad 2.2.2.$$

Therefore since $\frac{\partial \bar{U}_i}{\partial x_i}$ must equal zero, $\frac{\partial u_i}{\partial x_i}$ will equal zero as well

Now consider the term:

$$(\bar{U}_j + u_j)\frac{\partial}{\partial x_j}(\bar{U}_i + u_i)$$

from equation (2.2.1.)

This becomes:

$$\bar{U}_j \frac{\partial \bar{U}_i}{\partial x_j} + \bar{U}_j \frac{\partial u_i}{\partial x_j} + u_j \frac{\partial \bar{U}_i}{\partial x_j} + u_j \frac{\partial u_i}{\partial x_j} \qquad 2.2.3.$$

and

$$u_j \frac{\partial u_i}{\partial x_j} = \frac{\partial}{\partial x_j}(u_j u_i) - u_i \frac{\partial u_j}{\partial x_j} \qquad 2.2.4.$$

but

$$-u_i \frac{\partial u_j}{\partial x_j} = 0$$ because of equation (2.2.2.)

Similarly

$$\bar{U}_j \frac{\partial \bar{U}_i}{\partial x_j} = \frac{\partial}{\partial x_j}(\bar{U}_i \bar{U}_j) \qquad 2.2.5.$$

Applying an averaging procedure to the terms in (2.2.3.) and noting equations (2.2.4.) and (2.2.5.), (2.2.3.) becomes

$$\frac{\partial}{\partial x_j}(\bar{U}_i \bar{U}_j) + \frac{\partial}{\partial x_j}(\overline{u_i u_j})$$

Completion of the averaging procedure on the rest of equations (2.2.1.) results in

$$\frac{\partial \bar{U}_i}{\partial t} + \frac{\partial}{\partial x_j}(\bar{U}_i \bar{U}_j) = -\frac{1}{\rho}\frac{\partial \bar{P}}{\partial x_i} + \nu \nabla^2 \bar{U}_i$$

$$- \frac{\partial}{\partial x_j}(\overline{u_i u_j}) \qquad 2.2.6.$$

Equations (2.2.6.) are called the Reynolds equations, and they govern turbulent motion.

In conventional Cartesian notation using

$$u, v, w = u_1, u_2, u_3$$

$$x, y, z = x_1, x_2, x_3$$

and $U, V, W = \bar{U}_1, \bar{U}_2, \bar{U}_3$

equations (2.2.6.) become

$$\frac{\partial U}{\partial t} + \frac{\partial}{\partial x}(U^2) + \frac{\partial}{\partial y}(UV) + \frac{\partial}{\partial z}(UW) = -\frac{1}{\rho}\frac{\partial \bar{p}}{\partial x}$$

$$+ \nu \nabla^2 U - \frac{\partial}{\partial x}(\overline{u^2}) - \frac{\partial}{\partial y}(\overline{uv}) - \frac{\partial}{\partial z}(\overline{uw}) \qquad 2.2.7.$$

$$\frac{\partial V}{\partial t} + \frac{\partial}{\partial x}(UV) + \frac{\partial}{\partial y}(V^2) + \frac{\partial}{\partial z}(VW) = -\frac{1}{\rho}\frac{\partial \bar{p}}{\partial y}$$

$$+ \nu \nabla^2 V - \frac{\partial}{\partial x}(\overline{uv}) - \frac{\partial}{\partial y}(\overline{v^2}) - \frac{\partial}{\partial z}(\overline{vw}) \qquad 2.2.8.$$

$$\frac{\partial W}{\partial t} + \frac{\partial}{\partial x}(UW) + \frac{\partial}{\partial y}(VW) + \frac{\partial}{\partial z}(W^2) = -\frac{1}{\rho}\frac{\partial \bar{p}}{\partial z}$$

$$+ \nu \nabla^2 W - \frac{\partial}{\partial x}(\overline{uw}) - \frac{\partial}{\partial y}(\overline{vw}) - \frac{\partial}{\partial z}(\overline{w^2}) \qquad 2.2.9.$$

It is easily seen that equations (2.2.7.) through (2.2.9.) are the Navier - Stokes equations for incompressible flow with nine additional terms in u, v, and w.

These additional terms are called the Reynolds stresses and they are a direct result of the turbulent fluctuations in the fluid.

Ferrari (1959) explains these additional terms in the following manner :

Consider a fluid in turbulent motion and consider an infinitesimally small element of area $d\sigma_j$, perpendicular to the x_j axis.

The term $e\, d\sigma_j\, u_j\, dt$ would represent the mass flow through σ_j in time dt that is brought about by the turbulent agitation of the fluid. This mass flow would have an associated momentum directed along the x_i axis of the amount

$$dq_i = u_j u_i e\, d\sigma_j dt .$$

This transport of momentum can be interpreted as a force of magnitude $\frac{dq_i}{dt}$ upon $d\sigma_j$. This force would act in the same direction and sense as the positive x_i axis.

It would be exerted by the particle masses making up the negative normal side of area $d\sigma_j$ upon the fluid located on the positive normal side of $d\sigma_j$. Hence the force would be orientated in the same direction as the positive x_j axis.

Then by the principle of action and reaction it may be seen that there is an opposing force transmitted across the face of each elemental area that would be orientated perpendicularly to one of the axes x_j. This opposing force may be represented by the expression $\frac{dq_i}{dt} = -e u_i u_j d\sigma_j$.

If a time average for these forces is constructed, and if they are divided by $d\sigma_j$ such that they will represent stresses, the result is

$$\tau_{ij}^{(t)} = -\rho\,\overline{u_i u_j}$$

where $\tau_{ij}^{(t)}$ represents the time-averaged stress tensor.

Hence the "turbulent stresses" have originated because of the velocity fluctuations introduced into the fluid as a result of the turbulent motion.

If a quantity Π_{ij} is now defined as

$$\rho\left(\nu\,(\bar{U}_i + \bar{U}_j) - \overline{u_i u_j}\right) \qquad 2.\ 2.\ 10$$

it will be possible to write the Reynolds equations in a manner that is formally identical to the Navier - Stokes equations for incompressible flow.

Noting that

$$\frac{\partial}{\partial x_j}\left(\frac{\partial U_j}{\partial x_i} + \frac{\partial U_i}{\partial x_j}\right) = \nabla^2 U_i$$

by virtue of continuity, equations (2. 2. 6) can be written as.

$$\frac{\partial U_i}{\partial t} + \frac{\partial}{\partial x_j}(\bar{U}_i \bar{U}_j) = -\frac{1}{\rho}\frac{\partial \bar{p}}{\partial x_i} + \frac{\partial}{\partial x_j}(\Pi_{ji})\cdot\frac{1}{\rho} \qquad 2.\ 2.\ 11$$

Equations (2. 2. 11) are identical in form to equations (2. 2. 0).

The main difference between equations (2. 2. 11) and equations (2. 2. 0) is that the internal forces in equations (2. 2. 0) are all associated with viscous stresses, while in equations (2. 2. 11) the internal forces are associated with the sum of the viscous and the Reynolds stresses.

2.3. Dissipation of Energy in Incompressible Turbulent Flow.

In order to arrive at a set of equations for energy dissipation it is first necessary to note the following:

1. If the Navier - Stokes equations are multiplied by a velocity the resulting equations have the dimensions of energy per unit time per unit volume.
   That is, energy per unit time per unit volume has the dimensions,

$$\frac{ML}{T^2} \cdot L \cdot \frac{1}{L^3} \cdot \frac{1}{T} = \frac{M}{LT^3}$$

Where M = mass
L = length
T = time

Given the term $\rho \frac{\partial U}{\partial t}$ in the Navier - Stokes equations, and multiplying by a velocity, the following is obtained:

$$\rho U \frac{\partial U}{\partial t} \text{ has dimensions } \frac{M}{L^3} \cdot \frac{L}{T} \cdot \frac{L}{T^2} = \frac{M}{LT^3}$$

This is identical to that which was obtained previously.

2. Energy per unit mass per unit time would result if the Navier - Stokes equations were divided by ρ and multiplied by a velocity.

   Energy per unit mass per unit time has the dimensions.
   $\frac{ML^2}{T^2} \cdot \frac{1}{T} \cdot \frac{1}{M} = \frac{L^2}{T^3}$

   $\rho U \frac{\partial U}{\partial t} \cdot \frac{1}{\rho}$ has dimensions $\frac{M}{L^3} \cdot \frac{L}{T} \cdot \frac{L}{T^2} \cdot \frac{L^3}{M}$
   Which is $\frac{L^2}{T^3}$.

3. The turbulent flow of fluids is dissipative in nature. Because of the instability of the flow turbulent eddies break up and get smaller and smaller until they are dissipated in the form of heat.
4. Because of this dissipative nature a continuous supply of energy is required to maintain the turbulence.

5. Because of the turbulent motion diffusion of fluid particles, along with their kinetic energy, takes place.

6. Because of 3, 4, and 5 above, it is clear that an average steady state cannot exist unless the energy supplied to the turbulent motion is equalled by the diffusion of turbulent energy plus the dissipation of turbulent energy.

Now consider a unit mass of fluid subjected to normal and shearing stresses σ_{ij} .

The work done by these stresses per unit mass and time during the deformation of the fluid is

$$W = \frac{1}{e}\frac{\partial}{\partial x_i}\sigma_{ij} U_j \qquad 2.3.1.$$

or:

$$W = \frac{1}{e} U_j \frac{\partial \sigma_{ij}}{\partial x_i} + \frac{1}{e}\sigma_{ij}\frac{\partial U_j}{\partial x_i} \qquad 2.3.2.$$

By Newton's second law

$$\frac{\partial}{\partial x_i}\sigma_{ij} = e\frac{dU_j}{dt}$$

where

$$\frac{dU_j}{dt} = \frac{\partial U_j}{\partial t} + U_i\frac{\partial U_j}{\partial x_i} \qquad 2.3.3.$$

therefore

$$U_j\frac{\partial \sigma_{ij}}{\partial x_i} = e\,U_j\frac{dU_j}{dt} = \frac{1}{2}e\frac{d}{dt}(U_j U_j)$$

2.3.4.

Equation (2.3.4.) represents the change in kinetic energy per unit volume of the fluid particles.
$\sigma_{ij}\frac{\partial}{\partial x_i}U_j$, the other term in equation (2.3.2.) is the work of deformation of the fluid per unit volume. This work of deformation must equal the dissipation of energy per unit volume.

Substituting in equation (2.3.2.)

$$W = \frac{1}{2}\frac{d}{dt}(U_j U_j) + \frac{1}{\rho}\sigma_{ij}\frac{\partial}{\partial x_i}U_j \qquad 2.3.5.$$

It can be shown that σ_{ij} , the stress tensor, can be represented as the sum of the normal stresses and shearing stresses.

$$\sigma_{ij} = -p\,\delta_{ij} + \mu\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right) \qquad 2.3.6.$$

(Schlichting, 1968)

where δ_{ij} is the Kronecker delta

$\delta_{ij} = 1$ if $i = j$

$\delta_{ij} = 0$ if $i \neq j$

When equation (2.3.6.) is substituted into equation (2.3.5.)

$$W = \frac{1}{2}\frac{d}{dt}(U_j U_j) - \frac{p}{\rho}\delta_{ij}\frac{\partial U_j}{\partial x_i} + \nu\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right)\frac{\partial U_j}{\partial x_i}$$

2.3.7.

$$\delta_{ij}\frac{\partial U_j}{\partial x_i} = 0 \quad \text{if } i \neq j \text{, and } \frac{\partial U_i}{\partial x_i} \quad \text{if } i = j$$

Therefore

$$-\frac{p}{\rho}\delta_{ij}\frac{\partial U_j}{\partial x_i} = 0 \quad \text{by virtue of continuity}$$

Hence

$$W = \underbrace{\frac{1}{2}\frac{d}{dt}(U_j U_j)}_{\mathrm{I}} + \underbrace{\nu\left(\frac{\partial U_j}{\partial x_i} + \frac{\partial U_i}{\partial x_j}\right)\frac{\partial U_j}{\partial x_i}}_{\mathrm{II}}$$

2.3.8.

Where (2.3.8. I) is the change in kinetic energy per unit mass and time of the fluid elements and (2.3.8. II) is the dissipation of energy per unit mass and time of the fluid elements. If equation (2.3.6.) is introduced into equation (2.3.1.) and the result is expanded, the following occurs:

$$W = \frac{1}{\rho}\frac{\partial}{\partial x_i}\sigma_{ij}U_j = \underbrace{-\frac{\partial}{\partial x_i}(pU_i)}_{\mathrm{I}} + \underbrace{\nu\frac{\partial}{\partial x_i}U_j\left(\frac{\partial U_i}{\partial x_j}+\frac{\partial U_j}{\partial x_i}\right)}_{\mathrm{II}} \qquad 2.3.9.$$

where (2.3.9. I) represents the work done per unit mass and time by the hydrostatic pressure and (2.3.9. II) represents the work done per unit mass and time by the viscous stresses.

When equations (2.3.8.) and (2.3.9.) are equated, the energy equation is obtained.

$$\frac{1}{2}\frac{\partial}{\partial t}(U_jU_j) + \frac{1}{2}U_k\frac{\partial}{\partial x_k}(U_jU_j) = -\frac{\partial}{\partial x_i}\left(\frac{p}{\rho}U_i\right)$$

$$+\nu\frac{\partial}{\partial x_i}\left(U_j\left(\frac{\partial U_i}{\partial x_j}+\frac{\partial U_j}{\partial x_i}\right)\right) - \nu\left(\frac{\partial U_i}{\partial x_j}+\frac{\partial U_j}{\partial x_i}\right)\frac{\partial U_j}{\partial x_i}$$

2.3.10.

For an incompressible fluid

$$\frac{\partial U_k}{\partial x_k} = 0$$

Hence

$$U_k \frac{\partial}{\partial x_k}(U_j U_j) = \frac{\partial}{\partial x_k}(U_k U_j U_j) = \frac{\partial}{\partial x_i}(U_i U_j U_j)$$

Therefore equation (2.3.10.) becomes

$$\underbrace{\frac{1}{2}\frac{\partial}{\partial t}(U_j U_j)}_{\mathrm{I}} = \underbrace{-\frac{\partial}{\partial x_i}\left[U_i\left(\frac{p}{\rho} + \frac{U_j U_j}{2}\right)\right]}_{\mathrm{II}}$$

$$\underbrace{+\nu \frac{\partial}{\partial x_i}\left[U_j\left(\frac{\partial U_j}{\partial x_i} + \frac{\partial U_i}{\partial x_j}\right)\right]}_{\mathrm{III}} \underbrace{-\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right)\frac{\partial U_j}{\partial x_i}}_{\mathrm{IV}}$$

2.3.11.

The terms in equation (2.3.11.) have the following significance:

1. (2.3.11. I) is the local change in kinetic energy per unit mass and time.
2. (2.3.11. II) is the work done per unit mass and time by the sum of the static and velocity pressures.
3. (2.3.11. III) is the work done per unit mass and time by the viscous stresses.
4. (2.3.11. IV) is the dissipation of energy per unit mass.

Now, in order to see what influence turbulence fluctuations have on the equation (2.3.11.) the usual perturbation method is followed.

$$U_i = \bar{U}_i + u_i$$

$$p = \bar{p} + \tilde{p}$$

$$U_i U_i = \bar{U}_i \bar{U}_i + 2\bar{U}_i u_i + u_i u_i$$

$$= \bar{U}_i \bar{U}_i + 2\bar{U}_i u_i + q^2$$

If these above are substituted into equation (2.3.11.) and an averaging procedure is carried out, the following occurs:

$$\underbrace{\frac{1}{2}\frac{\partial}{\partial t}(\bar{U}_j\bar{U}_j)}_{A} + \underbrace{\frac{1}{2}\frac{\partial}{\partial t}(\bar{q}^2)}_{B} = \underbrace{-\frac{\partial}{\partial x_i}\left[\bar{U}_i\left(\frac{\bar{p}}{\rho} + \frac{1}{2}\bar{U}_j\bar{U}_j\right)\right]}_{C}$$

$$\underbrace{-\frac{\partial}{\partial x_i}\overline{\left[u_i\left(\frac{p}{\rho} + \frac{q^2}{2}\right)\right]}}_{D} \underbrace{- \frac{1}{2}\frac{\partial}{\partial x_i}(\bar{U}_i\bar{q}^2)}_{E} \underbrace{- \frac{\partial}{\partial x_i}(\bar{U}_j\overline{u_i u_j})}_{F}$$

$$\underbrace{+\nu\frac{\partial}{\partial x_i}\left[\bar{U}_j\left(\frac{\partial \bar{U}_i}{\partial x_j} + \frac{\partial \bar{U}_j}{\partial x_i}\right)\right]}_{G} \underbrace{+ \nu\frac{\partial}{\partial x_i}\overline{\left[u_j\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right]}}_{H}$$

$$\underbrace{-\nu\left(\frac{\partial \bar{U}_i}{\partial x_j} + \frac{\partial \bar{U}_j}{\partial x_i}\right)\frac{\partial \bar{U}_j}{\partial x_i}}_{I} \underbrace{- \overline{\nu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_j}{\partial x_i}}}_{J}$$

The above shall be termed equations (2.3.12.) and are the energy equations for a turbulent flow field.

In order, however, to assess explicitly the energy contributions of the turbulence fluctuations alone it is necessary to eliminate the mean motion terms. Consider the Navier - Stokes equations for turbulent flow in the form

$$\rho\left[\frac{\partial \bar{U}_j}{\partial t} + \frac{\partial}{\partial x_i}(\bar{U}_i \bar{U}_j)\right] = -\frac{\partial \bar{p}}{\partial x_j} + \frac{\partial}{\partial x_i}\left(\mu \frac{\partial \bar{U}_j}{\partial x_i} - \rho \overline{u_i u_j}\right)$$

2.3.13.

If equations (2.3.13.) are multiplied by U_j and divided by ρ they will have the same units as equations (2.3.12.). (Cf. previous argument on dimensions)

Thus $\frac{U_j}{\rho}$ times equations (2.3.13.) becomes

$$\frac{1}{2}\frac{\partial}{\partial t}(\bar{U}_j \bar{U}_j) + \frac{\partial}{\partial x_i}(\bar{U}_i \bar{U}_j \bar{U}_j) = -\bar{U}_j \frac{\partial \bar{p}}{\partial x_j} + \nu \bar{U}_j \frac{\partial^2 \bar{U}_j}{\partial x_i \partial x_i}$$

$$- \bar{U}_j \frac{\partial(\overline{u_i u_j})}{\partial x_i}$$

Because of continuity

$$\frac{\partial^2 \bar{U}_j}{\partial x_i \partial x_i} = \frac{\partial}{\partial x_i}\left(\frac{\partial \bar{U}_j}{\partial x_i} + \frac{\partial \bar{U}_i}{\partial x_j}\right)$$

and

$$-\bar{U}_j \frac{\partial \bar{p}}{\partial x_j} = -\frac{\partial}{\partial x_j}(\bar{p}\bar{U}_j)$$

Recalling that $\bar{p}$ is actually $\bar{p}\delta_{ij}$, it can be said that

$$-\frac{\partial}{\partial x_j}(\bar{p}\,\bar{U}_j) = -\frac{\partial}{\partial x_i}(\bar{p}\,\bar{U}_i)$$

Hence equations (2.3.13.) become

$$\underset{(i)}{\frac{1}{2}\frac{\partial}{\partial t}(\bar{U}_j\bar{U}_j)} = \underset{(ii)}{-\frac{\partial}{\partial x_i}\bar{U}_i\left(\frac{\bar{p}}{\rho}+\frac{1}{2}\bar{U}_j\bar{U}_j\right)} + \underset{(iii)}{U_j\frac{\partial}{\partial x_i}\left(\frac{\partial U_i}{\partial x_j}+\frac{\partial U_j}{\partial x_i}\right)}$$

$$\underset{(iv)}{-\bar{U}_j\frac{\partial}{\partial x_i}(\overline{u_iu_j})} \qquad 2.3.14.$$

If equations (2.3.14.) are subtracted from equations (2.3.12) it can be seen that the following will happen:

2.3.12. A - 2.3.14. i = 0
2.3.12. C - 2.3.14. ii = 0

If 2.3.12. G is expanded, the subtraction will result in the following:

$$\frac{1}{2}\frac{\partial\bar{q}^2}{\partial t}+\frac{1}{2}\frac{\partial(\bar{U}_i\bar{q}^2)}{\partial x_i} = -\frac{\partial}{\partial x_i}\overline{\left[u_i\left(\frac{p}{\rho}+\frac{1}{2}q^2\right)\right]} - \frac{\partial}{\partial x_i}(\bar{U}_j\,\overline{u_iu_j})$$

$$+\bar{U}_j\frac{\partial}{\partial x_i}(\overline{u_iu_j}) + \nu\frac{\partial}{\partial x_i}\overline{\left[u_j\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)\right]} - \nu\overline{\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_j}{\partial x_i}}$$

or

$$\frac{1}{2}\left[\frac{\partial}{\partial t}(\bar{q}^2) + \bar{U}_i \frac{\partial(\bar{q}^2)}{\partial x_i}\right] = -\frac{\partial}{\partial x_i}\overline{u_i\left(\frac{p}{\rho} + \frac{q^2}{2}\right)} - \bar{U}_j \frac{\partial(\overline{u_i u_j})}{\partial x_i}$$

$$+ \overline{u_i u_j}\frac{\partial \bar{U}_j}{\partial x_i} + \bar{U}_j \frac{\partial(\overline{u_i u_j})}{\partial x_i} + \nu \frac{\partial}{\partial x_i}\left[\overline{u_j\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)}\right]$$

$$- \nu \overline{\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_j}{\partial x_i}}$$

which becomes

$$\underset{\mathrm{I}}{\frac{d(\bar{q}^2)}{dt}} = \underset{\mathrm{II}}{-\frac{\partial}{\partial x_i}\left[\overline{u_i\left(\frac{p}{\rho} + \frac{q^2}{2}\right)}\right]} \underset{\mathrm{III}}{- \overline{u_i u_j}\frac{\partial \bar{U}_j}{\partial x_i}}$$

$$\underset{\mathrm{IV}}{+ \nu \frac{\partial}{\partial x_i}\left[\overline{u_j\left(\frac{\partial u_j}{\partial x_i} + \frac{\partial u_i}{\partial x_j}\right)}\right]}$$

$$\underset{\mathrm{V}}{- \nu \overline{\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_j}{\partial x_i}}} \qquad 2.3.15.$$

Equations (2.3.15.) are the equations which show how the actual turbulent energy terms act. The various terms in equation (2.3.15.) have the following significance:

1. 2.3.15. I represents the change in kinetic energy per unit mass for the turbulence fluctuations.
2. 2.3.15. II represents the convective diffusion by turbulence of the total turbulence energy.
3. 2.3.15. III represents the energy transferred from the mean motion by the Reynolds stresses. It represents the production of the turbulence energy
4. 2.3.15. IV represents the work done per unit mass per unit time by the viscous shear stresses of the turbulent motion.
5. 2.3.15. V represents the dissipation of energy per unit mass by the turbulent motion.

For the purposes of this work there is a very interesting point to be noted about the energy production term in the energy equation. Consider this 'production' term,

$$-\overline{u_i u_j}\frac{\partial \bar{U}_j}{\partial x_i} \qquad 2.3.16.$$

For the purposes of discussion, assume a mean motion along the x_1 axis and assume that $\frac{\partial \bar{U}_1}{\partial x_1} > 0$.

The term (2.3.16.) corresponding to this would be $-\overline{u_1^2}\frac{\partial \bar{U}_1}{\partial x_1}$

That is, the negative sign would be retained. In other words, a positive velocity gradient would result in a decrease in turbulent energy.

On the other hand, assume that $\frac{\partial \bar{U}_1}{\partial x_1} < 0$.

The corresponding term (2.3.16.) would now be $\overline{u_1^2}\frac{\partial U_1}{\partial x_1}$ or, turbulence energy would increase.

Since a negative velocity gradient is usually associated with an increasing static pressure, the turbulent energy would be expected to increase in a diffusive process. That this is in fact the case will be shown in Chapter V.

2.4. Theory of Measurement of Turbulence Parameters.

2.4.1. Introduction

The measurement of turbulence parameters is complicated by the very nature of the turbulent flow. The fact that turbulent flow is random, fluctuating, and three - dimensional requires that any device used to acquire physical knowledge about that flow has the following characteristics:

1. The sensing element must be small enough to cause only the minimum possible disturbance of the flow.
2. The sensing element must have as rapid as possible a response to high frequency fluctuations.
3. The instrumentation associated with the sensing element must be stable enough to preclude the necessity of frequent recalibration.

The hot - wire anemometer is, to date, the instrument which best satisfies these conditions.

2.4.2. Hot - Wire Anemometry - General

There are two types of hot - wire anemometer. These are the constant current hot - wire anemometer and the constant temperature hot - wire anemometer.

The constant current hot - wire anemometer operates on the principle of heat transfer from a fine wire which is placed in the flow field and heated by passing a constant electrical current through it. As heat is transferred from the wire its temperature decreases, causing a change in the electrical resistance of the wire. This change in resistance causes a change in the voltage drop across the wire and this change in voltage produces a measurable signal.

The constant temperature anemometer operates on the same principle except that the wire is held at a constant temperature. When heat is transferred from the wire its temperature starts to change. This in turn brings about a change in wire resistance which changes the current through the wire. As soon as the current through the wire starts to change, however , the change is sensed and fed to a negative feed back amplifier. This negative feed back amplifier changes the current through the wire such that the wire regains its original temperature.

Figures 2.1.a and 2.1.b are block diagrams of the circuitry involved in both types of anemometer.

2.4.3. Theory of Operation of Hot - Wire Anemometers.

King (1914) found that the relationship describing the

cooling of a wire by a gas flow was:

$$\frac{I^2 Rw}{Rw-Rg} = A + B\sqrt{U} \qquad 2.4.1.$$

Where I = current through the wire
Rw = electric resistance of the wire.
Rg = resistance of the wire at the gas temperature.
U = mean flow velocity
A,B = constants depending on the length and diameter of the wire and the heat transfer properties of the gas.

The values of A and B have been calculated by theoretical considerations (King,1914), (Kramers,1946), but the most acceptable method to date for finding them is by calibrating the wire in a moving air stream. I^2 is plotted versus $U^{\frac{1}{2}}$ and a graph similar to figure 2.2 is obtained.

In order to see how equation (2.4.1) is modified by turbulence fluctuations for the constant temperature method, the following assumptions are made:

1. $I = \bar{I} + i$
2. $U = \bar{U} + u$
3. Rw is the wire resistance and is essentially constant because of the constant temperature of the wire.
4. All fluctuations are small.

Substituting (1) and (2) above in equation (2.4.1) gives:

$$(\bar{I} + i)^2 Rw = (Rw - Rg)\left[A + B\sqrt{\bar{U}}\left(1 + \frac{u}{\bar{U}}\right)^{\frac{1}{2}}\right] \qquad 2.4.2.$$

Expanding equation 2.4.2. and ignoring second order small terms gives

$$I^2 Rw + 2i\bar{I}\bar{R}w = (Rw - Rg)\left[A + B\sqrt{\bar{U}}\right] + (Rw - Rg)\, B\sqrt{\bar{U}}\,\frac{u}{2\bar{U}} \qquad 2.4.3.$$

Noting equation (2.4.1.) it can be seen that equation (2.4.3.) reduces to

$$2i\bar{I}\, Rw = (Rw - Rg)\, B\sqrt{\bar{U}}\,\frac{u}{2\bar{U}} \qquad 2.4.4.$$

Therefore

$$i = \frac{Rw - Rg}{4\bar{I}\, Rw}\, B\sqrt{\bar{U}}\,\frac{u}{2\bar{U}} \qquad 2.4.5.$$

Therefore, by Ohm's law, the voltage fluctuation, e, associated with the current fluctuation, i, will be

$$e = Rw\, i$$

The sensitivity, s, of the hot wire is defined as that quantity which, when multiplied by the velocity fluctuation, will give the voltage fluctuation of the wire. Therefore, if

$$e = Rw\, i = \frac{Rw - Rg}{4\,\bar{I}}\, B\sqrt{\bar{U}}\,\frac{u}{\bar{U}} = s\, u \qquad 2.4.6.$$

then s must be

$$\frac{Rw - Rg}{4\,\bar{I}}\;\frac{B\sqrt{\bar{U}}}{\bar{U}} \qquad 2.4.7.$$

In a manner similar to the preceding it is possible to arrive at a sensitivity for constant current operation. If s_{c-c} is defined as the constant current sensitivity it can be found that

$$s_{c-c} = \frac{(Rw - Rg)^2}{2\,\bar{I}\,Rg}\;\frac{B\sqrt{\bar{U}}}{\bar{U}} \qquad 2.4.8.$$

Dividing equation (2.4.7.) by (2.4.8.) gives

$$\frac{s}{s_{c-c}} = \frac{1}{2}\left[\frac{Rg}{Rw - Rg}\right]$$

It can be seen that, for values of $Rw/Rg > 3/2$, s is less than s_{c-c}. ie: the sensitivity for constant current operation for $Rw/Rg > 3/2$ is greater than that for constant temperature.

The previous discussion points out the fact that the signal which is obtained from the hot wire is a function of the velocity fluctuations. The quantities which are lumped together as the sensitivity are all constants and can be acquired by calibrating the hot wire in a steady air stream.

There are certain limitations to the hot - wire method of measurement. It will be of advantage to note them.

2.5. Limitations of Hot - Wire Anemometers.

The limitations of both the constant current and the constant temperature methods of measurement shall be pointed out here. It will be seen that, in general, the constant temperature anemometer has certain advantages which make it a more versatile instrument for general purpose use.

Perhaps the most severe limitation to the hot - wire method of measurement results from the fact that the wires have a thermal inertia. That is, a finite time must elapse between the impingement of a fluctuation on the wire and the

cooling of the wire. It is easy to see that high frequency fluctuations could create a situation such that the wire would not have time to react to each individual perturbation and hence an incorrect signal would be received. In short, the wire has a maximum frequency limit. Once this limit is exceeded the sensitivity of the wire decreases markedly.

The reciprocal of this maximum frequency limit is called the time constant of the wire and is denoted by the symbol M. It can be shown mathematically (Hinze,1959) that the M for constant temperature operation is .005 times the M for constant current operation. A qualitative discussion of this phenomenon will suffice here, however.

Consider a constant current hot wire. Before it can produce an accurate signal it must first achieve a final lower temperature, and this temperature is dictated by the violence of the eddy. A constant temperature hot - wire, however, need only start to change its temperature before a signal is produced. Since not as much heat need be transferred, the thermal inertia does not have as great an effect in the constant temperature case as it does in the constant current case.

The more appreciable lag in the constant current case causes the sensitivity to fall at high frequencies, and it also introduces a phase shift in the output signal. Both of these must be corrected. Hence the reason for the compensator in figure 2.1. a.

Another limitation which is inherent in constant current operations results from the changing temperature of the wire.

As was previously stated (Cf. section 2.1.) the constants A and B rely on the heat transfer properties of the gas in which the wire is immersed. If the wire temperature changes, the film temperature of the gas next to the wire changes and hence A and B change. This does not have very much effect if turbulence intensities are low, but for high intensities it is quite possible that results will be calculated on the basis of calibration curves that are not accurate for the given conditions. This will obviously not occur with a constant temperature hot wire.

Finally, it has also been proven that constant temperature hot - wires collect less dust, and consequently do not require as much recalibration as constant current hot wires. (Collis, 1962)

In conclusion then, it would appear that, in spite of its possible greater sensitivity than the constant temperature hot wire (Cf. section 2.4.), the constant current hot wire is suited for low frequency, low intensity turbulence only. The constant temperature hot wire is more expensive because of its elaborate feedback circuitry, but it is a far more versatile instrument. It is for these reasons that constant temperature hot wire anemometers were chosen for the experimental portion of this work.

2.6. Mechanics of Hot - Wire Measurement.

This section deals with the actual method by which intelligence is gathered from the hot - wire signals.

2.6.1. Turbulence Intensities.

The cooling of any hot - wire is determined mainly by the component of velocity perpendicular to the wire. (Hinze, 1959) Therefore in figure 2.3 it can be seen that the wires I and II would be most sensitive to the fluctuation components $u\sin\theta$ and $v\cos\theta$.

If the $\sin\theta$ and the $\cos\theta$ terms were lumped with the wire sensitivity it could be said that the wires would react principally to the $a\,u$ and $b\,v$ components of the turbulence fluctuations where $a = (s)(\sin\theta)$ and $b = (s)(\cos\theta)$.

If wires I and II have the same sensitivity, and if the velocity fluctuations are directed as shown in figure 2.3 it can be seen that the signals e_I and e_{II} from the wires would be

$$e_I = a\,u + b\,v$$

$$e_{II} = a\,u - b\,v$$

and that

$$e_I + e_{II} = 2\,a\,u$$

and that

$$e_I - e_{II} = 2\,b\,v$$

Thus by adding and subtracting the signals from wires I and II and knowing the wire sensitivity from a calibration curve, the values of the turbulence velocity fluctuations can be obtained.

The reason that no w component intrudes on the signals from wires I and II is that there is no component of mean velocity in the w direction. Consequently any contribution it could make would be negligible compared to u and v. (Cf. equations (2.4.2.) through (2.4.7.))

In order to measure the w component the wires I and II must be rotated 90° about the x axis and then w will replace v in the previous discussion.

It should be noted here that the value actually read on the hot wire anemometer is the root mean square value of the velocity fluctuations. The final results, when they are calculated, are $\sqrt{\overline{u^2}}$, $\sqrt{\overline{v^2}}$, and $\sqrt{\overline{w^2}}$.

2.6.2. Measurement of the Reynolds Stresses.

The Reynolds stresses are denoted by the tensor

$$-\rho \begin{pmatrix} \overline{u^2} & \overline{u\,v} & \overline{u\,w} \\ \overline{u\,v} & \overline{v^2} & \overline{v\,w} \\ \overline{u\,w} & \overline{v\,w} & \overline{w^2} \end{pmatrix} \qquad \text{(Cf. section 2.2)}$$

In order to measure these quantities it is necessary to find some way of acquiring the time averaged values of u multiplied by v, u multiplied by w, and v multiplied by w.

This is done in the following manner:

Consider a parameter $\qquad Ruv = \dfrac{\overline{uv}}{\sqrt{\overline{u^2}}\sqrt{\overline{v^2}}}$

This shall be termed the correlation coefficient between u and v.

Consider figure 2.3:

If the Root Mean Square values of e_I, e_{II}, e_{I+II}, and e_{I-II} can be found the following will result:

$$e_{I\ RMS} = \sqrt{\overline{(au + bv)^2}} = \sqrt{a^2\overline{u^2} + 2ab\overline{uv} + b^2\overline{v^2}}$$

$$e_{II\ RMS} = \sqrt{\overline{(au - bv)^2}} = \sqrt{a^2\overline{u^2} - 2ab\overline{uv} + b^2\overline{v^2}}$$

$$(e_I + e_{II})_{RMS} = \sqrt{4a^2\overline{u^2}}$$

$$(e_I - e_{II})_{RMS} = \sqrt{4b^2\overline{v^2}}$$

Now consider the term

$$\frac{e_{I\ RMS}^2 - e_{II\ RMS}^2}{(e_I+e_{II})_{RMS}(e_I-e_{II})_{RMS}}$$

Subsituting for the e values the result is,

$$\frac{a^2\overline{u^2} + 2ab\overline{uv} + b^2\overline{v^2} - a^2\overline{u^2} + 2ab\overline{uv} - b^2\overline{v^2}}{4ab\sqrt{\overline{u^2}}\sqrt{\overline{v^2}}}$$

Which reduces to $\dfrac{\overline{u\ v}}{\sqrt{\overline{u^2}}\sqrt{\overline{v^2}}}$

and this is equal to Ruv.

Therefore it is possible to measure $\overline{uv}$ if Ruv, $\sqrt{\overline{u^2}}$, and $\sqrt{\overline{v^2}}$ are known.

If the wires I and II are rotated 90° about the x axis $\overline{uw}$ can be found as well.

Unfortunately the measurement of $\overline{vw}$ presents a considerable problem. Since $\overline{vw}$ could not be measured during the experimental portion of this work it will not be discussed here. Suffice to say that it requires three anemometers and a three - wire hot wire probe.

The measurements discussed in this section are but a very few of the measurements which must be done in order to arrive at a comprehensive picture of the turbulent flow within a diffuser. They are, however, the only measurements which could be done at the present time.

2.7. Conclusion.

The preceding sections have discussed the general equations of motion for turbulent flows, the turbulence energy equations, and the theory behind turbulence measuring devices. Some of the limitations of the existing measuring instruments have been noted, and the mechanics of the measurements taken during the experimental portion of the work have been discussed.

The next chapter shall deal with a description of the test rig and the measuring instruments which were used.

III EXPERIMENTAL APPARATUS

3.1. Introduction.

This chapter describes the equipment that was used in the testing of the diffuser.

The requirements for the testing of the diffuser were as follows:

1. Air moving device
2. Wind tunnel
3. Flow straightener
4. Contraction nozzle
5. Straight pipes for boundary layer growth
6. Diffuser
7. Traversing mechanism and stand
8. Test equipment

Items 1. through 6. have been described in detail in Lipka (1968), and were assembled exactly as they had been by Lipka with one exception - Lipka's traversing mechanism was not used.

Figure 3.1 is a schematic representation of the wind tunnel and diffuser assembly and is a copy of the drawing from Lipka (1968). Figures 3.2 and 3.3 are photographs of the entire test setup as it appeared during the testing for this work.

The remainder of this chapter shall be a detailed description of those pieces of equipment which were not used by Lipka.

3.2 Stand and Traversing Mechanism.

A device was needed that could carry a sensing element into the diffuser from the diffuser outlet and would allow three dimensional movement of this sensing element.

It was decided that a combination of circular, transverse and longitudinal motion would be best suited to the problem at hand. Consequently the device shown in Figures 3.4 and 3.5 was designed. Its operation is as follows:

1. The hot - wire probe was mounted in a six foot aluminum tube oriented along the longitudinal axis of the diffuser.
2. This aluminum tube was fastened to a movable trolley such that the tube could be moved in and out of the diffuser. The motion of the trolley was perpendicular to the longitudinal axis of the diffuser.
3. The trolley ran on a track which was fastened to a circular frame capable of rotating through 360° .
4. The circular frame was mounted on a stand. When measurements were to be made, the stand was positioned in front of the diffuser such that the aluminum tube which carried the hot wire probe was true along the longitudinal axis of the diffuser.

With this arrangement it was possible to traverse any diameter at any position within the diffuser.

The following is a description of the wheel and the trolley assembly, and the trolley itself.

3.2.1. Wheel and Trolley Assembly.

Figure 3.6 is a drawing of the wheel and trolley assembly. The wheel portion of the assembly consisted of two standard bicycle wheel rims spot welded together. It had a diameter of 25 3/8 ", and was mounted on four rollers at points A, B, C, and D. The trolley track was mounted on the wheel by means of two 1/8 " steel flanges. The screws fastening the flanges to the wheel were considerably smaller than the holes through the flanges and this allowed for a certain amount of adjustment of the track in both elevation and tilt. The rollers upon which the wheel was mounted were made of brass to facilitate machining, and were mounted as shown in figure 3.7.

Because of the difficulty of maintaining close construction tolerances on the stand, and because of a certain degree of asymmetry in the bicycle wheels, the rollers were made adjustable in elevation.

3.2.2. Trolley.

Figures 3.8. and 3.9. are detailed drawings of the trolley. The trolley was fashioned from aluminum to facilitate machining and ran along the 3"x 1½" aluminum channel on two brass rollers. Guide slots were cut into the channel to keep the trolley stable in elevation and to provide a means of clamping the trolley in one fixed position. Subsequent testing showed that these clamps were insufficient and two more clamps were installed on the body of the trolley. The probe holder fitted through the 0.69" radius hole in the trolley, and could be fixed in

position by the probe holder lock screw.

The position of the probe holder, and hence the probe, was determined by a centimeter scale fastened to the bottom of the trolley track.

The size of the trolley was dictated by the size of the trolley track and the diameter of the diffuser outlet. Tolerances on the probe holder hole and the guide slots were dictated by ease of longitudinal movement of the probe holder and ease of transverse movement of the trolley. In short, the tolerances on the entire assembly were rather liberal, and were not the same for each piece. Hence the lack of information regarding tolerances in the drawings.

3.3. Test Equipment.

The equipment used for the experimental work was as follows:

3.3.1. Hot - Wire Anemometers.

Two Disa Type 55A01 constant temperature hot - wire anemometers, serial numbers 338 and 817 were used to make the turbulence measurements. Figure 3.10 is a photograph of this type of instrument with an external D.C. Voltmeter.

The frequency response of this instrument was 0 - 60 kHz, it had a probe operating resistance range of 0 - 50 Ω and a maximum available probe current of 250×10^{-3} amperes.

The D.C. Voltmeter with the instrument (marked V in Fig. 3.10) had operating ranges of 20, 10, 5, and 2 volts full scale, with zero - shift D.C. voltages of 1, 2, 5, and 10 volts. The meter accuracy was $\pm$ 1 %. This meter indicated bridge D.C. Voltage.

The RMS indicator (marked mV in Fig 3.10) had ranges of 5, 10, 20, 50, 100, 200, 500 and 1000 mV RMS full scale. It measured the RMS value of bridge voltage (velocity) fluctuations to 2 % accuracy.

The instrument had two input filters designated as high pass and low pass and these had settings of 0, 5, 20, 50, 100, 200, 500, and 1000 Hz and 0, 1, 2, 5, 10, 20, 50, 100 kHz respectively.

The maximum R.M.S. instrument noise level under normal operating conditions with the low pass filter set to 5 kHz was 0.7×10^{-3} volts.

The power supply for the instrument was switchable to 90, 100, 105, 110, 115, 120, 130 volts AC and 200, 210, 215, 220, 225, 230, and 240 volts AC, at either 50 or 60 Hz. Line voltage variations of $\pm$ 10 % were permitted in addition to these values. The power consumption was 190 Watts.

The instrument was 12.1 inches high, 16.25 inches wide, 14.45 inches deep, and weighed approximately 50 lbs.

3.3.2. Hot - Wire Probes.

The type of hot - wire probe used was a Disa 55A32 X - probe mounted on a Disa 55A30 X - probe holder. Figure 3.11 is a drawing

of the probe and probe holder.

The 55A32 X - probe is used in gases. The sensor material is platinum plated tungsten wire, 5 microns in diameter. The maximum sensor temperature allowed is 300° C, and the maximum ambient temperature (ie: temperature in which the sensor can be used) allowed is 150° C. The frequency response drops 3 db at 25 kHz for a mean gas flow of 100 ft/sec, but the frequency response is better at higher mean speeds.

The probe was connected to the two anemometers by standard Disa 5 meter, 2.5 ohm coaxial cables. [illegible]

3.3.3 Correlator.

The signals from the two anemometers were fed to a Disa type 55A06 Random Signal Indicator and Correlator, serial number 320, and all turbulence measurements were taken on the Correlator RMS. (Root Mean Square) meter.

The Correlator was capable of measuring the RMS. values of two signals, the RMS. value of their sum, and the RMS. value of their difference. The RMS. meter had a - 3 db frequency response of 3 Hz - 200 kHz with voltage ranges of .01, .0315, .1, .315, 1, 3.15, 10, 31.5, and 100 volts full scale.

The noise and hum level of the instrument was less than 50×10^{-6} volts RMS. The Voltmeter accuracy was ± 2 % at full - scale deflection.

The instrument also had a ratiometer and could provide a time derivative of one channel of the input signals. This meter could not be used for the present work. Information on it can be acquired from Disa (1962).

The correlator was 12.1 inches high, 16.25 inches wide, 14.45 inches deep, and weighed approximately 35 lbs.

Figure 3.12 is a photograph of the correlator hooked up to the two anemometers. The correlator is the middle instrument.

3.3.4. Digital Voltmeter.

Because of velocity fluctuations an averaging Bridge meter was used. The bridge D.C. Voltage, which is an indication of the mean flow velocity, was measured by a Disa type 55A30 Digital Voltmeter, serial number 321, which was connected to one of the anemometers. Fig. 3.10 is a close - up photograph of the anemometer and the digital voltmeter.

The Voltmeter had three ranges, 0.000 - 1.000 volts, 00.00 - 10.00 volts, and 000.0 - 100.0 volts. It had an accuracy of .3 % of full scale and a 500 volt overload capacity. The input could be averaged over periods of 1, 3, or 10 seconds. The power supply could operate on 110 or 220 volts ± 10 % at 50 or 60 Hz.

The instrument was 4.2 inches high, 8.35 inches wide, 9.25 inches deep, and weighed 7.7 pounds.

Figure 3.13 is a schematic representation of the entire test equipment hook - up.

3.3.5. Probe Calibration Equipment.

All probes used were calibrated with a Disa type 55D41 Calibration unit, serial number 240, in conjunction with a Disa type 55D42 motor control unit, serial number 142. (See Figure 3.14)

The calibration unit provided a low turbulence wind tunnel which could be used for probe calibration. It was used in conjunction with a Betz micromanometer, serial number 670120, which had a differential range of 400 mm of H_2O, in .1 mm increments.

The calibration unit provided continuously variable air speeds of 3.28 feet/sec to 656 feet/sec. The background turbulence of the wind tunnel was rated at less than 0.15 % at 328 ft/sec and 5 kHz bandwidth. The unit was 40.5 inches long, 15.75 inches wide, 11.8 inches high, and weighed approximately 44 pounds.

The power supply for the calibration unit was a variable transformer which had a tapped primary that would permit operation from 100, 110, 120, 200, 220, or 240 V AC at 50 or 60 Hz. The maximum power consumption of the unit was 500 Watts. The transformer was 9.7 inches wide, 7.5 inches high, 7.1 inches in depth, and weighed approximately 26 pounds.

3.3.6. Probe Repair Equipment.

All probes were repaired with a Disa type 55A11 micromanipulator, used in conjunction with an Olympus VS - IV Zoom microscope, serial # 201316. Figure 3.15 is a photograph of this apparatus. The power supply for the micromanipulator was a Unitek 1048 B capacitor discharge power supply which supplied ample current for probe welding. Standard Disa 5 micron platinum

coated tungsten wire was used to effect all probe repairs.

3.3.7. Miscellaneous Manometers.

In addition to the equipment previously mentioned two other manometers were used in the testing. These can be seen in Figure 3.3 . The manometer fluid used was Meriam red.(Specific Gravity = 0.827)

The large U tube manometer was used to measure the pressure drop across the contraction piece. It was the control for the tunnel calibration. It was fabricated of $\frac{1}{4}$ inch I.D. glass tubing and had a differential range of 30 inches in .1 inch increments.

The bank manometer consisted of a series of pizometer tubes and was connected to the diffuser at each measuring station for the purpose of measuring the differential static pressure along the diffuser. The pizometer tubes were of $\frac{1}{4}$ " I.D. glass and had a range of 13 inches in .1 inch increments.

3.4 Conclusion.

The aforementioned apparatus was all used during the experimental portion of this work. The next chapter shall deal with the experimental procedure followed during the testing of the diffuser.

IV EXPERIMENTAL PROCEDURE AND RESULTS

This chapter shall be divided into the following sections:

1. Preliminary Considerations and Tests
2. Testing Procedure
3. Interpretation of Readings
4. Post Experimental Tests

4.1. Preliminary Considerations and Tests

It was decided that the diffuser would be tested for only one inlet air speed and various inlet boundary layer thicknesses because previous work had indicated that diffuser performance was virtually the same for inlet air speeds of 50 ft/sec to 300 ft/sec. (Lipka, 1968)

It was also decided that measurements would be made at various points along the four traverses shown in Figure 4.1 at each of the eleven stations shown in Figure 4.2. These measurements were to be repeated for five different inlet boundary layer thicknesses.

It was necessary to make some preliminary tests to see how the test equipment would react to the existing test conditions and to ascertain just what type of flow could be expected in the diffuser. These shall now be discussed briefly.

4.1.1. Surface Roughness Measurements within the Diffuser.

Because turbulence measurements were to be made it was thought that surface roughness measurements within the diffuser would be valuable.

A Bruel and Kjoer type 6102 surface roughness meter with a 3910 motor drive and an MP 6100 pick up was used to make surface roughness measurements along the generator over a 3cm. distance about the points shown in Figure 4.3. Table 4.1 shows these results

It can be seen from Table 4.1 that the surface roughness varied randomly. It was thought that this variation was attributable to the fact that the interior surface of the diffuser had been coated with a ceramic substance and therefore had no regular lay.

4.1.2. Hot - Wire Probe Calibration.

The Disa 55A01 Anemometers were placed in operation according to the manufacturer's specifications. For the probes being used the high pass and low pass filters on both anemometers were found to require settings of 200 Hz and 5 kHz respectively.

The Disa 55A32 hot - wire probes were calibrated as per the instruction manual for the 55D41/42 probe calibration equipment.

This calibration entailed the reading of the anemometer Bridge D.C.Voltmeter for varying flow velocities. These readings formed the ordinate of a graph whose abcissa was the flow velocity. Graph 4.1, is an example of such a calibration curve.

The flow velocities were calculated on the basis of the differential pressure across the calibration equipment nozzle. The formula used for this calculation was

$$V^2 = \frac{2k}{k-1} RT_o \left[1 - \left(1 - \frac{\Delta P}{P_o}\right)^{\frac{k-1}{k}}\right] \qquad 4.1.1.$$

where

v = flow velocity (metres/sec)
k = the isentropic exponent for air, 1.4
R = 287.1 joules/kilogram °K
T_o = nozzle reservoir temperature (°K)
p_o = nozzle reservoir pressure (kg/cm^2)
Δp= differential pressure across the nozzle (kg/cm^2)

All Δp were measured with the Betz Micromanometer.

It was found that the differences between p_o and T_o and atmospheric conditions were negligibly small. Consequently no corrections had to be applied to equation (4.1.1.).

Probes were calibrated when it was necessary, (eg. after repairing a probe) and the calibration of the probes was checked frequently. (ie. prior to each new testing sequence)

It was found that the sensitivities of sides I and II of the X - probes (refer to Figure 3.11) were the same.

4.1.3. Tests for Vibration.

It was thought that the vibration of the probe in the air stream would affect the measurement of the turbulence

parameters. That is, that the vibration would cause wrong information to be fed to the anemometer.

With the low pass filter set at 200 Hz in order to cut out general flow unsteadiness turbulence intensities were checked at several points with the probe vibrating and with the vibrations damped. It was found that the effect of the vibrations was cut out by this filter setting as well.

4.1.4. Measurement of the Mean Velocity Components in the Radial Direction.

Since the flow field in the diffuser was expanding it was known that there would be components of mean velocity in the radial direction. It was necessary to see if these radial components were significant.

These radial velocity components were measured using the method of Fiedler and Sakagami (1964). It was found that these components were negligible compared to the longitudinal mean velocity. They were less than 1 % of the longitudinal velocity.

4.2. Testing Procedure

The procedure followed in the testing of the diffuser will now be described.

The apparatus was assembled as shown in Chapter 3 and it was decided that the first two tests would be made at the extreme limits of boundary layer thickness.

The pipes used for boundary layer growth were all 3.94 in. in inner diameter. These pipes were installed between the diffuser inlet and the contraction nozzle outlet. The ratio of the length of pipe installed (L), and the entrance diameter of the diffuser (D_e), was used to code the tests. High L/D_e ratios mean a greater boundary layer growth before the diffuser, and low L/D_e ratios mean a smaller boundary layer growth before the diffuser.

The first test was carried out at an L/D_e ratio of 0.6, the second test was carried out at an L/D_e ratio of 16.6, and subsequent tests were carried out at L/D_e ratios of 10.6, 4.6, and 1.6 in that order.

At every L/D_e ratio with the exception of 0.6 and 16.6 the method of testing was the same. It was found after the first two tests (L/D_e = 0.6 and 16.6) that the traversing mechanism could not follow satisfactorily along traverses 4 - 8, and 2 - 6. (See Figure 4.1.) Consequently the remaining three L/D_e ratios were tested along traverses 1 - 5 and 3 - 7 only. With this exception the testing for each L/D_e ratio proceeded in the following manner:

4.2.1. Wind Tunnel Calibration.

It was decided to test the diffuser with an average inlet velocity of 195 ft/sec and it was necessary to have some method of knowing when the average inlet velocity was at this level. With this in mind the tunnel was calibrated as follows:

1. A U tube manometer, (Cf Section 3.3.7.) was connected between the inlet and the outlet of the contraction nozzle.

2. The wind tunnel fan was set at an arbitrary speed.

3. The hot wire probe tip was positioned in the diffuser inlet plane.

4. The mean velocities at the inlet were measured along traverses 1 - 5 and 3 - 7.

5. The wind tunnel fan was set at a different speed and the mean velocity readings were repeated.

6. After measurements at different fan speeds the average velocity for each fan speed was calculated and these average velocities were plotted versus the differential pressure across the contraction nozzle to form a calibration curve.

The average velocities were calculated by the formula

$$V = \frac{1}{2R^2} \int_{-R^2}^{R^2} u \, d(r^2) \qquad 4.2.1.$$

where

V = average inlet velocity (ft/sec),
R = inlet radius (5 cm),
r = any radial distance from the center line (cm),
u = velocity at any r (ft/sec).

For various points on a traverse values of u were plotted versus values of r^2. The resulting velocity profile was integrated by a planimeter and the area obtained was divided by $2R^2$ to obtain V. The V obtained for profile 1 - 5 was averaged with the V obtained for profile 3 - 7 to obtain a final value for inlet mean velocity.

During the calibration it was found that the liquid level in the U tube manometer bounced considerably. It was necessary to judge visually the point about which it was bouncing. Consequently the differential pressure readings obtained were not accurate to more than ± .2 inches.

Since local density changes affected the magnitude of the differential pressures these differential pressures were corrected for local density changes by the relationship

$$\frac{p_1 - p_2}{.075 \frac{B_a}{30} \cdot \frac{528}{460+T_a}} \qquad 4.2.2.$$

where

$p_1 - p_2$	=	pressure differential across contraction nozzle (inches of Meriam red),
Ba	=	barometric pressure (inches Of Hg),
Ta	=	atmospheric temperature (°F),
.075	=	specific weight of air at 68 °F and 30 inches of Hg.

Finally, in order to obtain a straight line graph, V was plotted versus

$$\sqrt{\frac{p_1 - p_2}{.075 \frac{B_a}{30} \cdot \frac{528}{T_a+460}}}$$

and the tunnel calibration curve was obtained. Graph 4.2 is an example of such a calibration curve for $L/D_e = 0.6$.

After the tunnel was calibrated the inlet average velocity was set to 195 ft/sec and the measurements began.

4.2.2. Anemometer Measurements.

At each station the traverses mentioned previously were measured. The measuring procedure was as follows:

1. The probe tip was positioned in the plane of the station being measured.

2. The probe tip was positioned as close as possible to the diffuser wall in the vertical plane and the trolley was clamped.

3. Five measurements were taken with the wires of the probe in the position they are shown in Figure 2.3. These measurements were called Av, Bv, (A+B)v, (A-B)v, and Bridge D.C. Voltage. The A signal was from side I of the probe and the B signal from side II. The Bridge D.C. Voltage measurement was read from the Digital Voltmeter and the other readings were taken from the RMS Indicator on the Random Signal Indicator and Correlator.

4. The probe was rotated 90° about the longitudinal axis of the diffuser and five more measurements called Aw Bw, (A+B)w, (A-B)w, and Bridge D.C. Voltage were taken. These measurements were read from the same indicators as in 3.

5. The trolley clamps were loosened, the probe was moved a short distance away from the wall, and 3. and 4. above was repeated. This went on until the opposite wall was reached.

The number of points measured on a traverse varied with the diameter of the station. In general more measurements were taken in the boundary layer than in that portion of the stream where the mean velocity did not vary as the station was traversed.

4.2.3. Differential Pressure Measurements.

The differential pressures between the diffuser stations were measured with a bank manometer (Cf. Section 3.3.7) which was hooked to the diffuser as is shown in Figures 3.2 and 3.3.

Measurements were made at various time intervals for each L/D_e ratio and the results were averaged to arrive at the final values.

During the measurements the liquid level in the manometers bounced considerably and it was necessary to visually average the readings which were taken. The accuracy of measurement was approximately ± .2 inches in 6 inches of Meriam red.

Graph 4.3 is a graph of the pressures along the diffuser for each L/D_e ratio.

4.3. Interpretation of Readings.

The various readings which were taken with the hot - wire anemometers were reduced to a usuable form in the following manner:

1. Bridge D.C. Voltage measurements were used to find the mean velocity at each measuring point. This mean velocity could be found directly from the probe calibration curve.

2. The (A+B)v, (A-B)v, (A+B)w, (A-B)w readings were used to find the turbulence intensities. The v subscripted readings measured u' and v', and the w subscripted readings measured u' and w'. The actual values of the intensities were found in the manner stated in section 2.6.1.

   The sensitivity of the hot wire to small voltage fluctuations was found by taking the slope (m) of the probe calibration curve at the mean velocity for each measuring point. Values of u' and v' were found by dividing the RMS sum or the RMS difference of the signals from the hot-wire by twice this slope.

   That is

$$u' = \frac{(A+B)_{v,w}}{2m}$$

$$v' = \frac{(A-B)_v}{2m}$$

$$w' = \frac{(A-B)_w}{2m}$$

The final value for u' was found by averaging the $\frac{(A+B)_v}{2m}$ and the $\frac{(A+B)_w}{2m}$ values for u'.

During the measurements it was found that some of the turbulence readings fluctuated considerably. This will be discussed later.

3. The Av,w and Bv,w readings were used in conjunction with the (A+B)v,w and (A-B)v,w readings to find the correlation coefficients Ruv, and Ruw. This was done by the method of section 2.6.2

That is

$$R_{uv} = \frac{A_v^2 - B_v^2}{(A+B)_v (A-B)_v}$$

$$R_{uw} = \frac{A_w^2 - B_w^2}{(A+B)_w (A-B)_w}$$

The results of these calculations are shown in Appendix A. All of the calculations were carried out by an IBM series 360 computer. The program used for the calculations is shown in Appendix B.

4.4. Post Experimental Tests.

4.4.1. Fan Stability Measurements.

Because of the bouncing of the contraction nozzle manometer and the bank manometer it was decided to check the fan speed regulation.

The fan control potentiometer was left at a constant setting for a period of time and the R.P.M. was checked at intervals. The R.P.M. was measured by the method of Lipka (1968). Table 4.2 is the result of this testing.

4.4.2. Diffuser Roundness.

Certain asymmetry in the flow prompted an accurate measurement of the interior roundness of the diffuser. The results of these measurements are shown in Table 4.3. The measurements were made as follows:

1. The diffuser was placed on a turntable with its x-axis at right angles to the turntable.
2. A dial gauge mounted on a rod which was parallel to the diffuser x-axis was set to mid-scale at position 1. (Cf. diagram, Table 4.3)
3. The turntable was rotated and readings were taken at each of the 8 positions shown. This was done for all 11 stations.

The preceding chapter described the methods used to arrive at the experimental results for this work. The following chapter will discuss these results.

V. ANALYSIS AND DISCUSSION OF RESULTS

The discussion of the experimental results shall proceed in the following order:

5.1 Surface Roughness Tests

5.2 Vibration Tests

5.3 Fan Speed Regulation Tests

5.4 Roundness Tests

5.5 Pressure Rise Along the Diffuser

5.6 Turbulence Tests

5.7 Discussion of Errors

5.1 Surface Roughness Tests.

It proved impossible to find an actual "value" of surface roughness throughout the diffuser (Cf. Table 4.1). However it can be stated that the maximum surface roughnesses encountered were so small (less than 150 microinches RMS) that the diffuser could be classified as smooth. Doyle et al (1964) state that the range of roughness such as this falls within the range of rougnness that would be encountered on a surface - ground finish. Surface grinding would produce a finish which would be about the same as the finish in a seamless copper tube.

5.2 Vibration Tests.

It was stated previously that the vibration of the hot-wire probe did not affect the turbulence readings (Cf. Section 4.1.3). The probable reason for this was that the high-pass filters on the anemometers were set at a value of 200 Hz. This meant that any fluctuation whose frequency was less than 200 Hz would have been heavily attenuated. Any vibrations in the probe which could have caused a spurious signal were far below 200 Hz. Unfortunately any true turbulence fluctuations below 200 Hz were cut out as well. This will be discussed in a later section.

5.3 Fan Speed Regulation Tests.

Table 4.2 shows the results of the tests which were carried out to determine whether or not the excessive bouncing in the manometers (Cf Sections 4.2.1 and 4.2.3) was caused by variations in fan speed.

It can be seen that the maximum variation in fan RPM was approximately 0.9 %. According to the fan laws the average flow will vary directly as the RPM.

Consequently this change of 0.9% could have caused a change of roughly 2 feet per second in the average flow velocity. Graph 4.2 will show that a change of 2 feet per second will be indicated by a $\sqrt{\frac{P_1 - P_2}{.075}}$ change of approximately 0.05 inches.
This could not possibly have been noticed on the U tube manometer. It is obvious that the manometers did not bounce because of variations in fan speed.

The reason for the relatively large bounce in the liquid in the manometers is unknown. The results of Lipka(1968) showed that the velocity profile entering the contraction nozzle was uniform and symmetrical and the presence of the straightening grids would have precluded any large scale turbulence fluctuations.

The only conclusion that can be drawn is that something in the combination of the contraction nozzle, the boundary

layer growth pipes, and the diffuser produced an instability in the flow.

5.4 Roundness Tests.

Table 4.3 shows the results of the tests which were done to determine the symmetry of the diffuser. It can be seen that the maximum amount the diffuser is out of round is roughly 0.05 inches, and this is for one station only.

It is doubtful that the asymmetry in the flow noted by Van der Spiegel (1968) at higher L/De ratios could have been caused by the slight asymmetry in the diffuser. It is more likely that his asymmetric mean velocity profiles were caused by the flow's being yawed by the boundary layer growth pipes or that there was something in the system which promoted more rapid boundary layer growth on one side of the pipe than on the other.

5.5 Pressure Rise Along the Diffuser.

Graph 5.1 is a plot of dp/dx along the diffuser for each L/De ratio. Considering the aforementioned accuracy of measurement in the bank manometers it can be stated that it would be as feasible to draw one average curve through the experimental points as it would be to draw separate curves through the points for each L/De ratio.

If there were a significant difference for the curves for each L/De ratio it could be said that the inlet boundary layer thickness affects the pressure recovery characteristics of the diffuser.

If, on the other hand, one average curve is the correct curve for all L/De ratios it could be said that inlet boundary layer thickness does not affect the pressure recovery characteristics of the diffuser.

The measurements taken were just not accurate enough to conclude which one of the above statements was true.

5.6 Turbulence Tests.

The results of the turbulence tests will be discussed as follows:

5.6.1 General Trends.

5.6.2 Agreement With Published Data.

5.6.3 Relationship of Turbulence Intensities to Boundary Layer Growth.

5.6.4 Reasons for Anomalies.

5.6.1 General Trends.

Graphs 5.2 through 5.19 are representations of u', v' and w' versus Y/D at every second station for each L/De ratio on the 3 - 7 traverse. These graphs are representative of the 1 - 5, 2 - 6, and 4 - 8 traverses as well.

Here:

Y = distance from top diffuser wall

D = diameter at the station.

From these graphs it can be seen that the turbulence intensities had the following characteristies:

1. For any given L/De ratio the peak values of turbulence intensity tended to move out from the diffuser walls as the outlet was approached.

2. The greater the L/De ratio the greater were the peak values of intensity, and the more rapid was the movement of these peaks away from the diffuser walls.

Graphs 5.20 through 5.25 are representations of $\rho(\overline{u^2}+\overline{v^2}+\overline{w^2})$ versus Y/D for the 3 - 7 traverse for every second station and each L/De ratio. The area under each curve is representative of the turbulent energy in the flow at that L/De ratio for the particular station. ρ was kept constant at .00242 lbm/ft^3 and this may have resulted in an error in energy magnitudes of up to 4%. The following trends could be noted:

1. Turbulent energy increased as the L/De ratio increased.

2. Turbulent energy increased as the outlet was approached.

3. The peaks of turbulent energy behaved the same way as the peaks of turbulent intensity.

Statement 2. above is consistent with theoretical considerations for energy production in an adverse pressure gradient. (Cf section 2.3)

Graphs 5.26 through 5.28 are plots of u', v' and w' versus Y/D for every second station for the 1 - 5 traverse of L/De = 10.6. Graphs 5.29 through 5.31 are the same graphs for the 3 - 7 traverse.

These graphs point out more clearly the motion of the peak turbulence intensities towards the centre of the diffuser as the outlet is approached.

Graphs 5.32 and 5.33 are graphs of $\rho(\bar{u}^2+\bar{v}^2+\bar{w}^2)$ for the 1 - 5 and 3 - 7 traverses of L/De = 10.6. It can be seen that the total energy increased as the outlet was approached.

Graphs 5.34 through 5.38 are representations of Ruv and Ruw under the same conditions as the graphs 5.26 through 5.33. The following trends can be noted for these graphs:

1. The values of Ruv and Ruw were lower in the mid Y/D range for stations nearer the inlet than for stations nearer the outlet.

2. There appears to be no pattern in the way the Ruv and Ruw values varied from positive to negative.

Ruv and Ruw ratios which are close to 1. imply that turbulence parameters are nearly the same in the x, y, and z directions. If they were exactly the same in the x, y and z directions the turbulence would be called isotropic.

It should be noted here that the L/De = 10.6 ratio was representative of all the L/De ratios. (Refer to Appendix A)

In general then the following statements can be made:

1. The greater the L/De ratio, the greater the turbulence intensities.

2. The greater the L/De ratio, the greater the turbulent energy.

3. The closer to the outlet, the greater the turbulence intensities.

4. The closer to the outlet, the greater the turbulent energy.

5. Peaks of turbulence intensity and energy moved towards one another as the outlet was approached.

6. The greater the L/De ratio, the more rapidly the peaks of both turbulence intensity and energy moved towards one another.
7. At stations close to the inlet the turbulence in the central portion of the diffuser was closer to being isotropic than it was at stations nearer the outlet.

8. In general the turbulence within the diffuser was non - isotropic and non - homogeneous, where homogeneous turbulence is defined as turbulence which has identical parameters at any point in a flow field. Homogeneous turbulence need not be isotropic.

5.6.2 Agreement With Published Data.

(i) Turbulence Intensities.

Laufer (1954) and Gaviglio (1958) measured turbulence parameters in fully developed pipe flow. Both of these researchers found the following :

1. The longitudinal component of turbulence intensity was at a maximum near the pipe wall and decreased to a minimum at the centre of the pipe.

2. The radial component of turbulence intensity was close to zero near the wall, rose to a peak as the pipe centre was approached, and fell to a low value at the pipe centre.

Graphs 5.2, 5.8, and 5.14 show that this was in fact the case for the diffuser inlet at the higher L/De ratios (10.6 and 16.6). It should be noted that the flow at the inlet was fully developed for L/De ratios of 10.6 and 16.6 only.

Therefore the turbulence intensities for fully developed flow at the diffuser inlet agreed with the turbulence intensities which had been found for fully developed pipe flow.

Spangenberg et al (1967) and Schubauer and Klebanoff (1951) have made turbulence intensity measurements in adverse pressure gradients. Spangenberg's results were of particular interest because they agreed so closely with the findings in the diffuser.

Spangenberg found the following for u' and v':

1. Turbulence intensities were low near the wall, rose to a peak as the boundary layer was traversed, and fell to a minimum as the local mean velocity approached the free stream velocity.

2. Turbulence intensities achieved higher peak values at measuring stations nearer the outlet of the test section. That is, peak values of turbulence intensity were higher at lower values of dP/dx.

These above results were identical to the findings in the diffuser. (CF Section 5.6.1)

(ii) Correlation Coefficients.

The correlation coefficients Ruv and Ruw which were found by Spangenberg et al (1967), Gaviglio (1958), Laufer (1951) did not agree at all with the values found for Ruv and Ruw in the diffuser.

The results obtained by Gaviglio for fully developed pipe flow were similar to the results obtained by Laufer. In both studies Ruv was approximately 0.3 near the wall, rose to about 0.5 as the boundary layer was traversed, and fell to zero at the centre of the pipe. It can be seen from appendix A and from graphs 5.34 through 5.37 that there appeared to be no pattern to the variation of Ruv or Ruw across any traverse in the diffuser.

Since the correlation coefficients varied erratically, the Reynolds stresses varied erratically. This made it impossible to derive a meaningful conclusion for the rate of production of turbulent energy. (CF. section 2.3) The only qualitative conclusion which could be drawn was that the positive values of Ruv and Ruw must have outweighed the negative values because the mean turbulent energy, $e(\overline{u^2}+\overline{v^2}+\overline{w^2})$, appeared to increase along the diffuser even though the true rate of transport of turbulent energy is

$$\int_A e\, u_i^2\, U dA$$

where U is local free stream velocity, and
A is cross-sectional area at the station.

5.6.3. Relationship of Turbulence Intensities to Boundary Layer Growth.

Van der Spiegel (1968) analyzed the turbulent boundary layer growth in the diffuser for all L/De ratios. The purpose of this section is to see if there was any relationship between the turbulence intensities and the boundary layer growth in the diffuser.

Prandtl first recognized that certain regions could be distinguished in a turbulent boundary layer. These are as follows:

1. A predominantly viscous region adjacent to the wall which is called either the viscous sublayer or the wall region.

2. A region just beyond the wall region in which the effect of viscosity decreases gradually with increasing distance from the wall. That is, a region in which the flow is partially viscous and partially turbulent. This region is called either the buffer region or the transition region.

3. A region of free turbulence which is characterized by a logarithmic mean velocity distribution. This region is called the logarithmic region.

4. A region called the wake region in which the local mean velocity is almost equal to the free stream velocity.

It is known that the maximum turbulence intensities in the boundary layer occur in the buffer region.(Hinze,1959)

Consider graphs 5.26 through 5.31, the graphs of turbulence intensities for L/De = 10.6.

It can be seen that, as the outlet of the diffuser was approached, the peak values of turbulence intensity moved further away from the diffuser walls and that the layers of higher turbulence intensity became larger. This implied that the buffer region was thickening and was moving further from the wall. This agreed with Van der Spiegel's results. He found that the buffer layer thickened as the outlet of the diffuser was approached.

Graphs 5.2 through 5.19 show the same trend as the above. They also show that the buffer layer was thicker for thicker entering boundary layers. This too was in agreement with Van der Spiegel's findings.

It should be noted here that the asymmetry which Van der Spiegel found in the growth of the boundary layer was indicated by the turbulence intensity measurements. Graphs 5.26 through 5.31 indicate a thicker boundary layer at the top of the diffuser than at the bottom, and a thicker boundary layer at the left of the diffuser than at the right. This is what was found by Van der Spiegel.

It can be said then, that the turbulence intensities reflected the boundary layer growth in the diffuser.

5.6.4 Reasons for Anomalies.

The only major difference between the results of the tests in the diffuser and findings which have been published previously is in the values found for Ruv and Ruw.

It has been stated that the Ruv and Ruw readings are erratic, and that the only conclusion that can be drawn from them is that they tend to be higher near the centre of the diffuser than near the walls for stations nearer the inlet. Unfortunately there are exceptions to even this tentative statement.

The only reason in sight for the gross differences between the correlations in the diffuser and the correlations noted by others is that the flow in the diffuser was not stable. The large amount of bouncing in the bank manometers implied a fairly large, erratic static pressure fluctuation and hence an erratic change in mean velocity. This means that the conditions governing the production of turbulence were constantly changing and this may have affected the correlation coefficients.

The fact that the turbulence intensities reflected published data need not contradict the above statement.

The setting on the high pass filter would have heavily attenuated fluctuations below 200 Hz. Consequently any large scale fluctuations due to a large change in mean velocity would have been filtered out. The values obtained for Ruv and Ruw however, depend on the degree of isotropy exhibited by the turbulence fluctuations. If the conditions governing turbulence production are changing it is likely that no consistent degree of isotropy can be attained.

In short then, the only reason that can be offered for the behaviour of the correlation coefficients is that the flow in the diffuser was unstable.

5.7 Discussion of Errors.

5.7.1 Error in Measurement.

The approximate errors in reading the manometers have already been mentioned. (Cf. Sections 4.2.1 and 4.2.3) and the errors involved in reading the anemometers were quite small.

The digital voltmeter could be read to the nearest 0.01 volts and this reading was rounded off to the nearest 0.05volts for the computer programs. This introduced an error of less than 1 % in the mean velocity readings. The error involved in reading a steady signal from the RMS voltmeter was negligible. The extreme number of meter ranges available made it

possible to read within 1 % of full scale.

A conservative estimate of the total error involved insofar as meter readings and calculations were concerned would be approximately 3 %. This includes the specified accuracy of the meters.

It was mentioned in Section 4.3 that certain of the turbulence readings fluctuated considerably. It was necessary to take a visual average of these readings, and in this case the error involved could have been as high as 15 % of the final result.

The fluctuations in the readings were charged to the phenomenon known as intermittency. Briefly, intermittency is a state whereby the fluid is turbulent for a period of time, then non - turbulent, then turbulent again, and so on. It occurs at the interface between a non - turbulent fluid and a turbulent one. Intermittency is charactarized by the intermittency factor, γ , which is the ratio of the length of time the fluid is turbulent to the period of time over which the turbulence measurements are made.

Since the fluctuations in measurement occurred at the lower L/De ratios (0.6, 1.6, and 4.6) at stations nearer the inlet it was thought that the central core of almost non - turbulent flow was interacting with the free turbulence, or logarithmic region of the boundary layer. No equipment was available for the quantitative measurement of intermittency.

Errors in the positioning of the probe were difficult to judge, but it can be said that the probe position was accurate to within $\pm$ 0.3 centimeters.

5.7.2 Error Due to Filter Settings.

It was mentioned previously that the high pass filters on both anemometers had been set at 200 Hz. It was quite probable that these settings affected the absolute magnitude of the turbulence intensities by removing those turbulence fluctuations which had frequencies below 200 Hz.

Laufer (1954) found that there was 25 times as much energy in his u' component at a wave number of 0.6, as there was at a wave number of 1.0. The wave number is defined as

$$\frac{2\pi n}{\bar{U}} \quad \text{cm.}^{-1}$$

where:

n = frequency of fluctuation (sec^{-1})

$\bar{U}$ = local mean velocity (cm./sec)

π = 3.1416

At the inlet to the diffuser the lowest wave number which could be obtained with a filter setting of 200 Hz was

$$\frac{6.2832 \times 200}{5950} = 0.211$$

As the outlet was approached this wave number would have become higher until it was approximately 1.0 near the wall on an outlet traverse. This means that portions of the u', v' and w' signals were being cut off in varying degrees throughout the diffuser. The effect that this had was to boost the magnitudes of the intensities near the centre of the diffuser relative to the intensities nearer the wall, and to boost the intensities near the inlet relative to those nearer the outlet. This means that the comparative values of the turbulence intensities are distorted. It should be noted that this will happen for any fixed setting of the high pass filters because the local mean velocities vary for a given traverse, and the mean velocity is changing throughout the length of the diffuser. However, had a lower filter setting been used, the distortion would probably not have been as great.

Unfortunately a filter setting low enough to minimize the comparative differences in intensity along the diffuser would have also allowed fluctuations due to vibration to affect the turbulence signal. It was the opinion of this author that the suppression if a portion of the actual signal was preferable to the introduction of a spurious signal because, when spectrum measurements are taken, the results of this work can be corrected.

The preceding chapter has discussed the results of the tests done on the diffuser, The next chapter shall state the conclusions which result from the work done and shall offer a few recommendations for future work

VI CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK.

The following conclusions can be drawn from the measurements which were taken:

1. The flow in the diffuser is unstable and asymmetric.

2. The turbulence in the diffuser is non - isotropic and non - homogeneous.

3. The turbulence intensity profiles near the inlet of the diffuser were similar to those which have been noted in fully developed pipe flow.

4. The turbulence intensity profiles reflected the boundary layer growth in the diffuser.

5. The turbulent energy in the diffuser increased as the diffuser outlet was approached, and this is in agreement with accepted theory.

6. Because of the erraticity of the flow, nothing meaningful could be concluded from the measurements of Ruv and Ruw.

The following is a list of suggestions for future work:

1. The instability in the diffuser flow should be removed. It is possible that a change in the shape of the contraction nozzle, or the addition of more flow straighteners would achieve this.

2. Careful consideration could be given to expanding the scale of the experiment. That is, perhaps the diffuser could be made larger so that it would be possible to take measurements within the diffuser more easily.

3. The problem of asymmetry in the boundary layer growth could be looked into.

4. Many more traverses than two could be measured at each station in order to give a more complete picture of the turbulence at any one station.

5. The traversing mechanism could be improved so that vibration would no longer be a determining factor in anemometer filter settings and so that the hot wire probe could be more accurately positioned.

6. Future studies could include measurements of spectrum, intermittency, longitudinal correlations, transverse correlations, and Rvw. Also very thorough measurements of Ruv and Ruw could be taken once the diffuser flow is no longer erratic.

In conclusion then, it can be said that this study of the turbulence parameters in the diffuser has shown that the turbulence intensities are in agreement with the findings for boundary layer growth, and that the Ruv and Ruw parameters require considerably more study. It is hoped that future work on the referencediffuser will benefit from what has been done here.

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TABLE 4.1.

DIFFUSER SURFACE ROUGHNESS MEASUREMENTS.

Position W	RMS μinches	Position S	RMS μinches
1 - 6"	52	1 - 4"	44 - 92
1 - 8"	20 - 32	1 - 6"	44 - 60
2 - 6"	16 - 95	1 - 8"	44 - 80
2 - 8"	28 -133	2 - 4"	32 - 60
3 - 6"	20 - 95	2 - 6"	32 - 60
3 - 8"	12 - 32	2 - 8"	32 - 65
4 - 6"	16 - 36	3 - 4"	40 - 72
4 - 8"	20 - 44	3 - 6"	44 -120
		3 - 8"	32 - 92
		4 - 4"	40 -140
		4 - 6"	32 - 60
		4 - 8"	40 - 64

Note: μinches = inches X 10^{-6}

TABLE 4.2.

FAN REGULATOR MEASUREMENTS.

Speed control setting = 65

Time	RPM	Time	RPM	Time	RPM
2:10	1040	3:13	1039	4:45	1049
2:15	1036	3:15	1035	4:46	1046
2:16	1039	3:45	1035	4:47	1048
2:17	1036	4:47	1039		
2:45	1039	4:15	1040		
2:47	1043	4:17	1045		

Speed control setting = 64.32

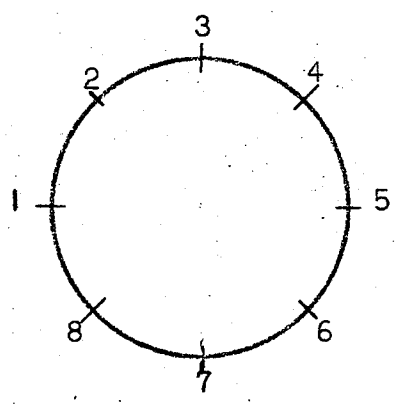
1:40	1000	2:46	1012	3:47	1019
1:45	1003	2:47	1012	4:16	1016
1:47	1006	3:15	1007	4:17	1017
2:15	1009	3:17	1003		
2:17	1012	3:45	1018		

Note: "Time" in above denotes time of day in hrs. and minutes. All times above are P.M.

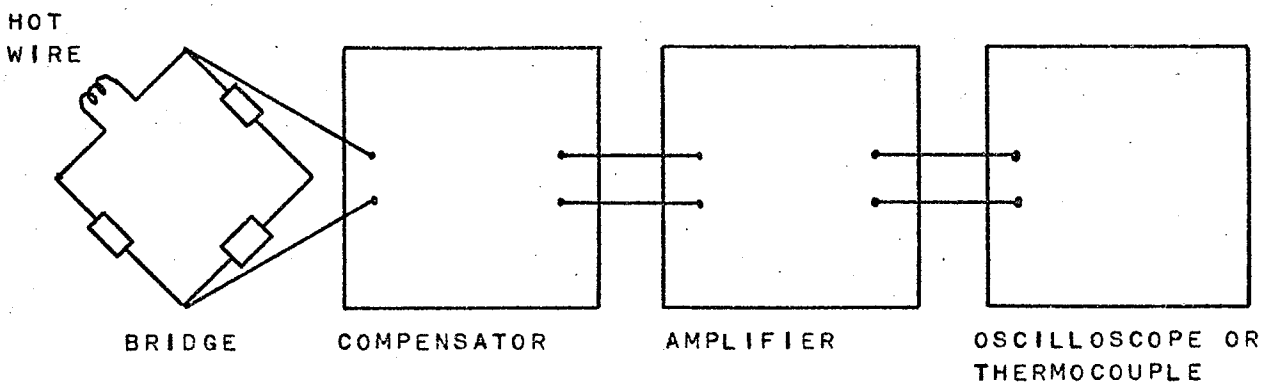
TABLE 4.3.

ROUNDNESS MEASUREMENTS

Stations	1	2	3	4	5	6	7	8
0	0	- 3	+ 2	+ 7	+ 6	+ 4	- 4	+ 7
1	0	+ 5	-14	+ 4	0	+12	- 5	- 4
2	0	- 4	-11	0	- 1	+10	-12	+ 5
3	0	+ 1	0	+ 5	- 4	+19	0	+10
4	0	+ 8	+14	+ 6	+ 5	+12	+ 4	+11
5	0	+10	+19	+13	+ 8	+20	+ 3	+12
6	0	+12	+27	+13	+ 8	+14	+ 3	+14
7	0	+20	+31	+ 2	+ 9	+13	+10	+23
8	0	+33	+37	+32	+15	+16	+16	+25
9	0	+37	+26	+36	+13	+14	+12	+20
10	0	+46	+45	+53	+ 7	+16	+19	+22

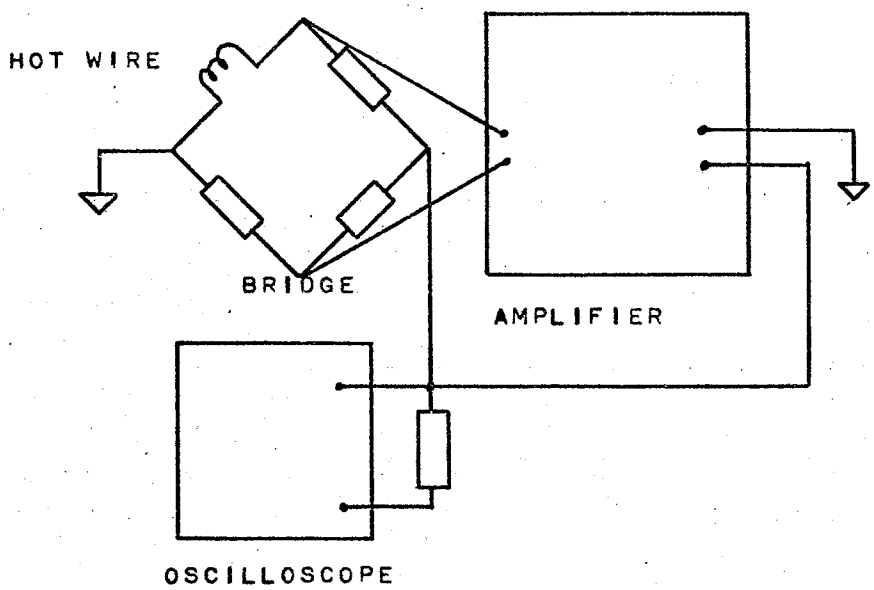


All measurements in thousandths of an inch.



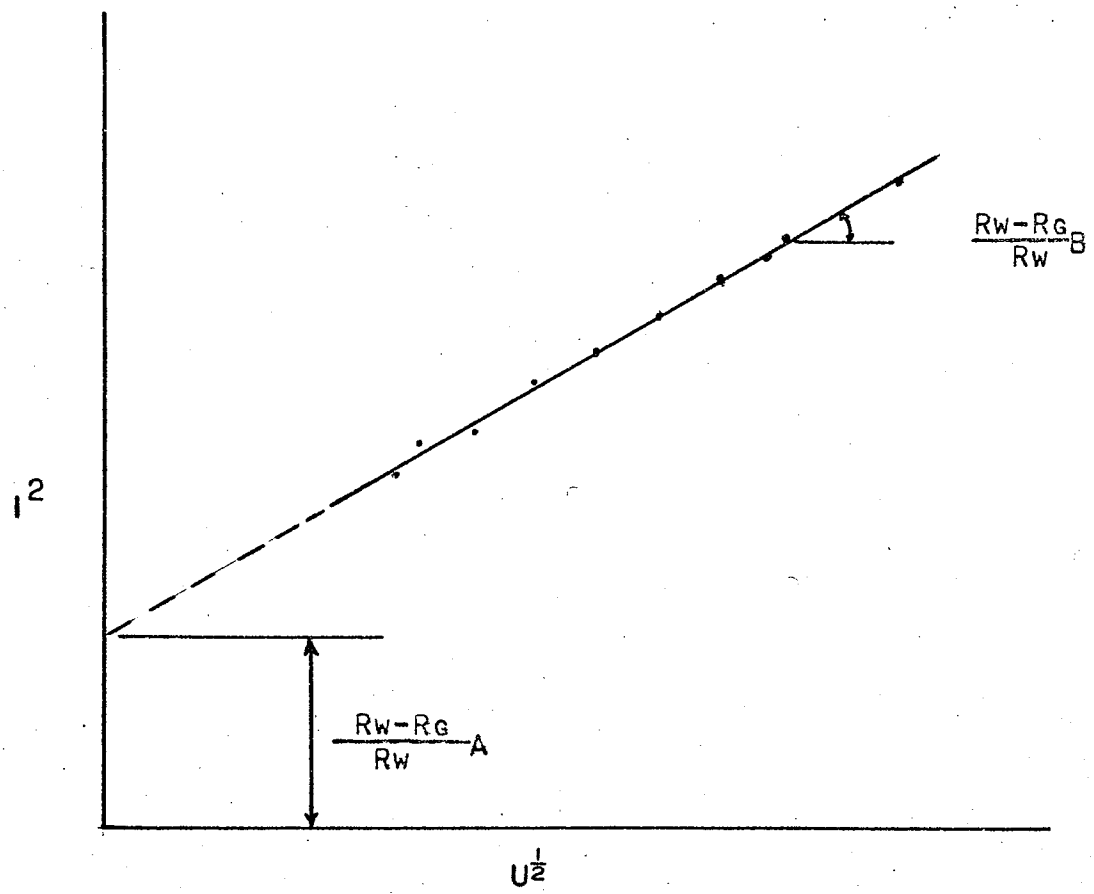
CONSTANT-CURRENT ANEMOMETER

FIGURE 2.1A



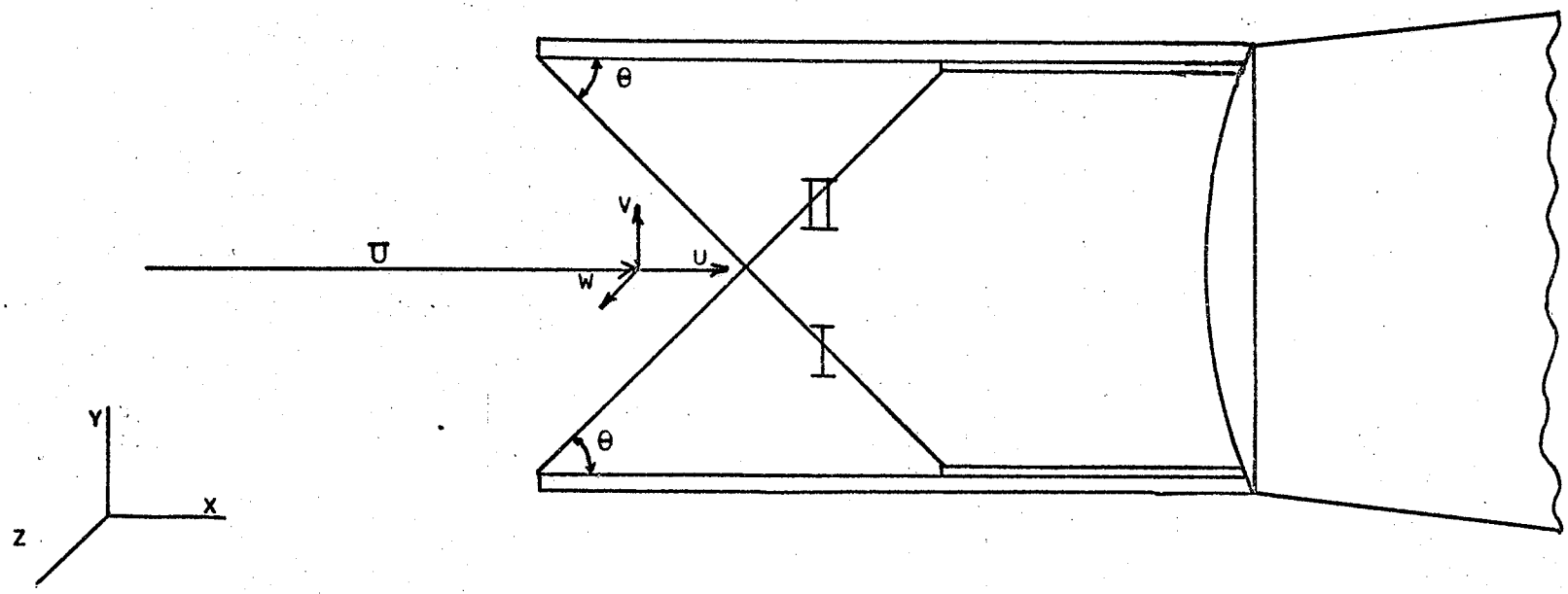
CONSTANT-TEMPERATURE ANEMOMETER

FIGURE 2.1B



METHOD OF PROBE CALIBRATION

FIGURE 2.2



X-PROBE CONFIGURATION

FIGURE 2.3

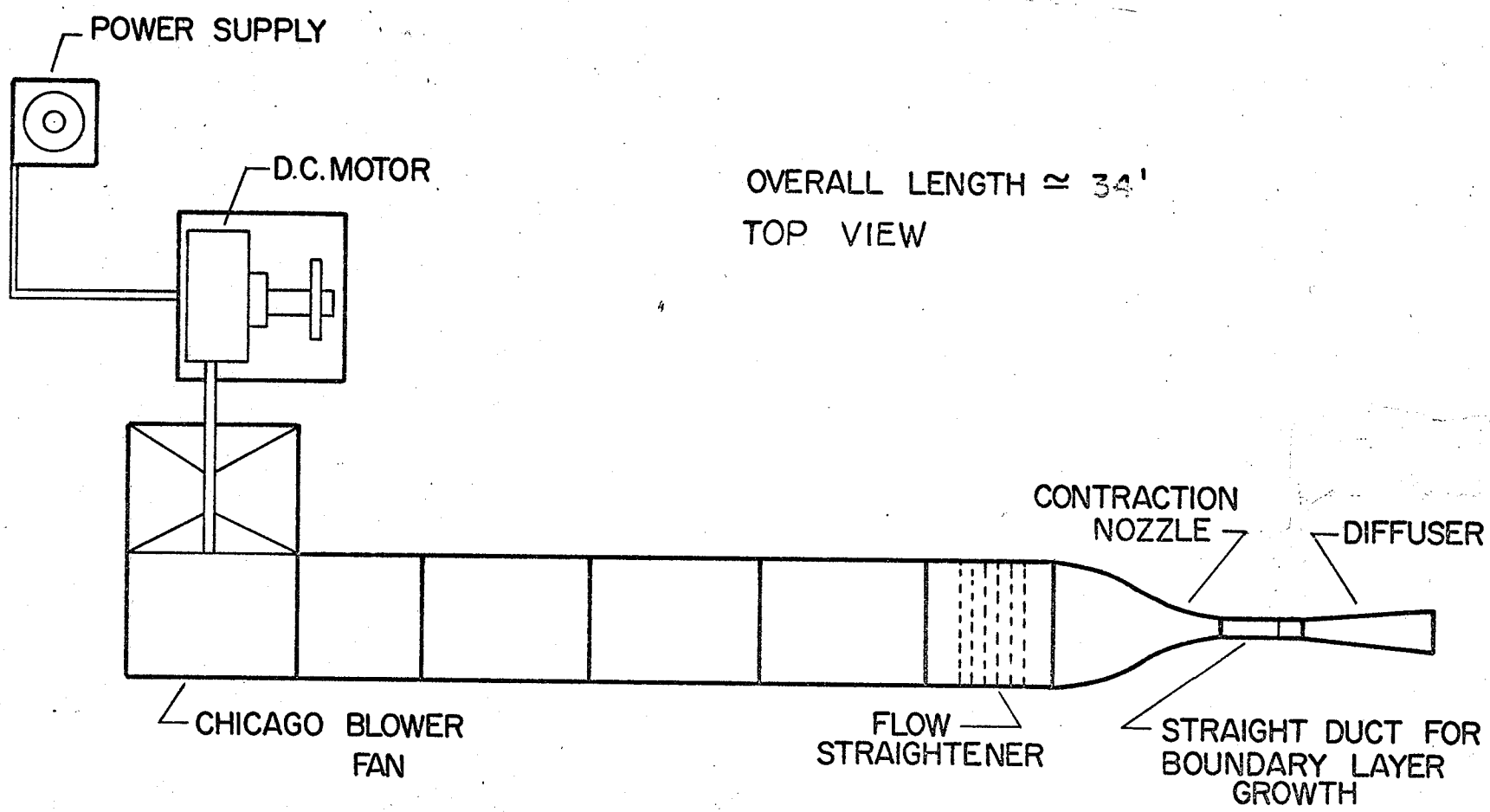


FIGURE 3.1

EXPERIMENTAL APPARATUS

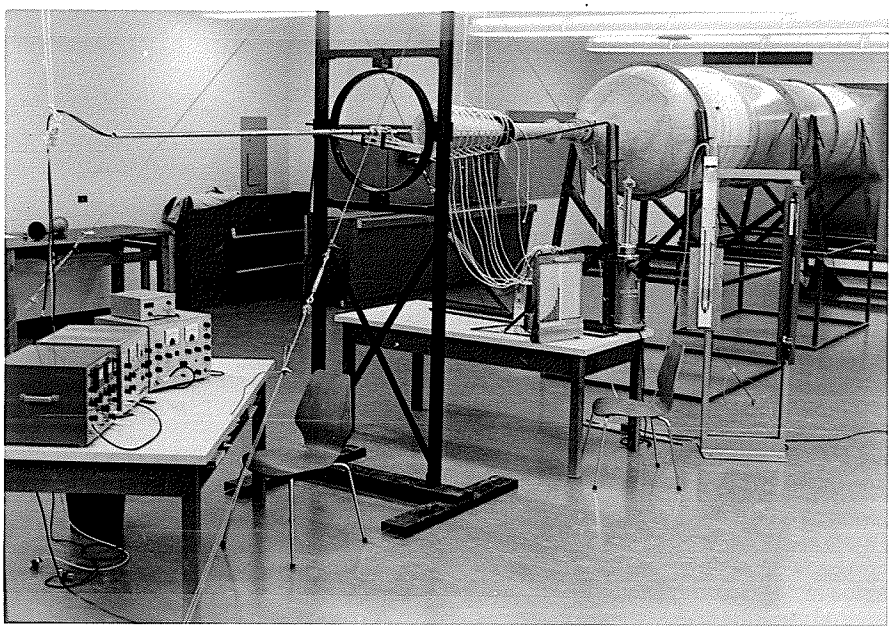


FIGURE 3.2 TEST RIG

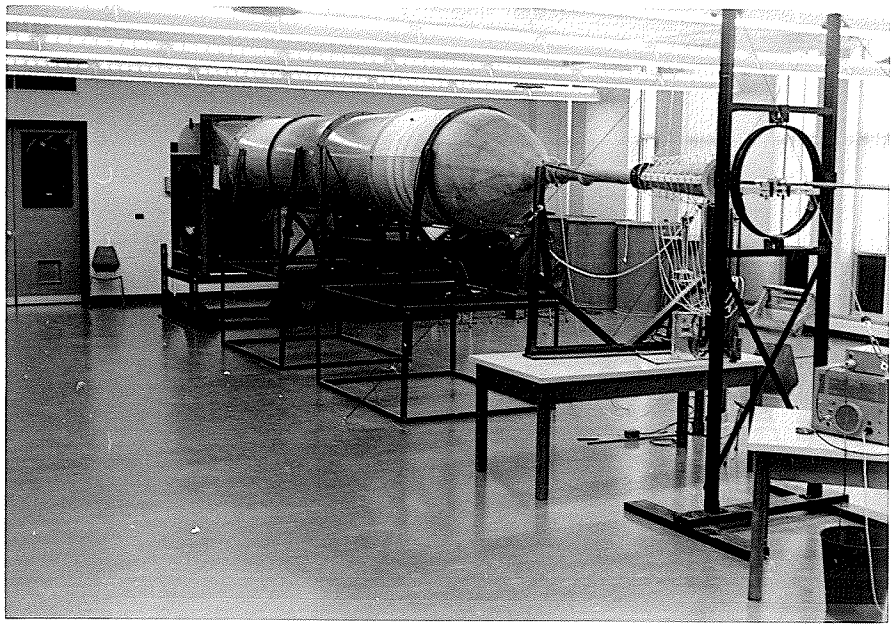
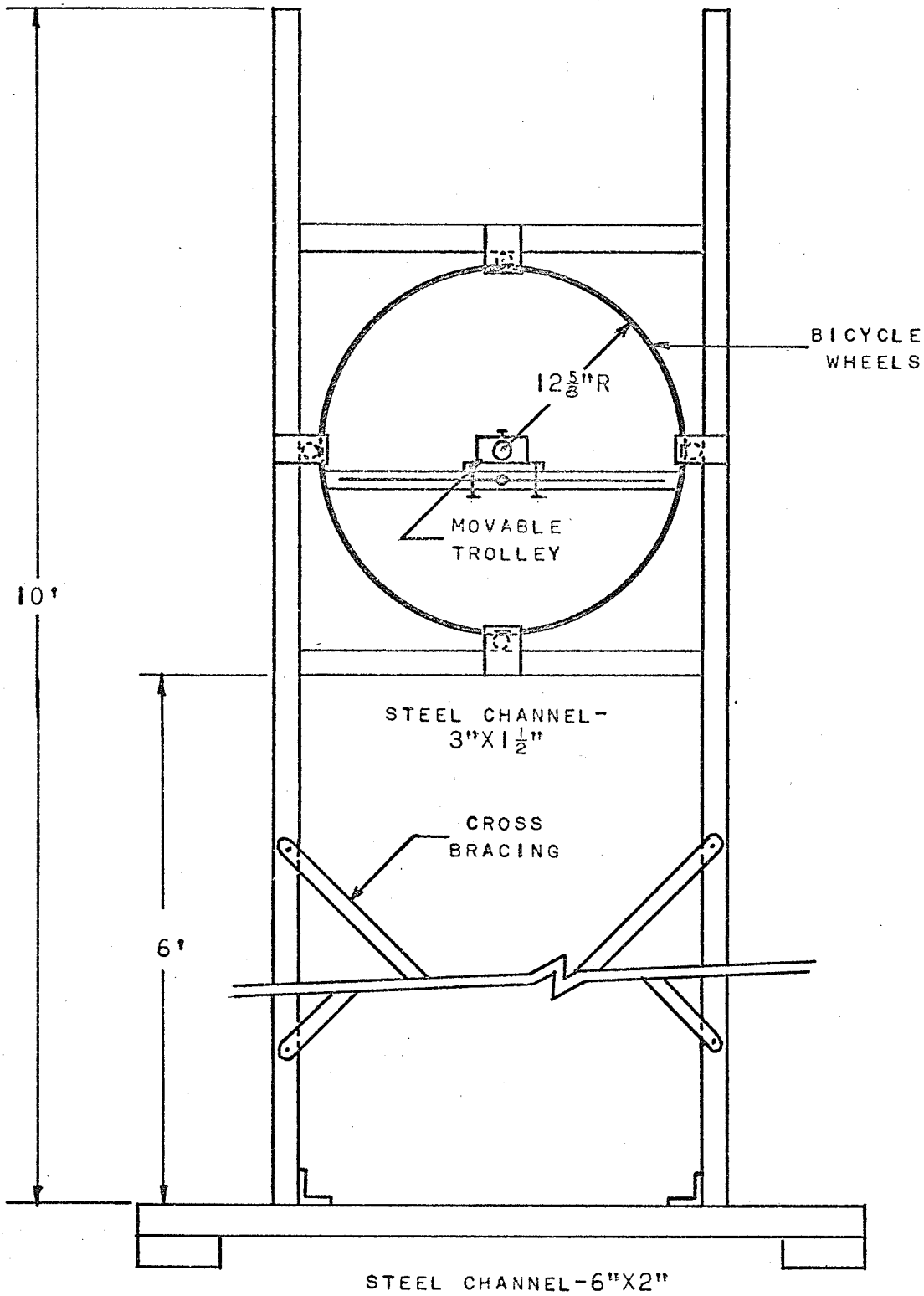


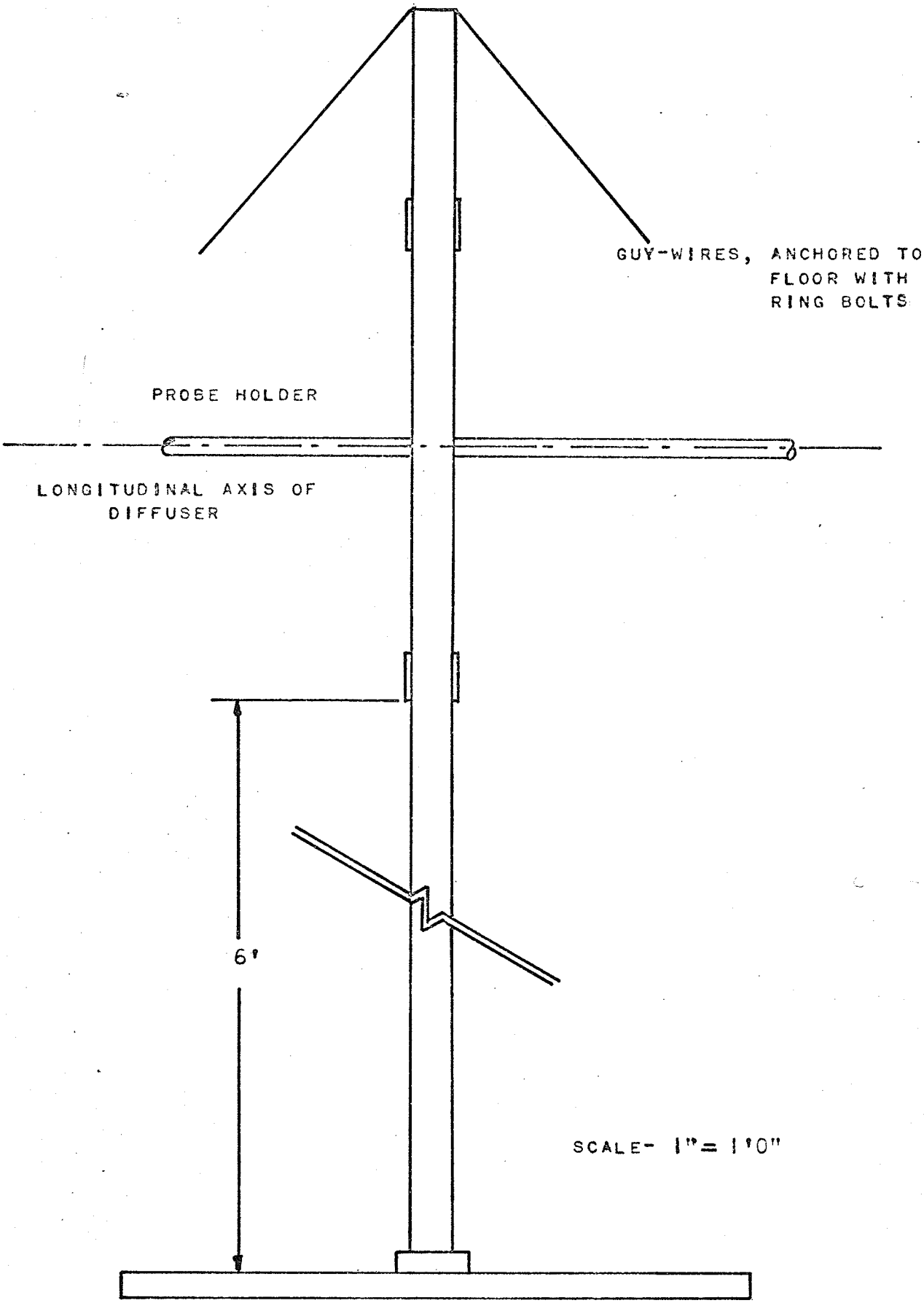
FIGURE 3.3 TEST RIG



SCALE- 1" = 1'0"

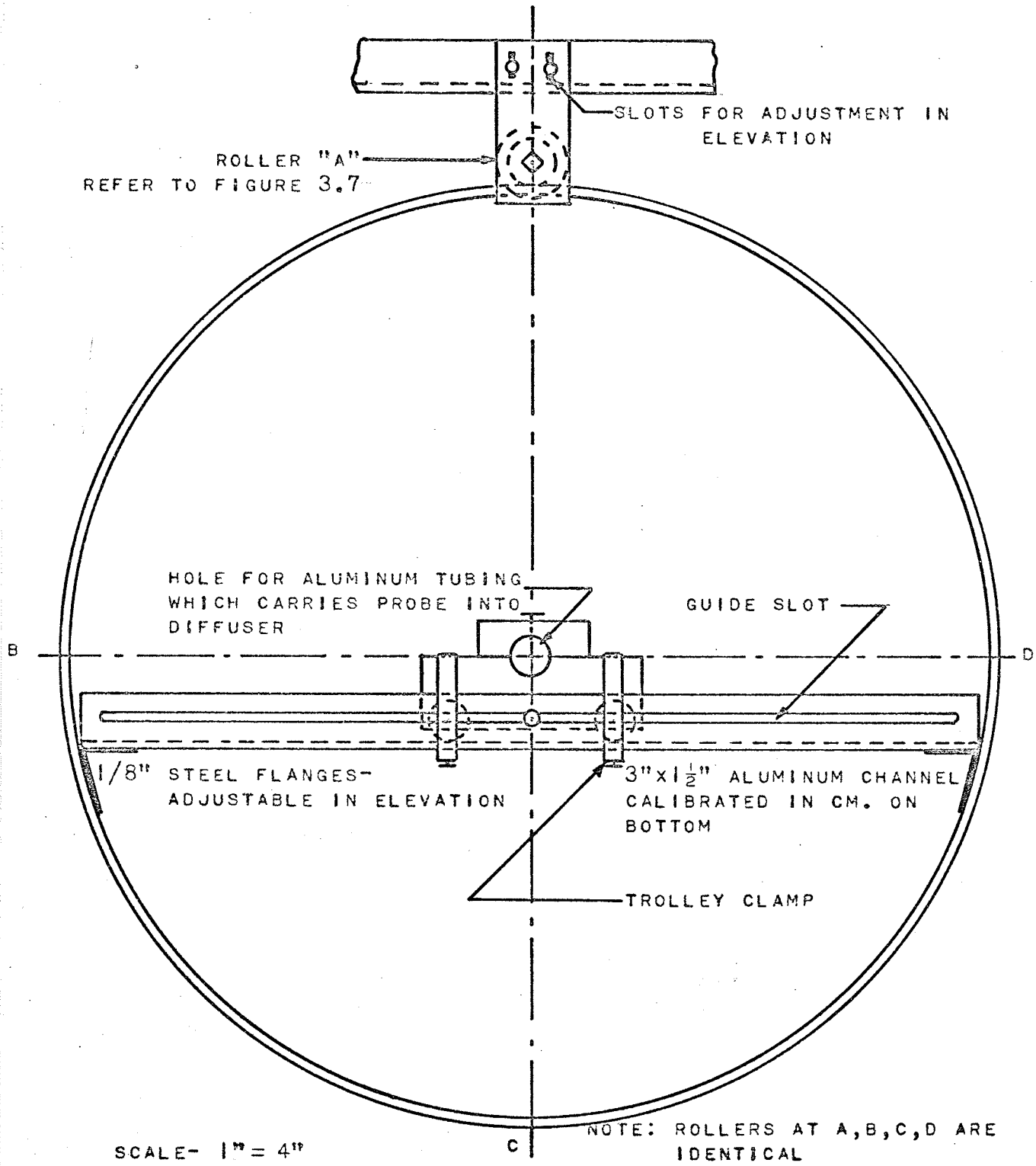
TRAVERSING MECHANISM

FIGURE 3.4



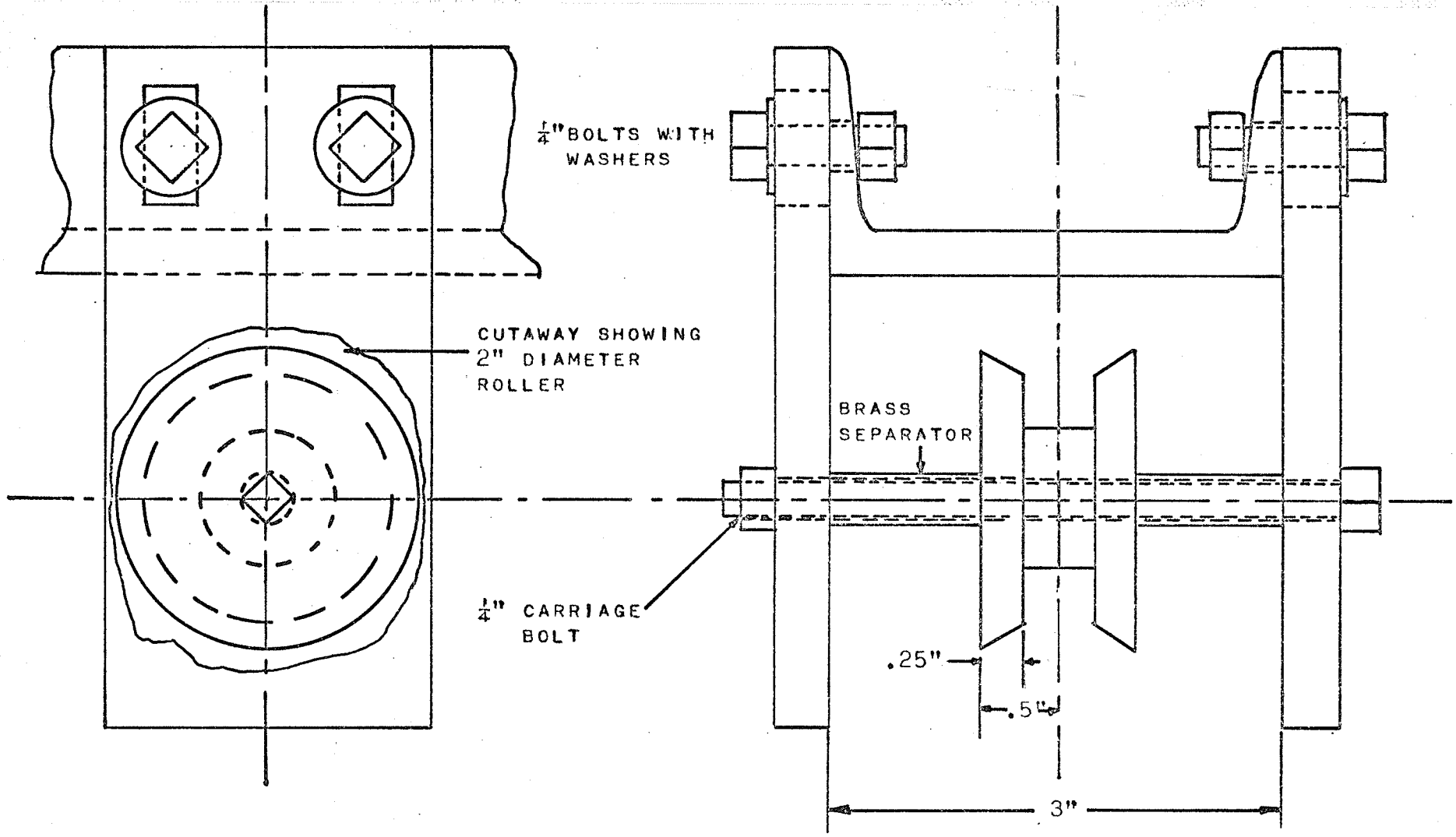
STAND AND PROBE HOLDER - SIDE VIEW

FIGURE 3.5



TRAVERSING MECHANISM WHEEL ASSEMBLY

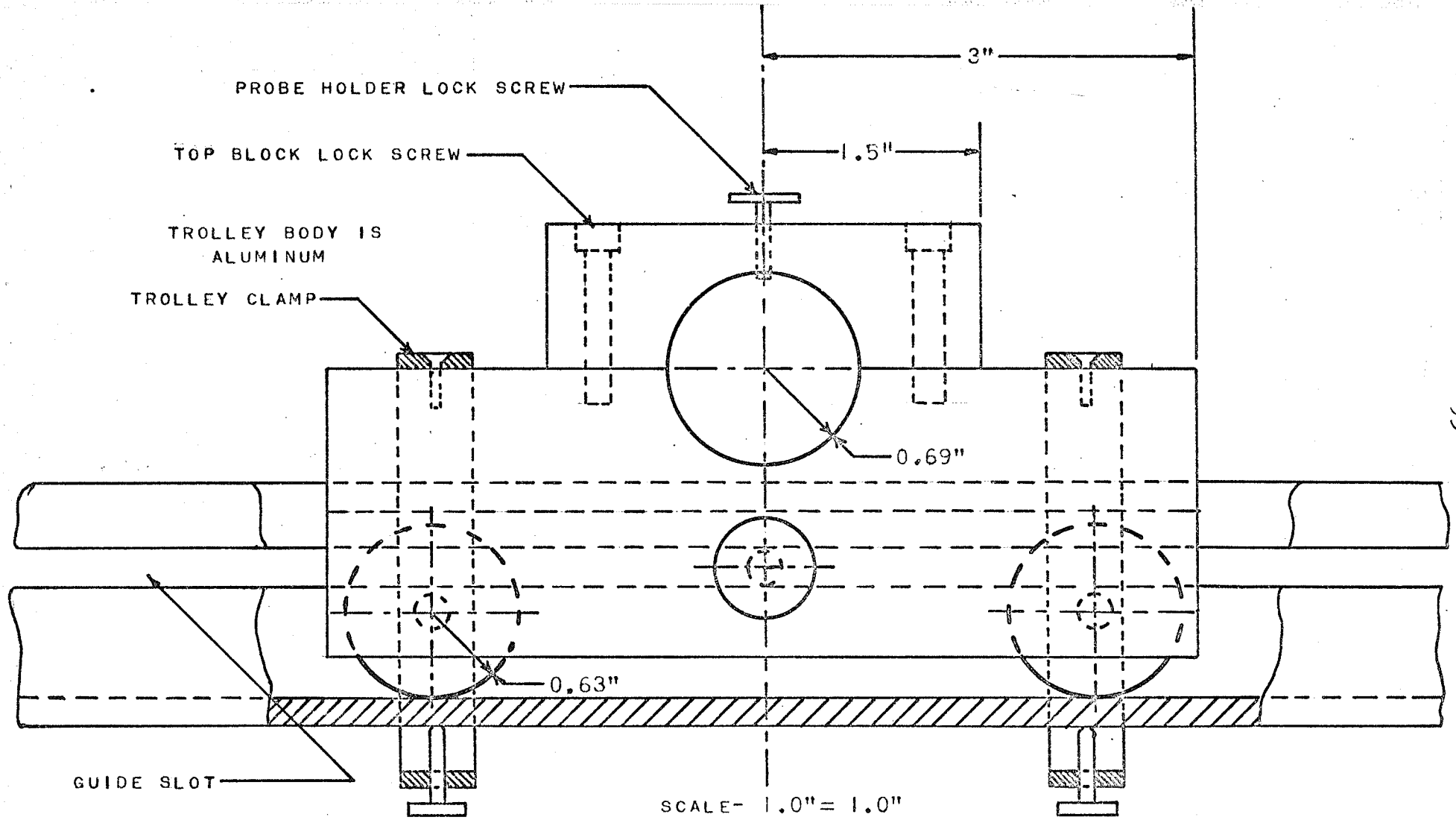
FIGURE 3.6



SCALE- 1" = 1"

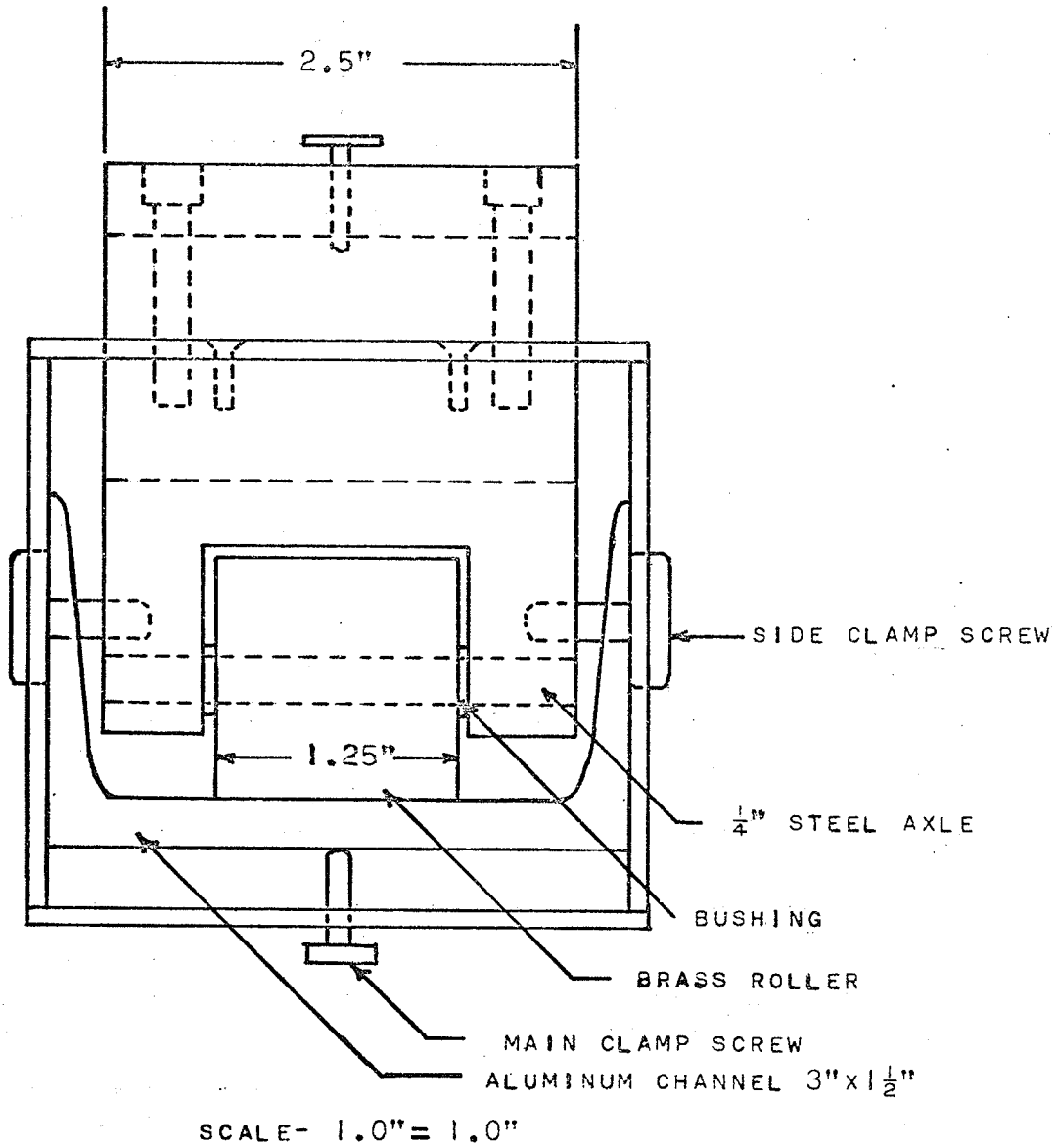
ROLLER DETAIL

FIGURE 3.7



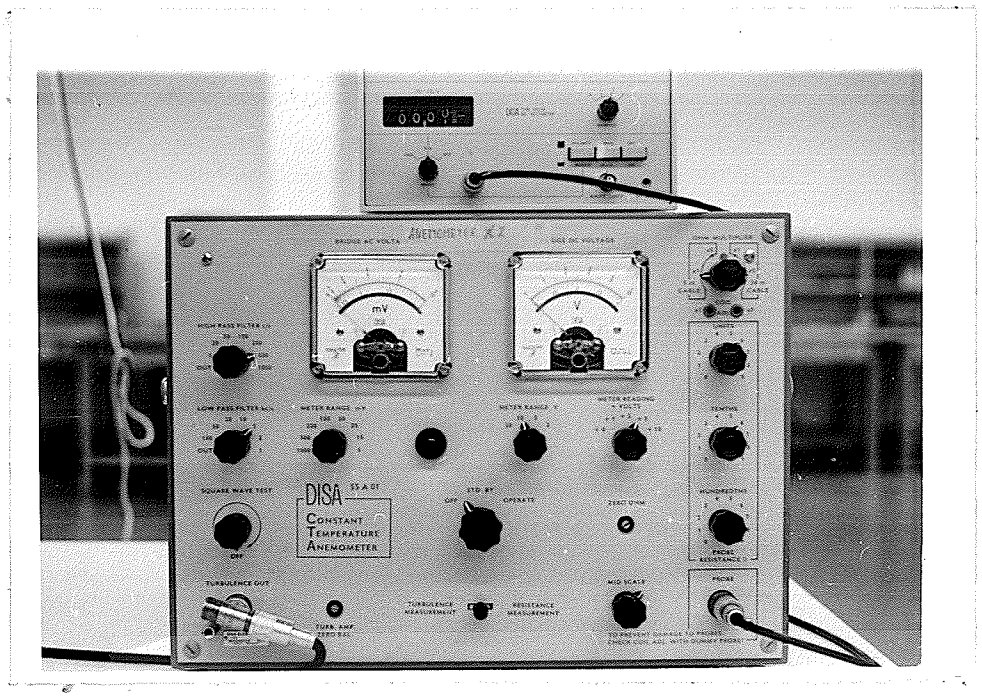
TROLLEY DETAIL - SIDE VIEW

FIGURE 3.8



TROLLEY DETAIL - END VIEW

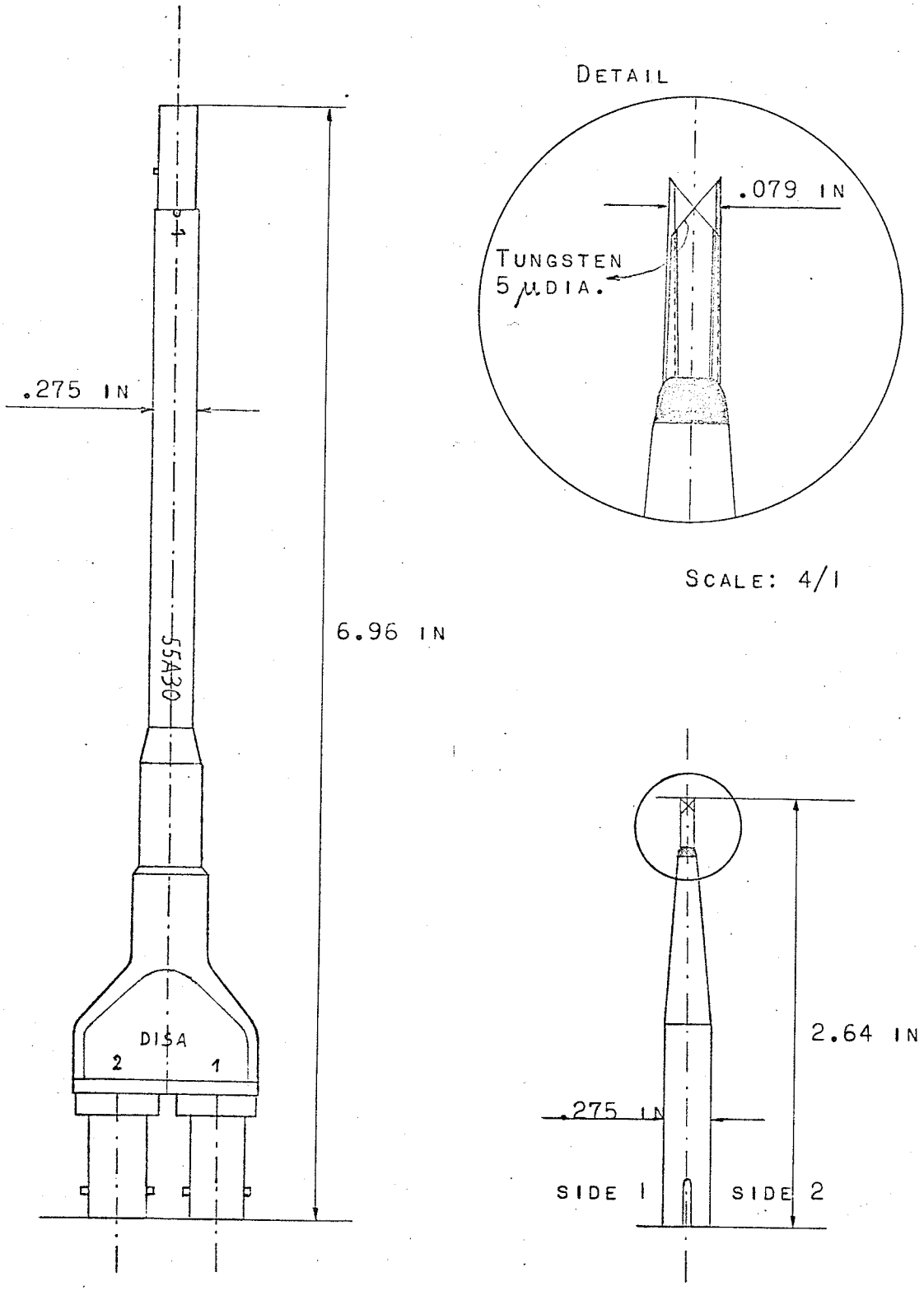
FIGURE 3.9



DISA 55A01 CONSTANT TEMPERATURE

ANEMOMETER WITH DIGITAL VOLTMETER

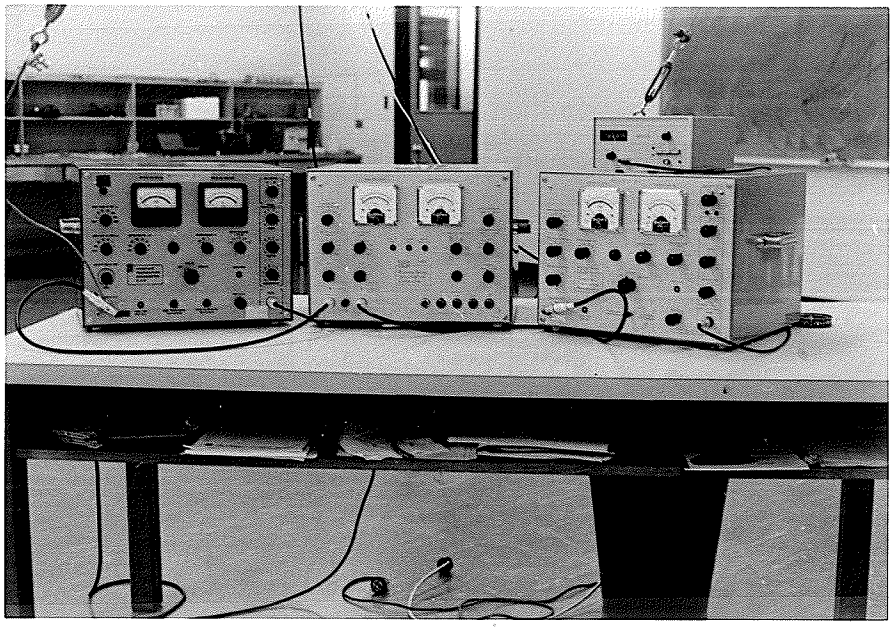
FIGURE 3.10



PROBE HOLDER
55 A 30

X PROBE
55 A 32
249

FIGURE 3.11
X-PROBE AND HOLDER



TEST EQUIPMENT Left- 55A01 anemometer, Centre- 55A06 correlator, Right- 55A01 anemometer, Top- 55D30 digital voltmeter.

FIGURE 3.12

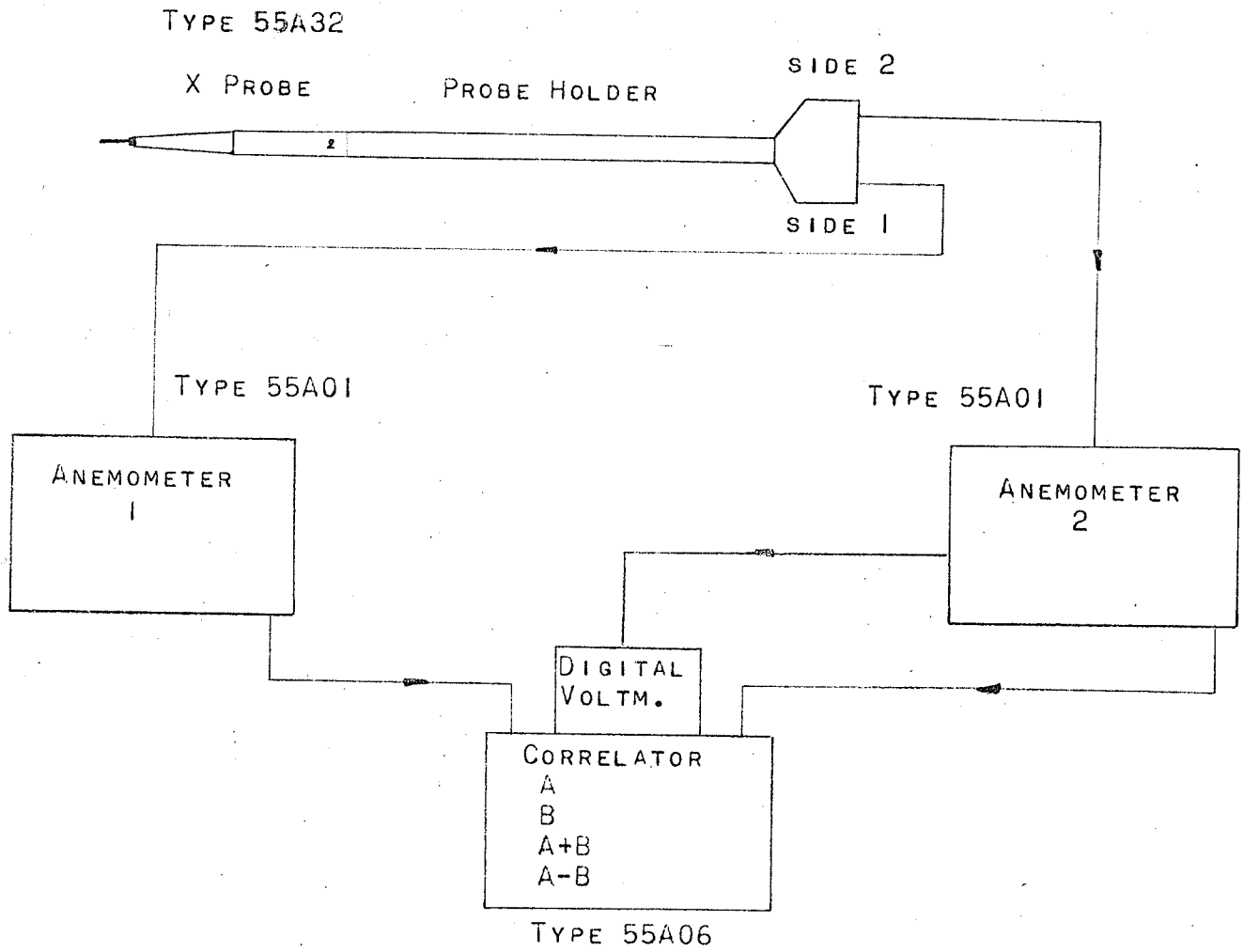
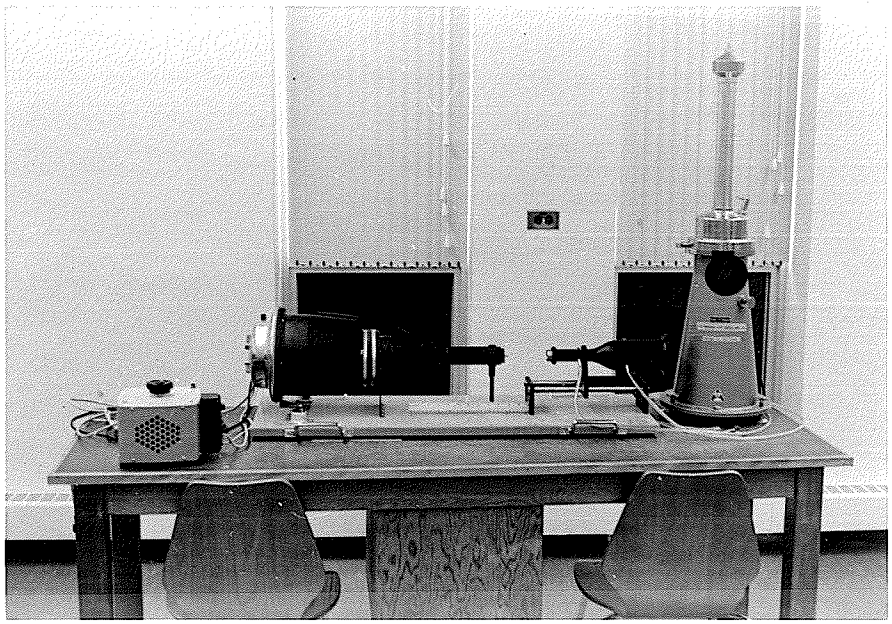
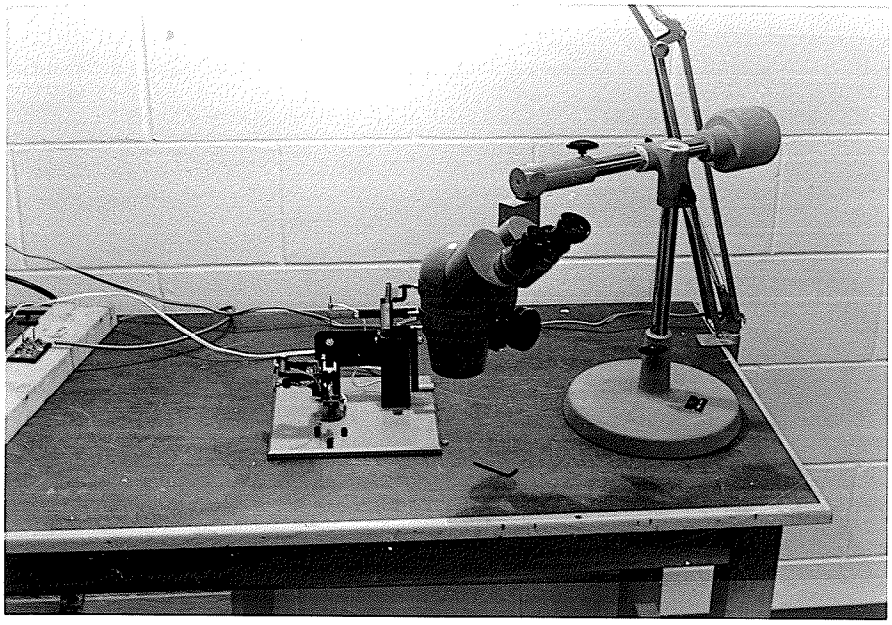


FIGURE 3.13
SCHEMATIC DIAGRAM OF TEST EQUIPMENT



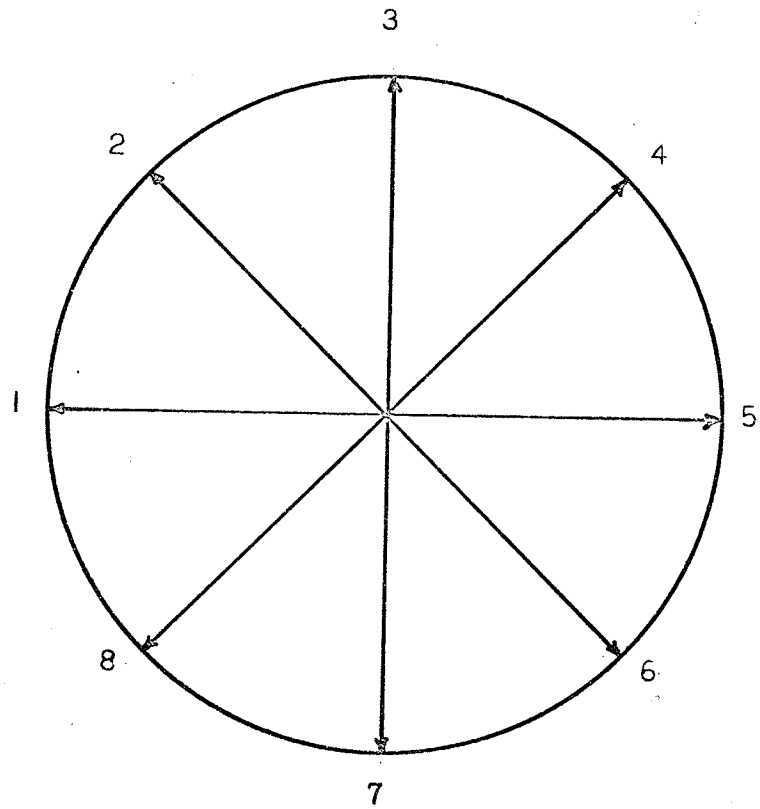
PROBE CALIBRATION EQUIPMENT Left- variable transformer for speed control, Centre- calibration tunnel, Right- Betz micromanometer.

FIGURE 3.14



PROBE REPAIR EQUIPMENT Left- micromanipulator
Right- microscope

FIGURE 3.15



OUTLET OF DIFFUSER- LOOKING IN TOWARDS FAN

DIFFUSER TRAVERSES

(1-5, 2-6, 3-7, 4-8)

FIGURE 4.1

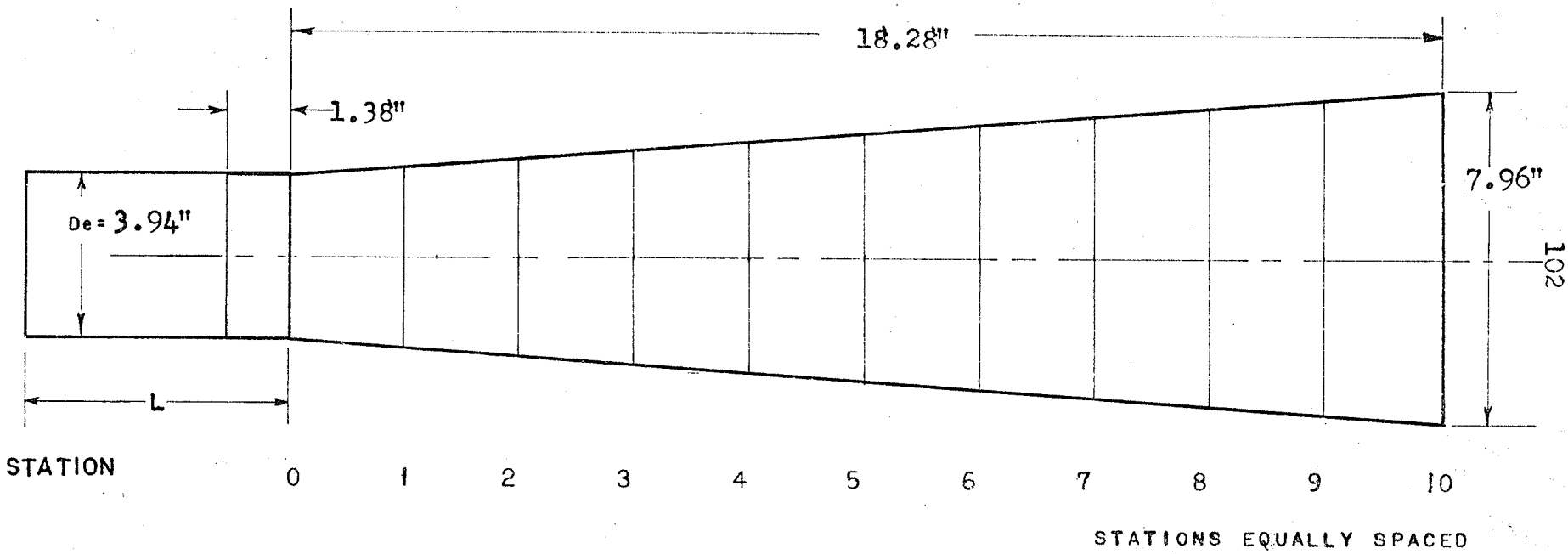
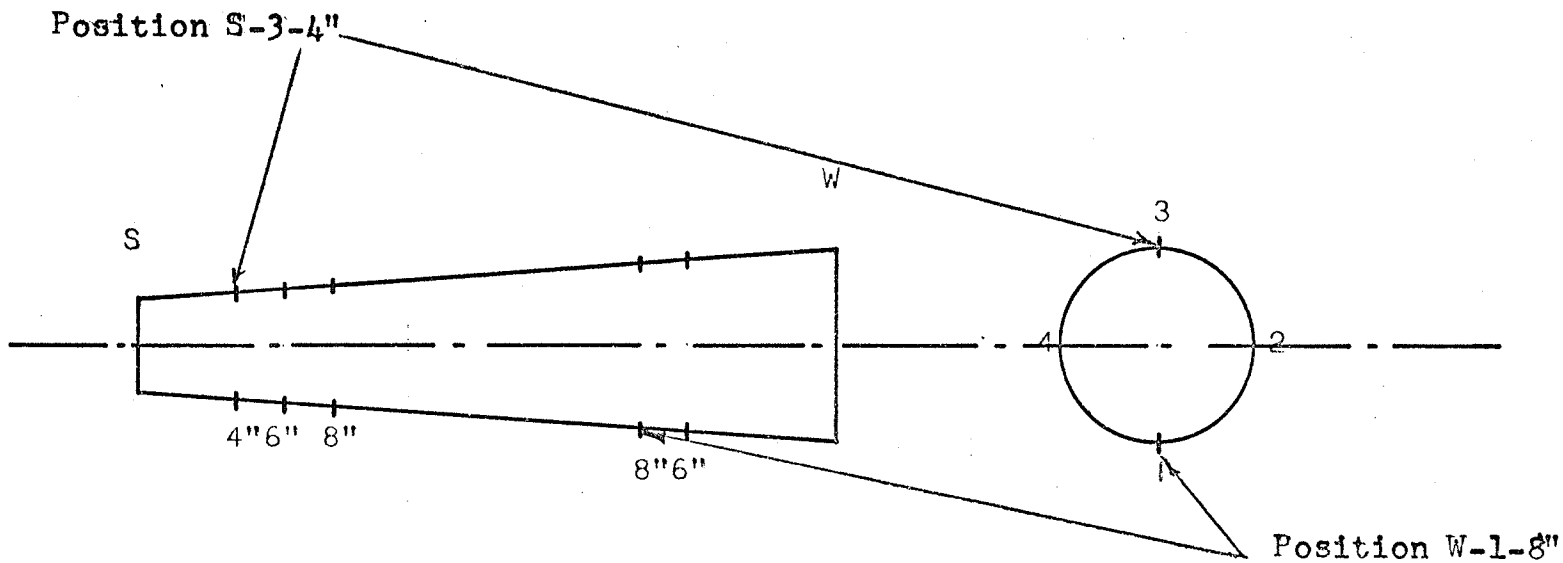


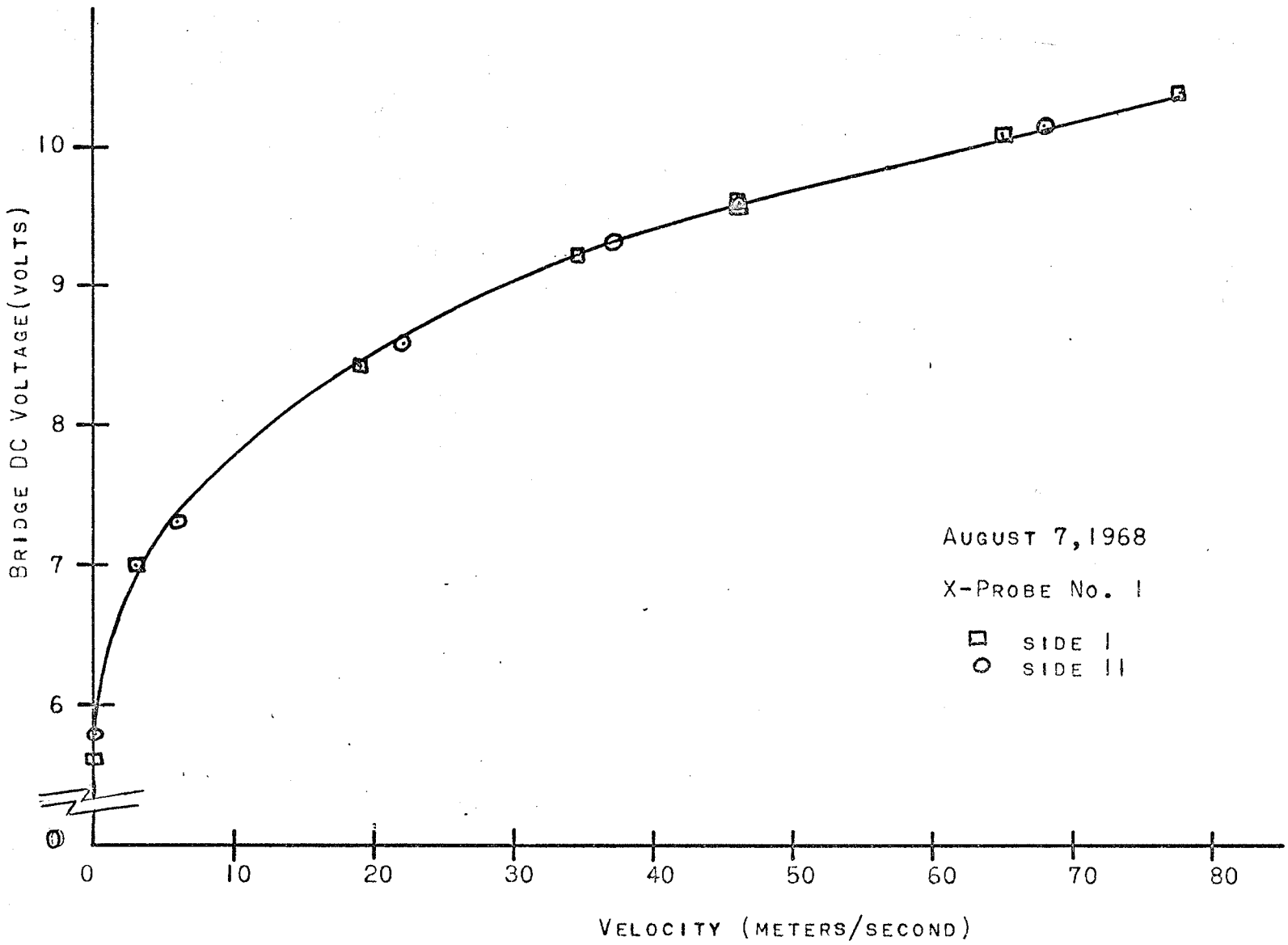
FIGURE 4.2

DIFFUSER TEST STATIONS

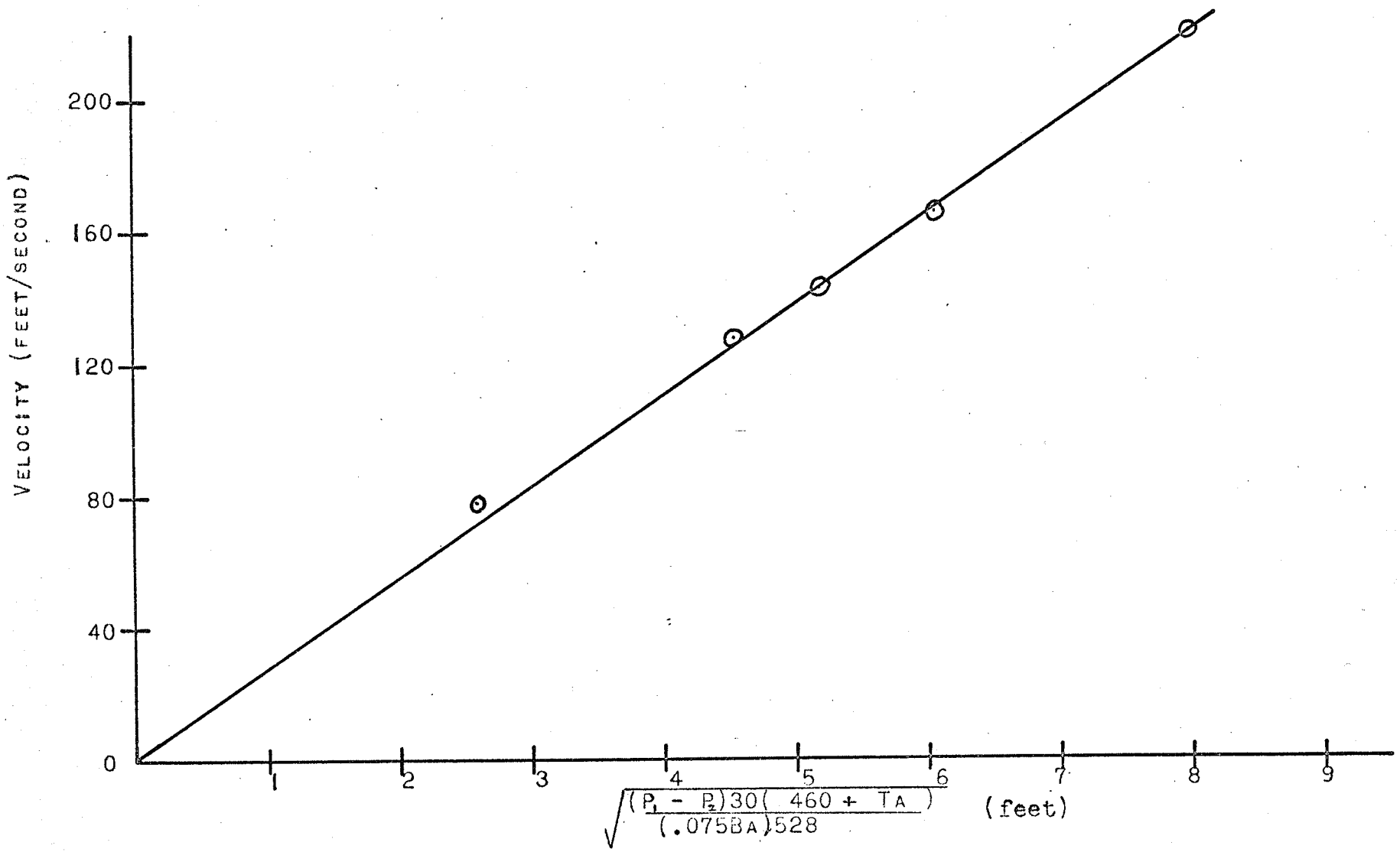


SURFACE ROUGHNESS MEASURING STATIONS IN DIFFUSER

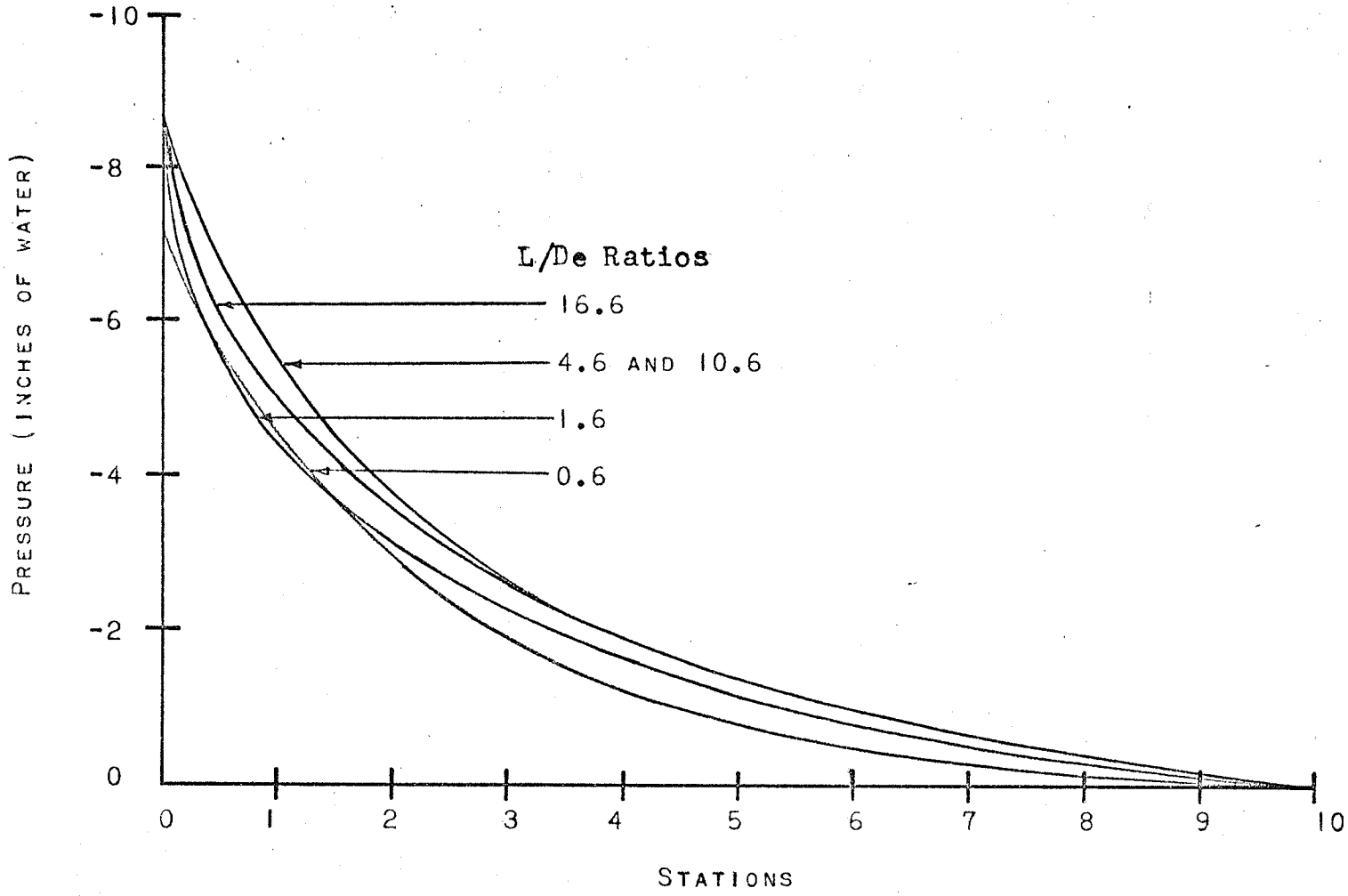
FIGURE 4.3



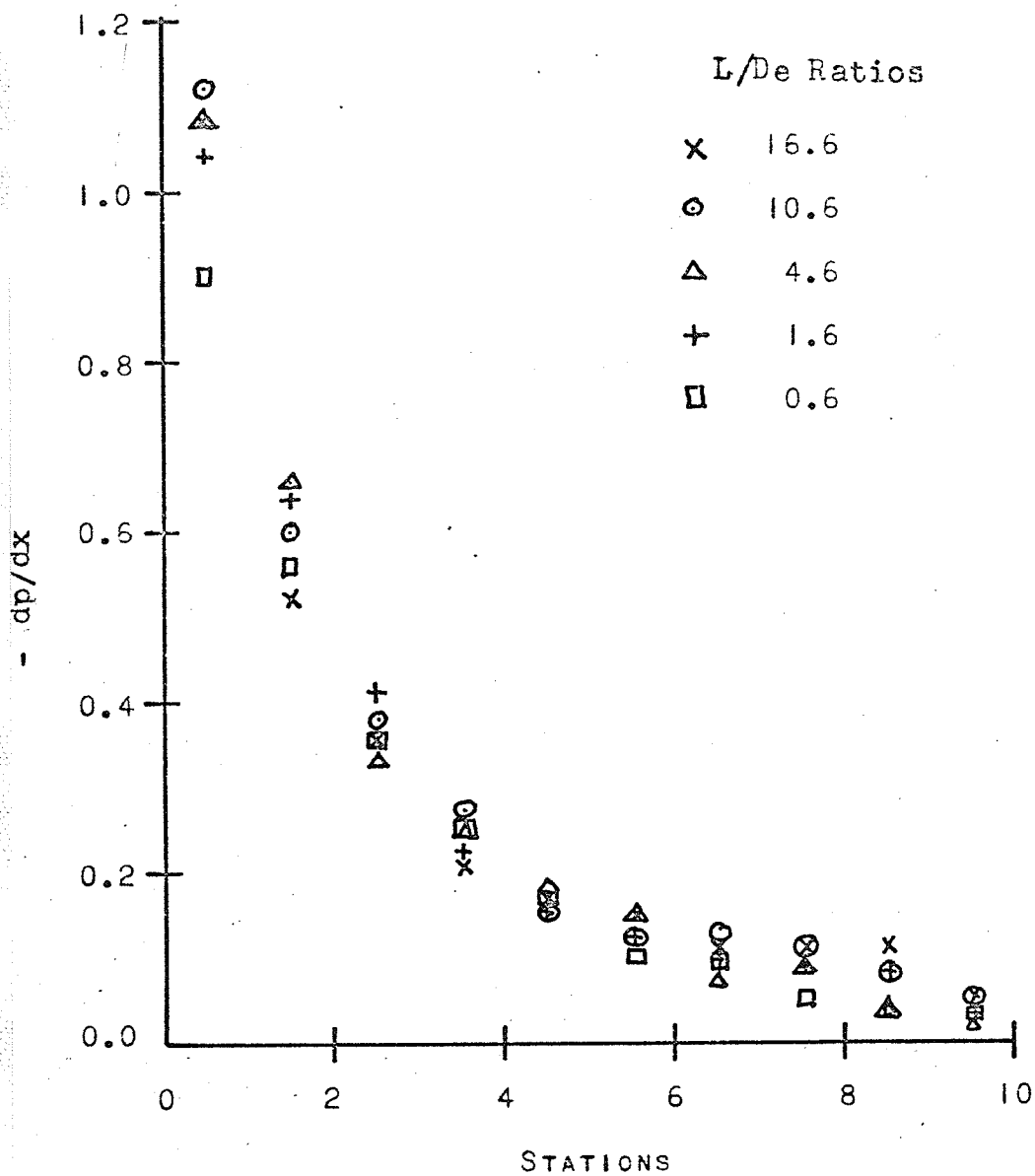
GRAPH 4.1 PROBE CALIBRATION



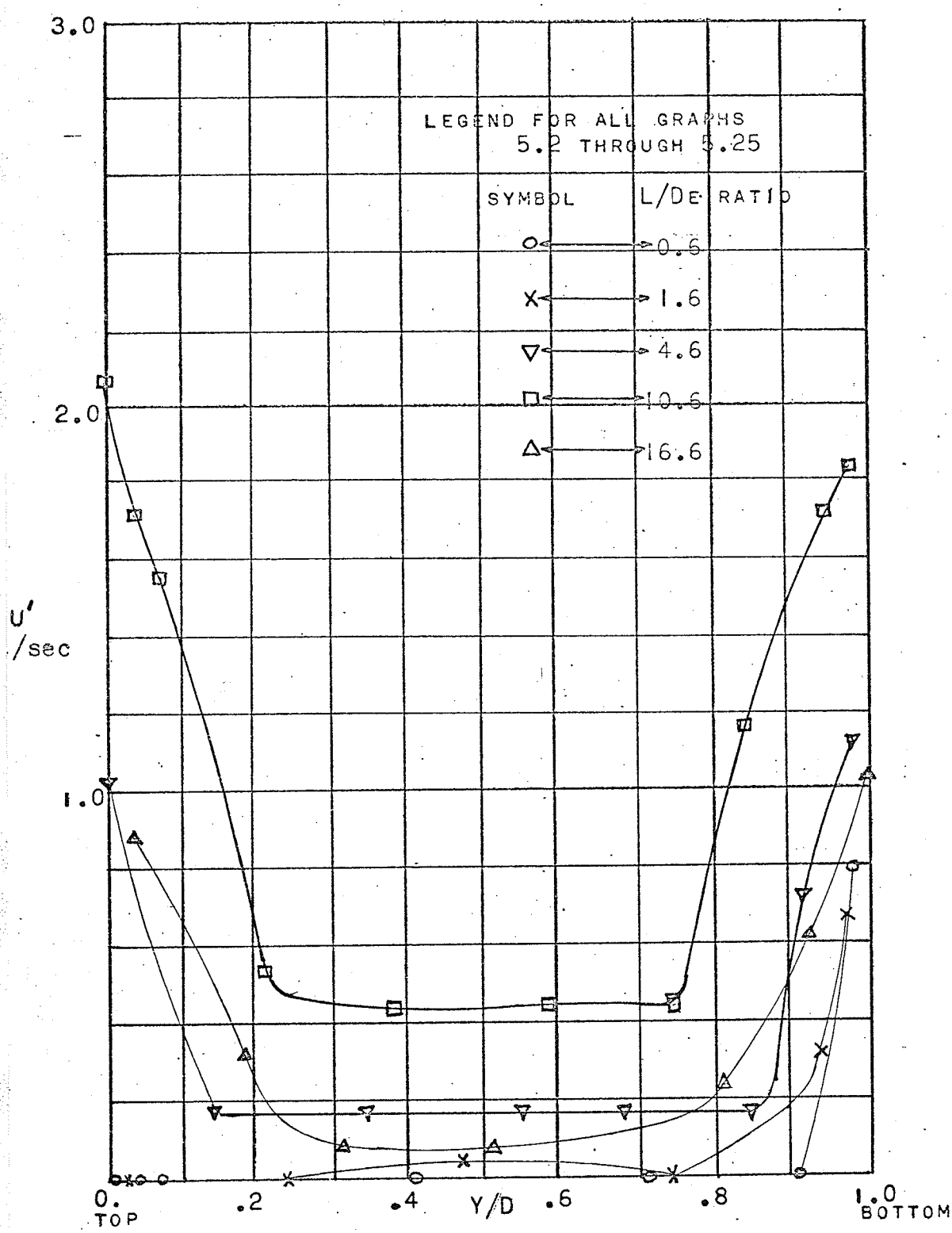
GRAPH 4.2 TUNNEL CALIBRATION



GRAPH 4.3 PRESSURE RISE ALONG DIFFUSER



GRAPH 5.1 dp/dx ALONG DIFFUSER

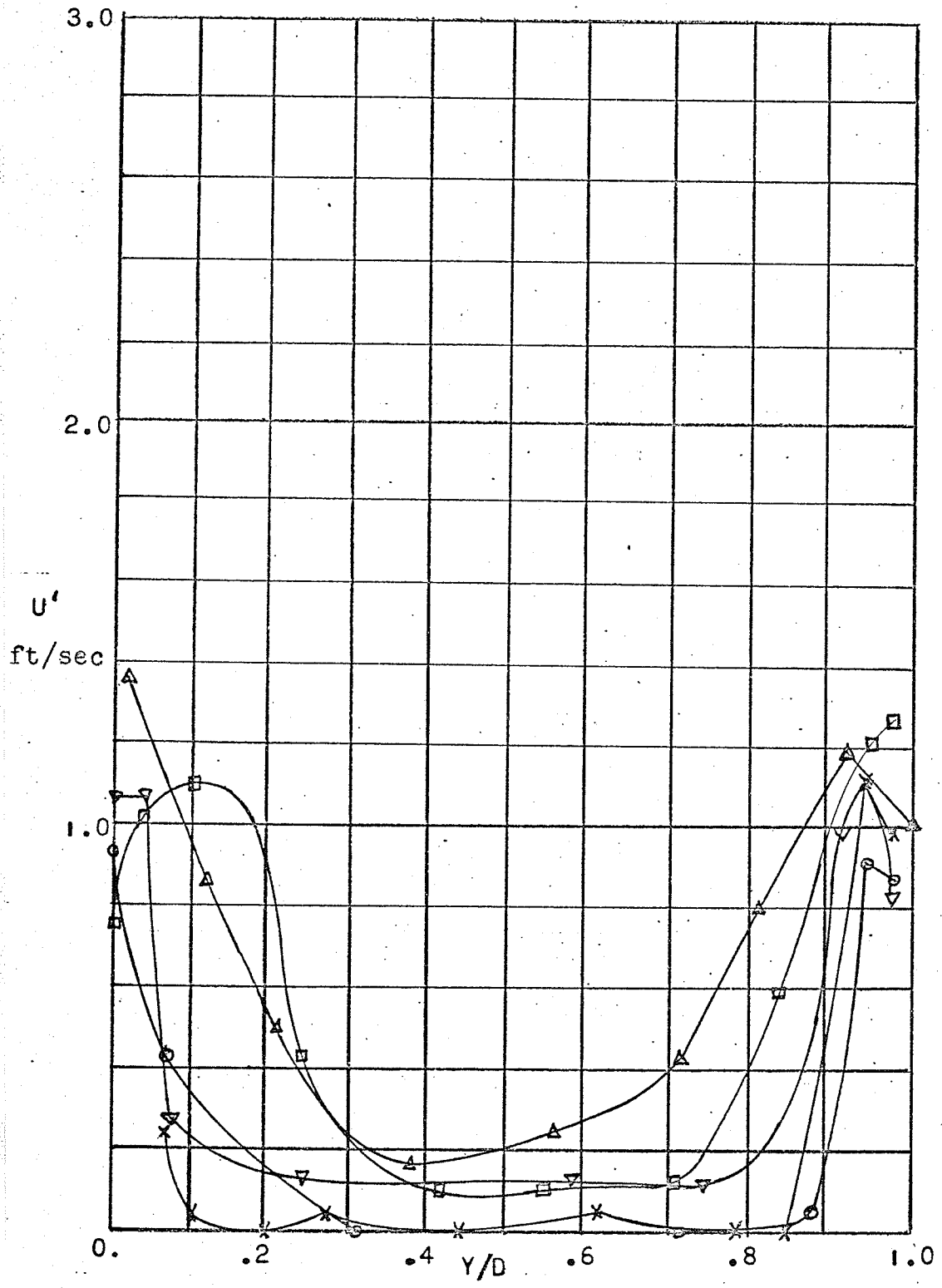


STN. 0

GRAPH 5.2 u' versus Y/D

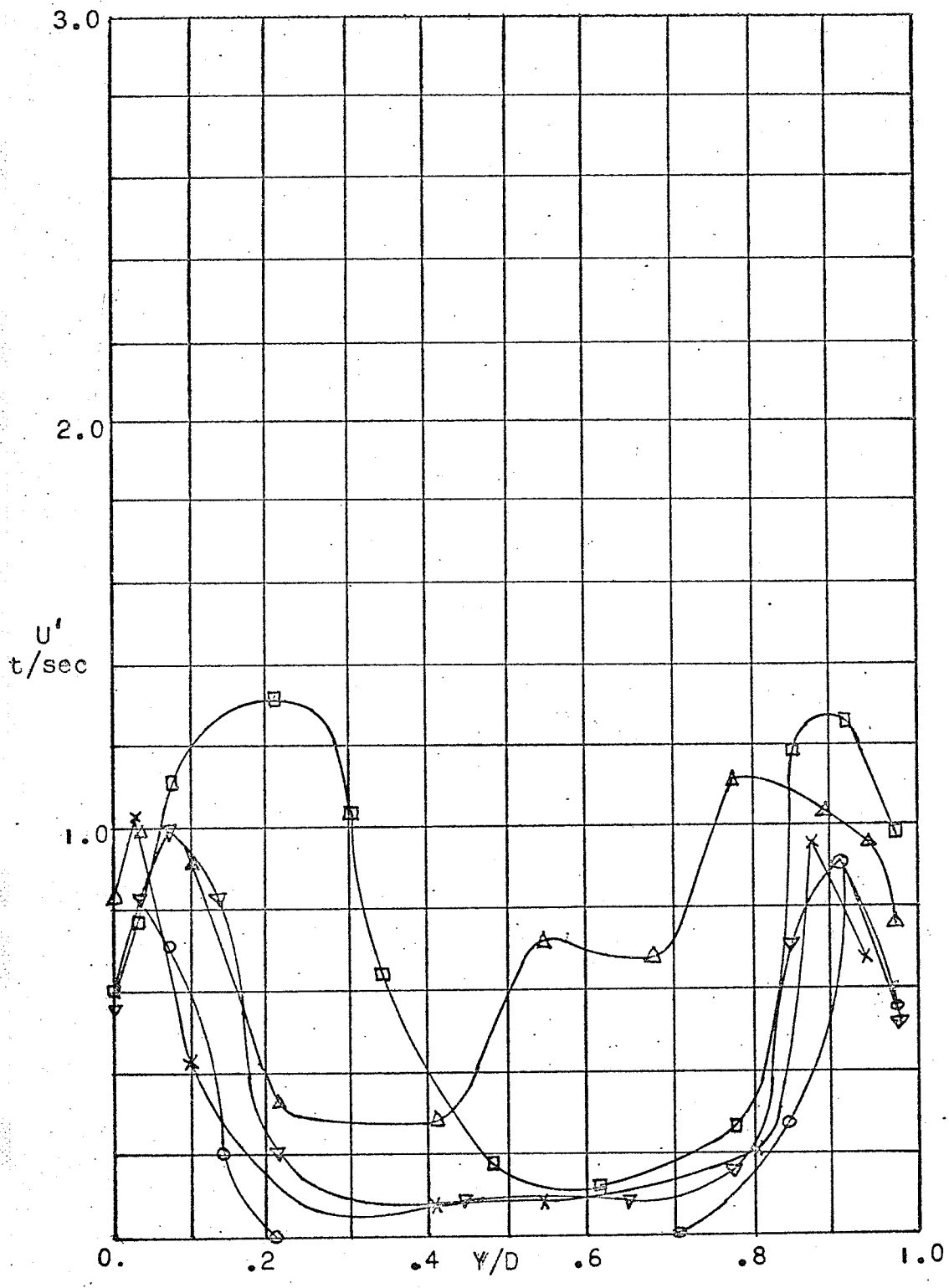
NOTE: GRAPHS 5.2 THROUGH 5.25 ARE ALL FOR TRAVERSE 3-7

THE TOP AND BOTTOM POSITIONS ARE AS SHOWN ABOVE



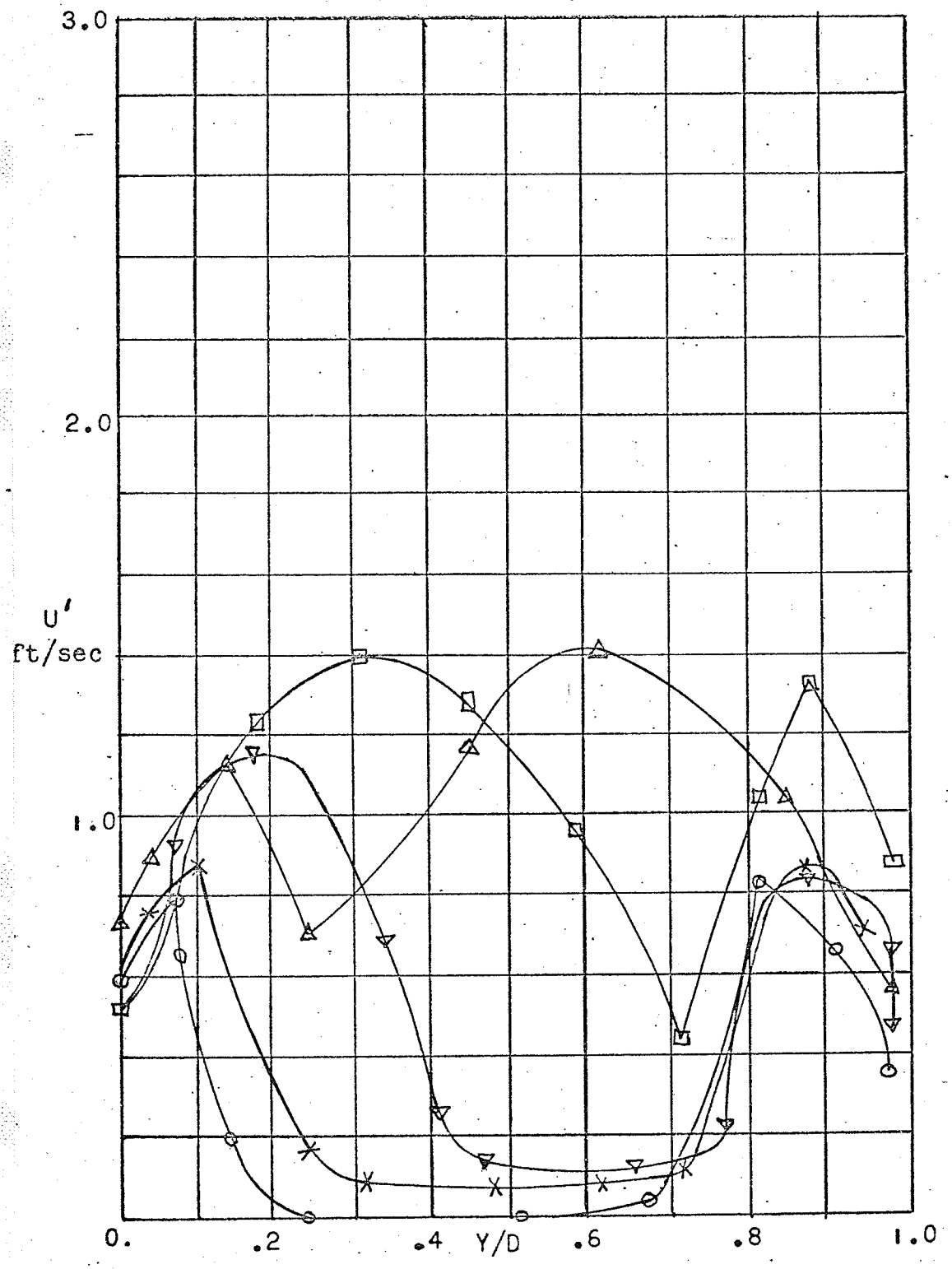
STN. 2

GRAPH 5.3 u' versus Y/D



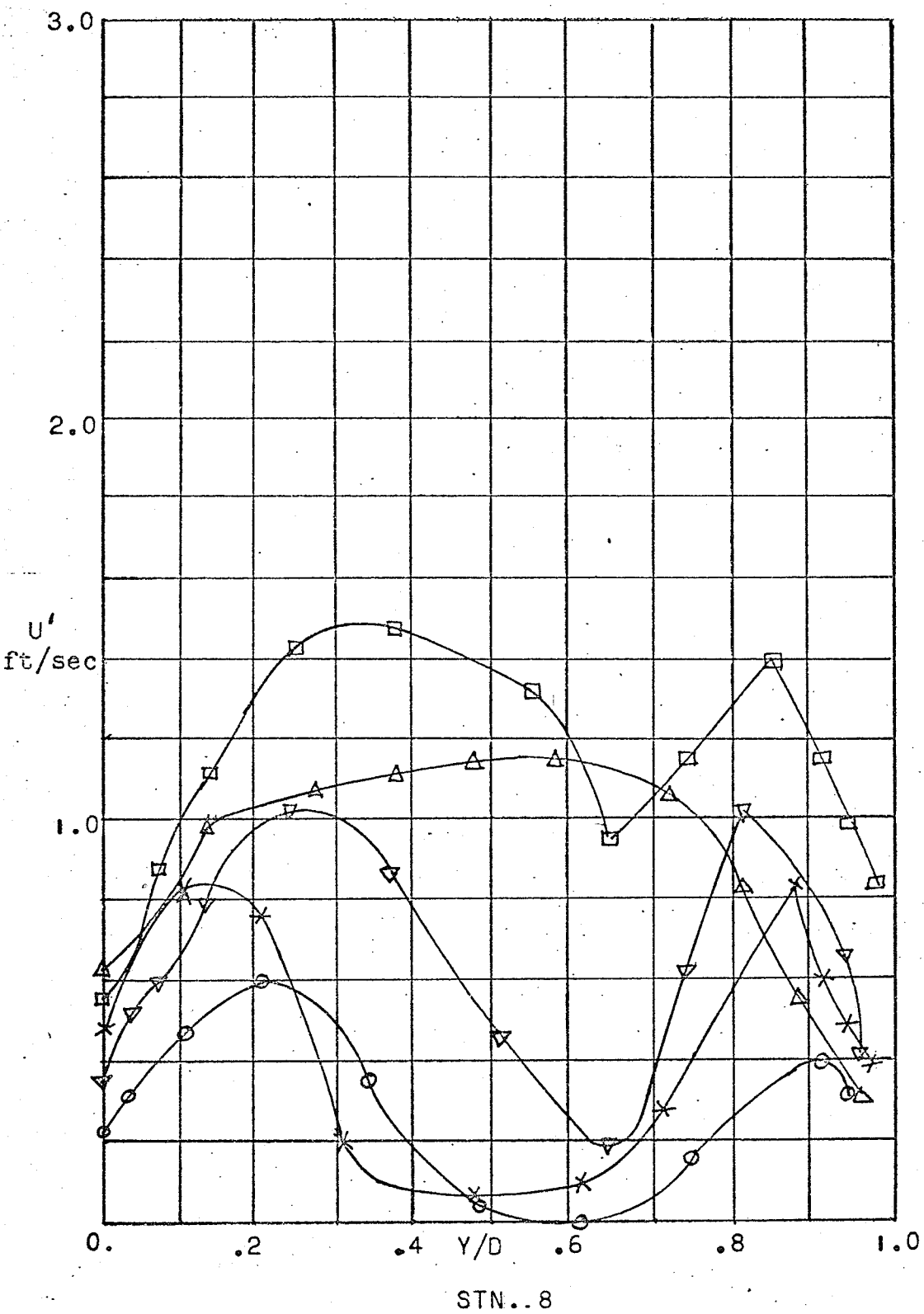
STN. 4

GRAPH 5.4 u' versus Y/D

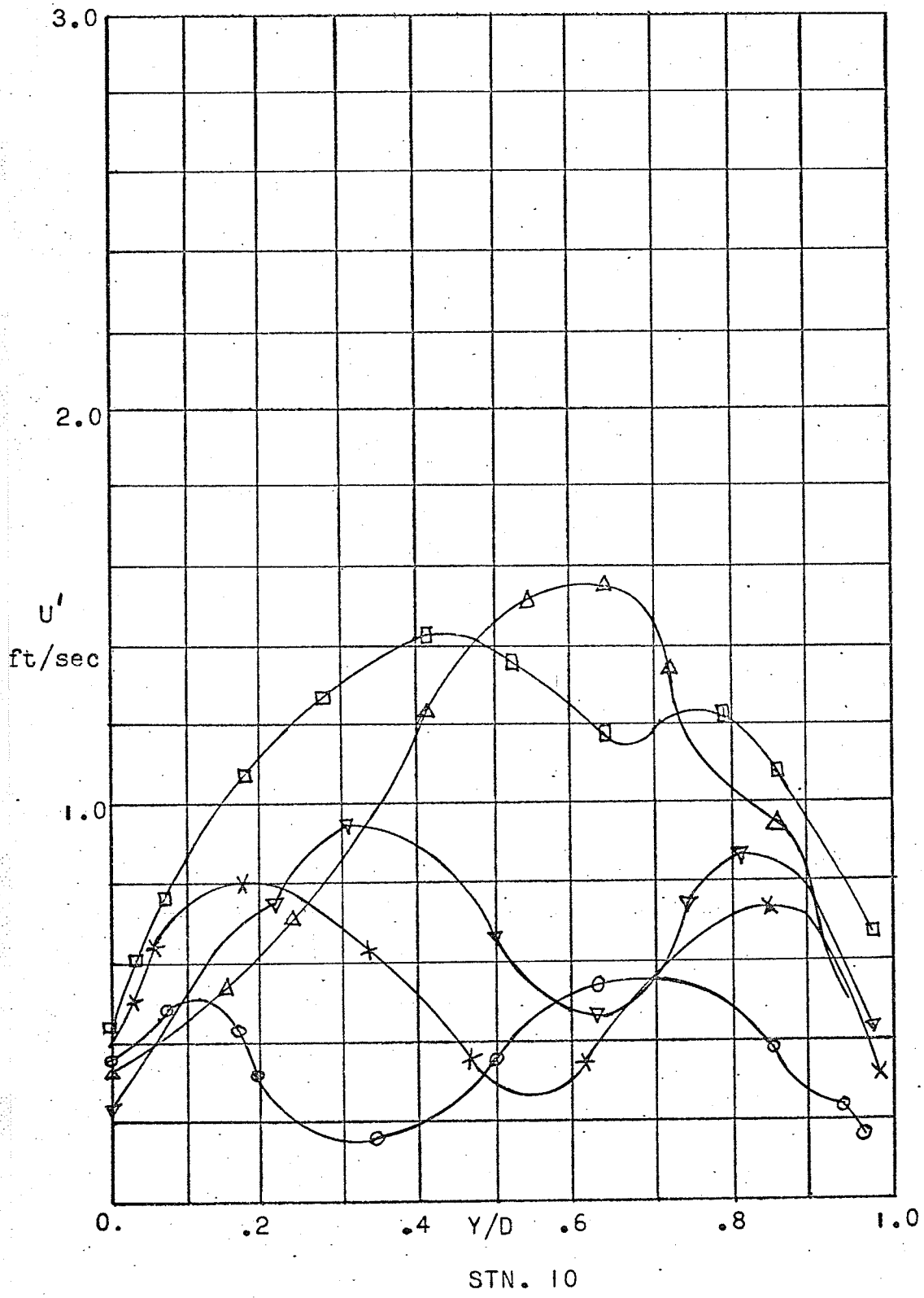


STN. 6

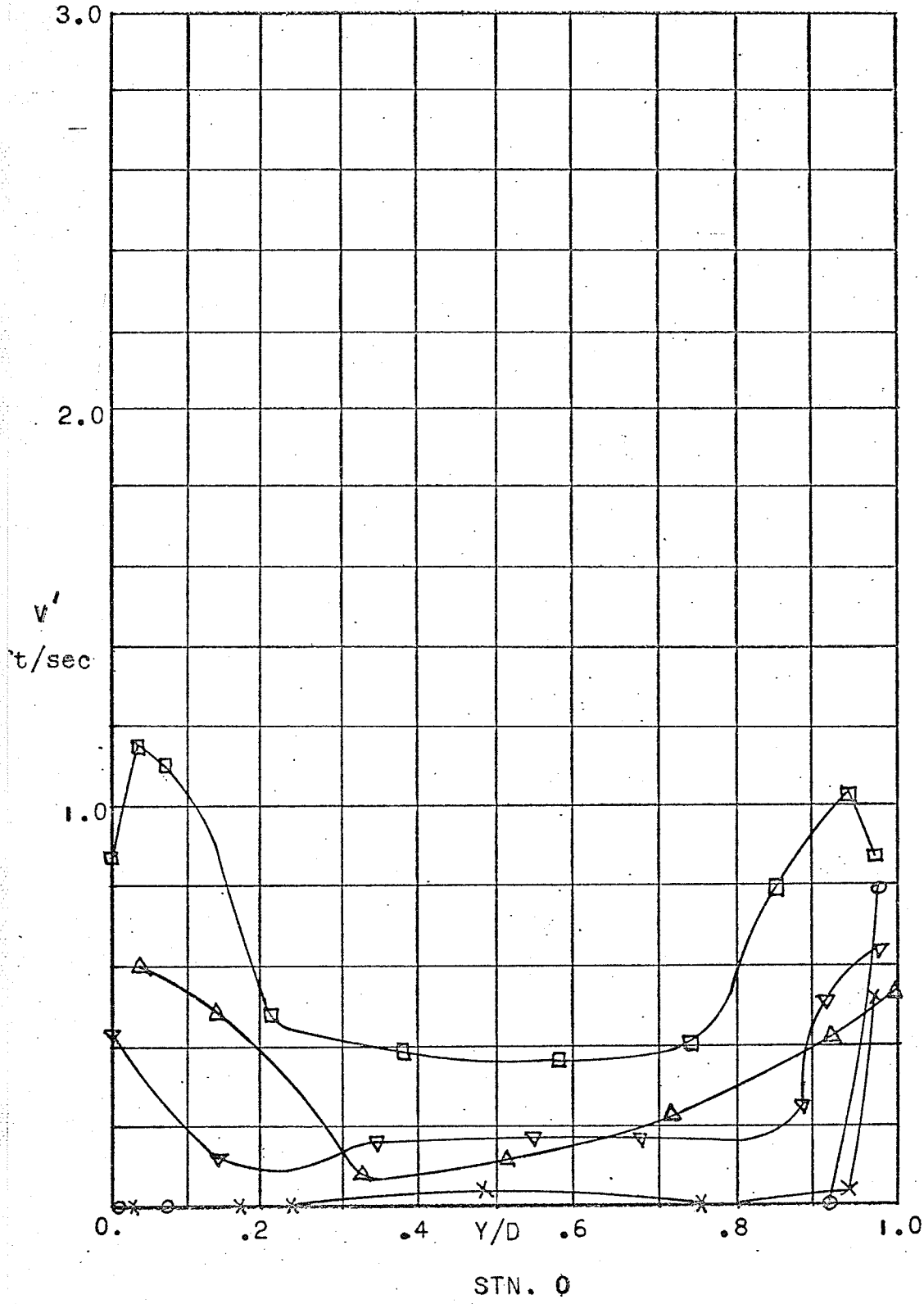
GRAPH 5.5 u' versus Y/D



GRAPH 5.6 u' versus Y/D

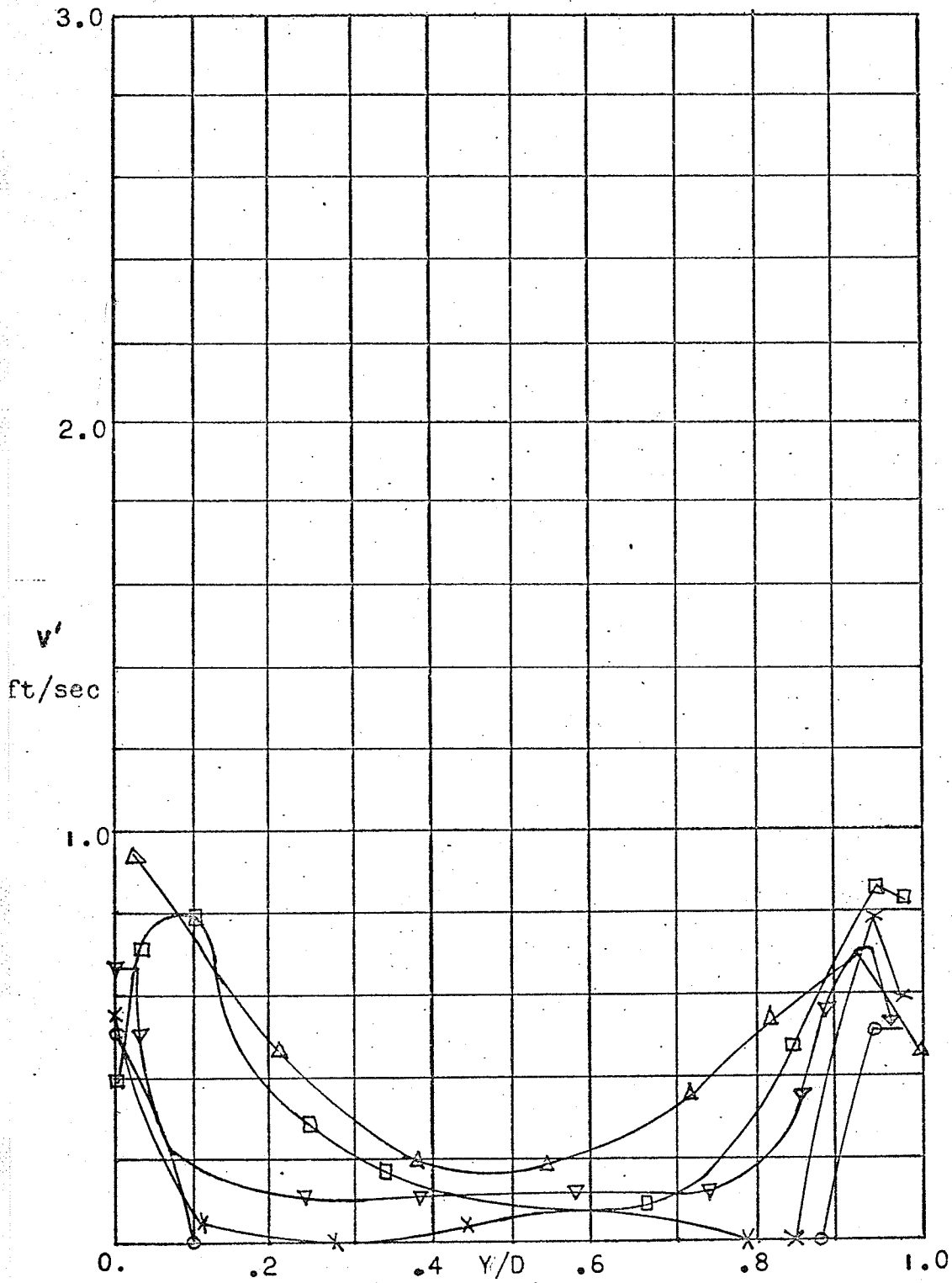


GRAPH 5.7 u' versus Y/D



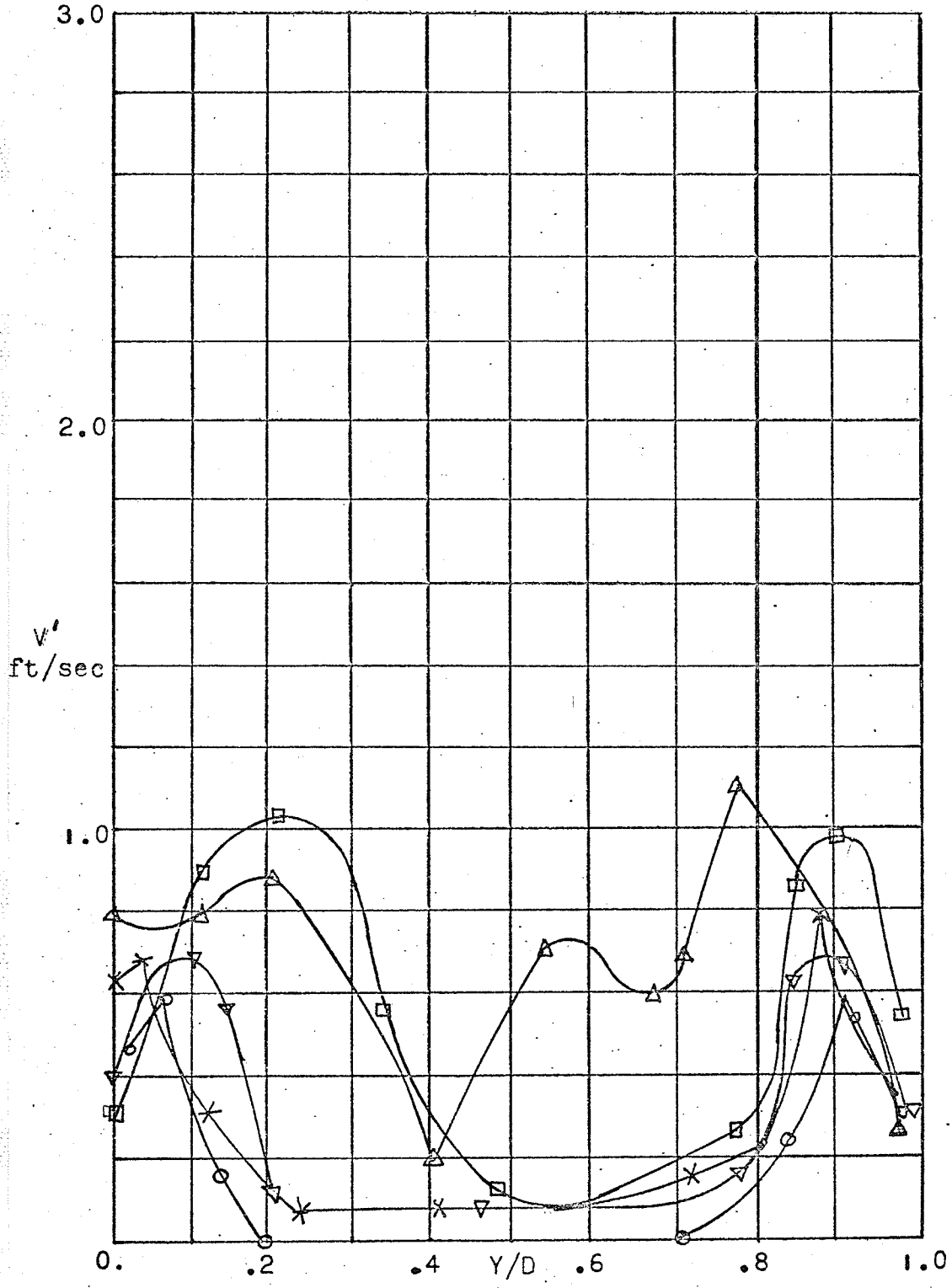
STN. 0

GRAPH 5.8 v' versus Y/D



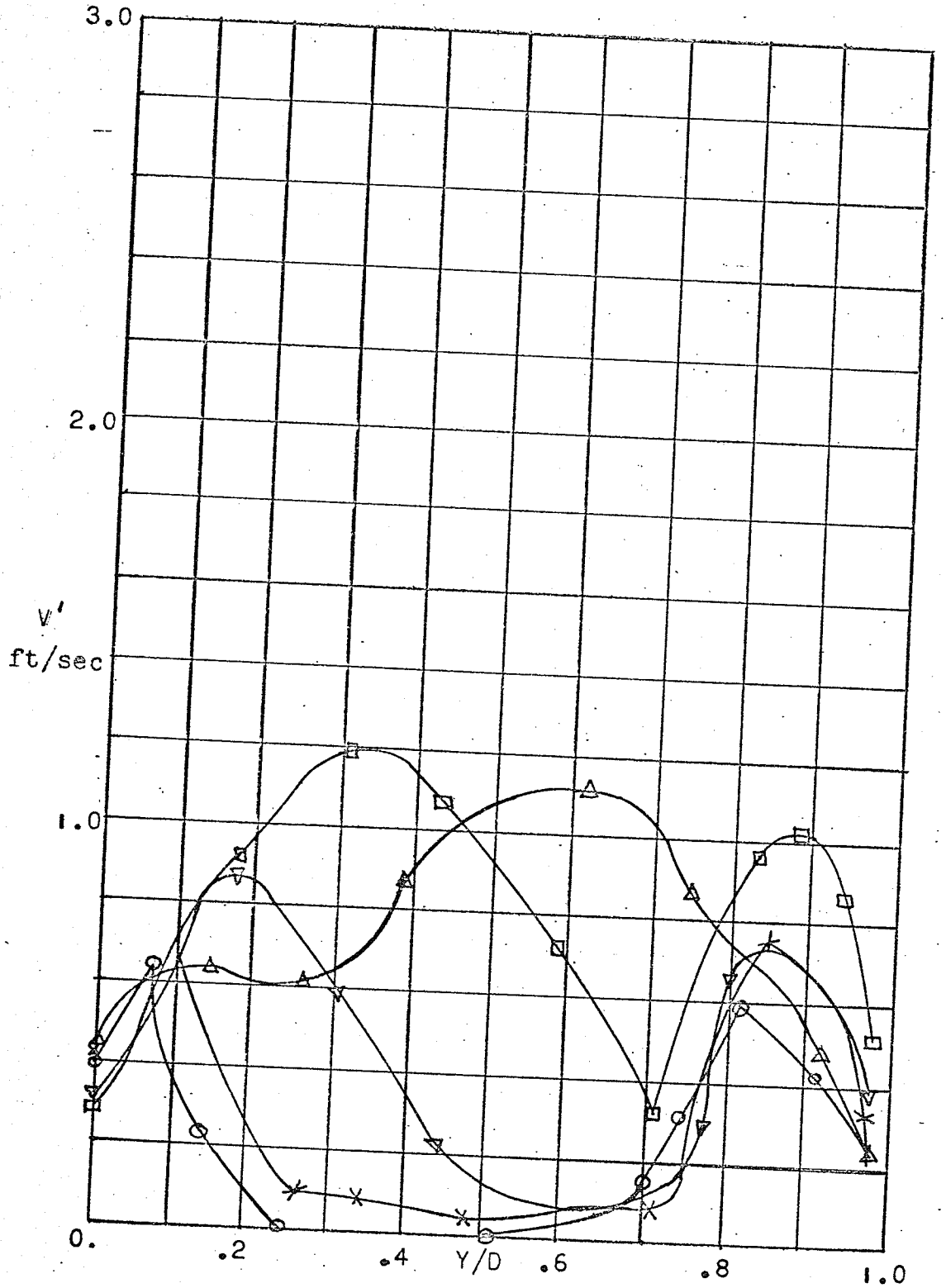
STN. 2

GRAPH 5.9 v' versus Y/D



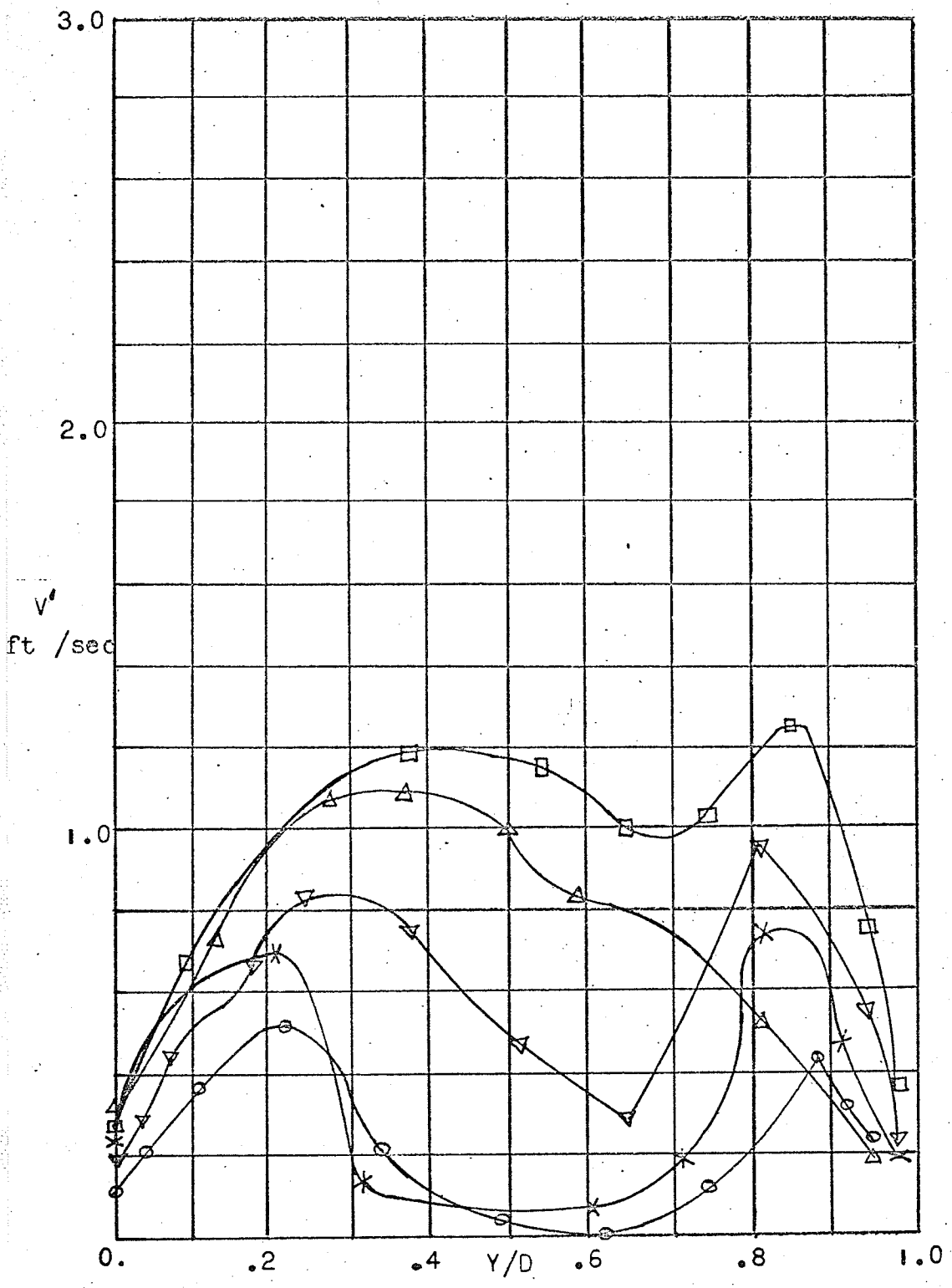
STN. 4

GRAPH 5.10 v' versus Y/D



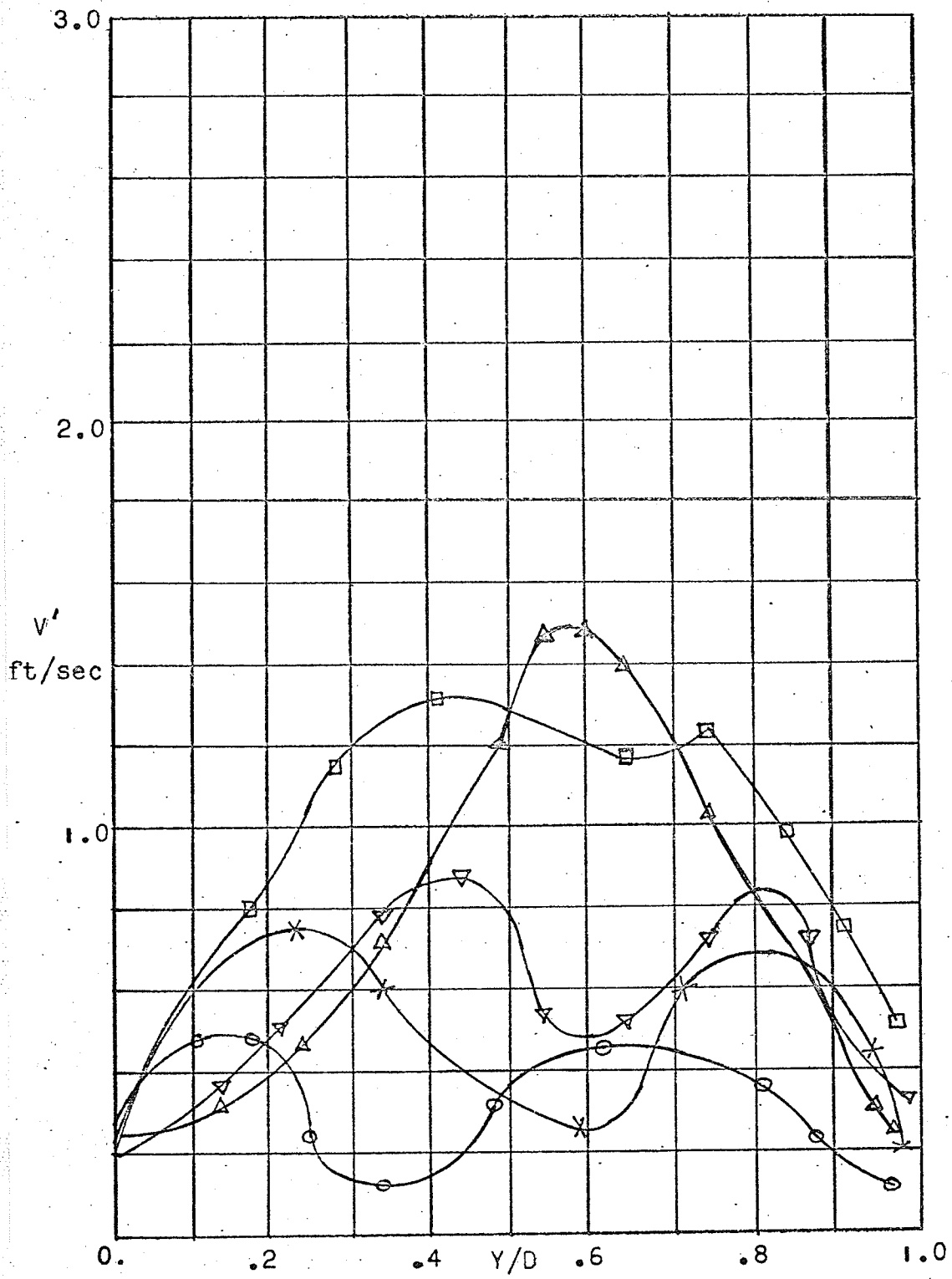
STN. 6

GRAPH 5.11 v^r versus Y/D



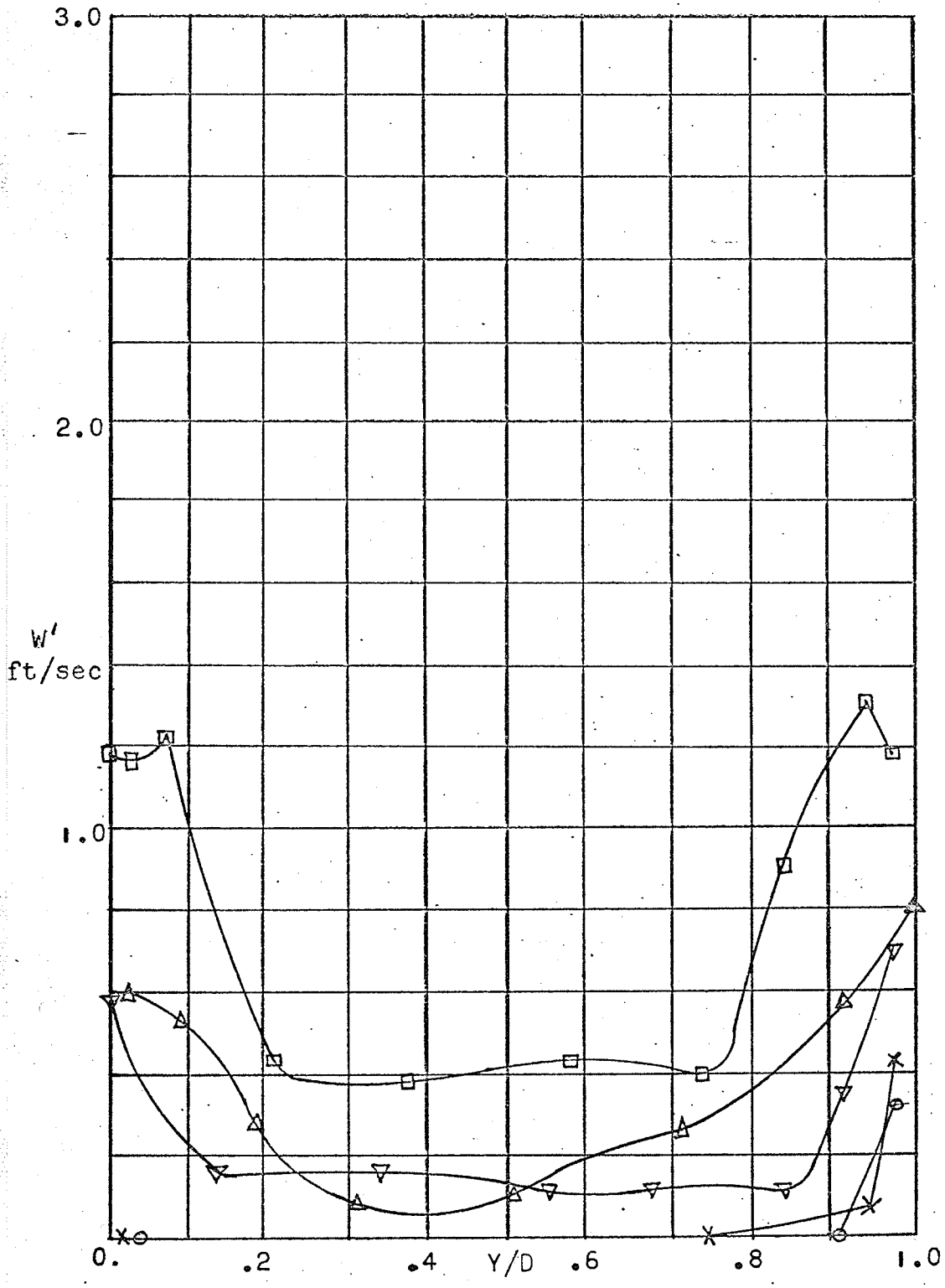
STN. 8

GRAPH 5.12 v' versus Y/D



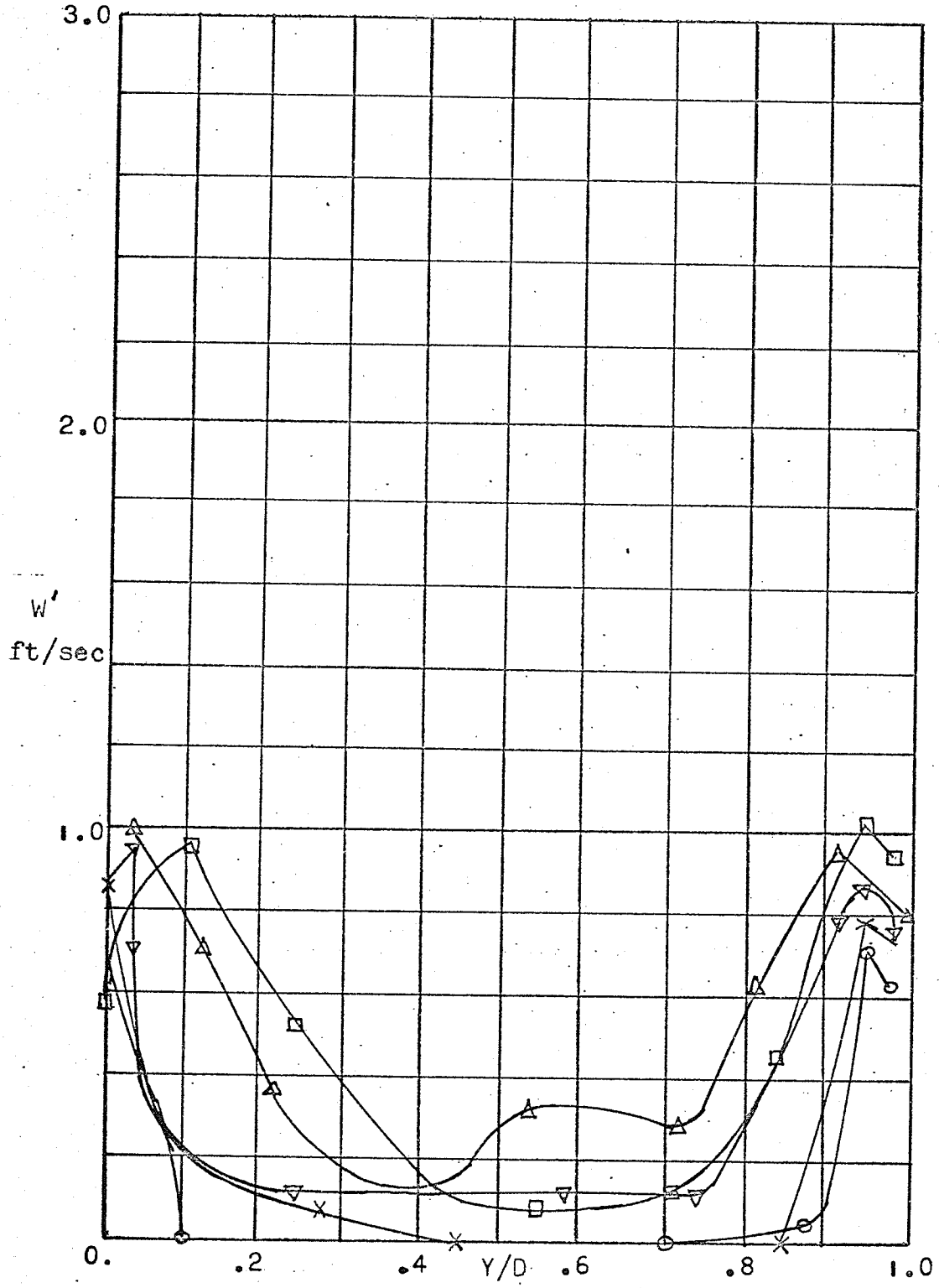
STN. 10

GRAPH 5.13 v' versus Y/D



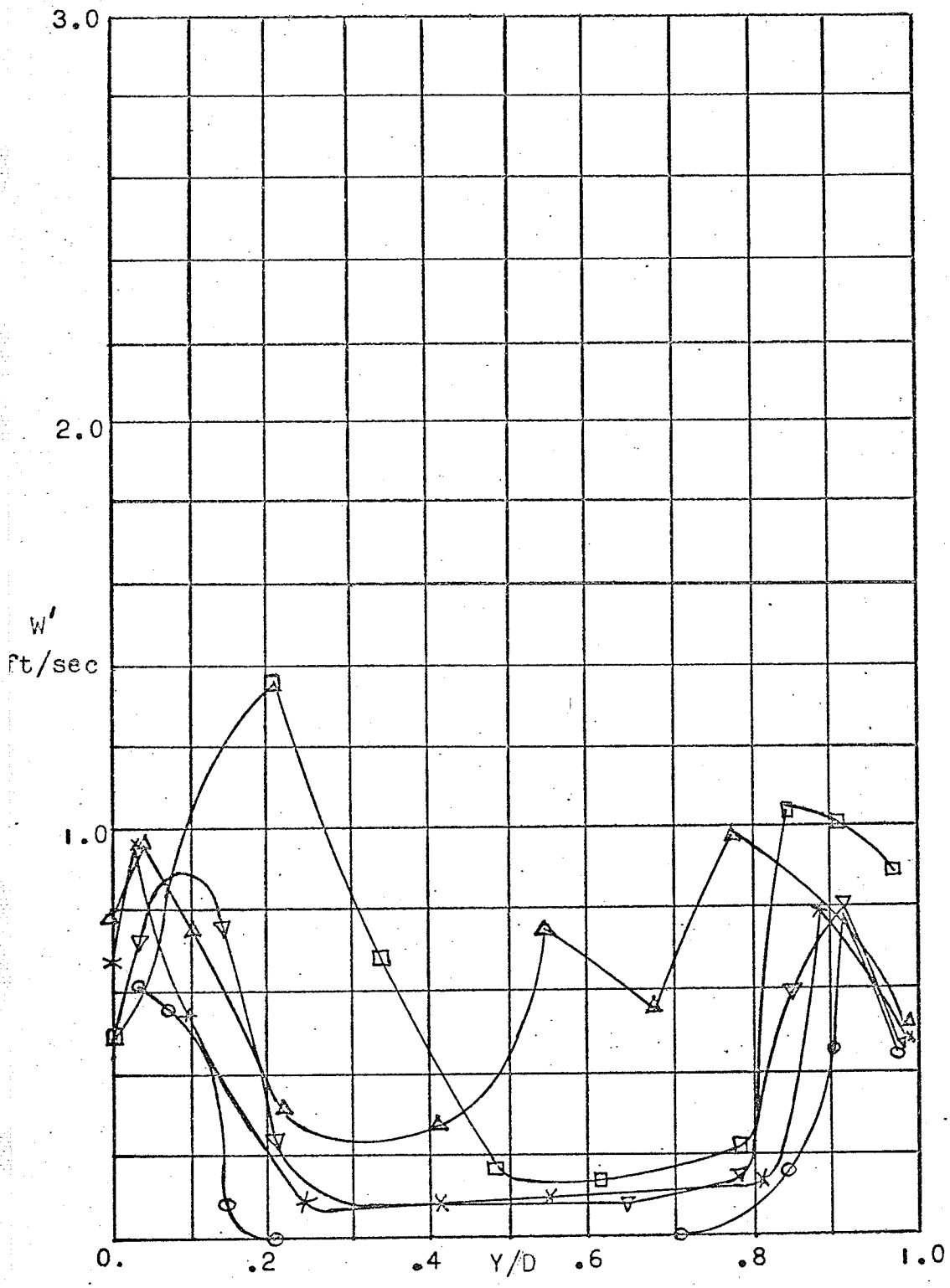
STN. 0

GRAPH 5.14 w' versus Y/D



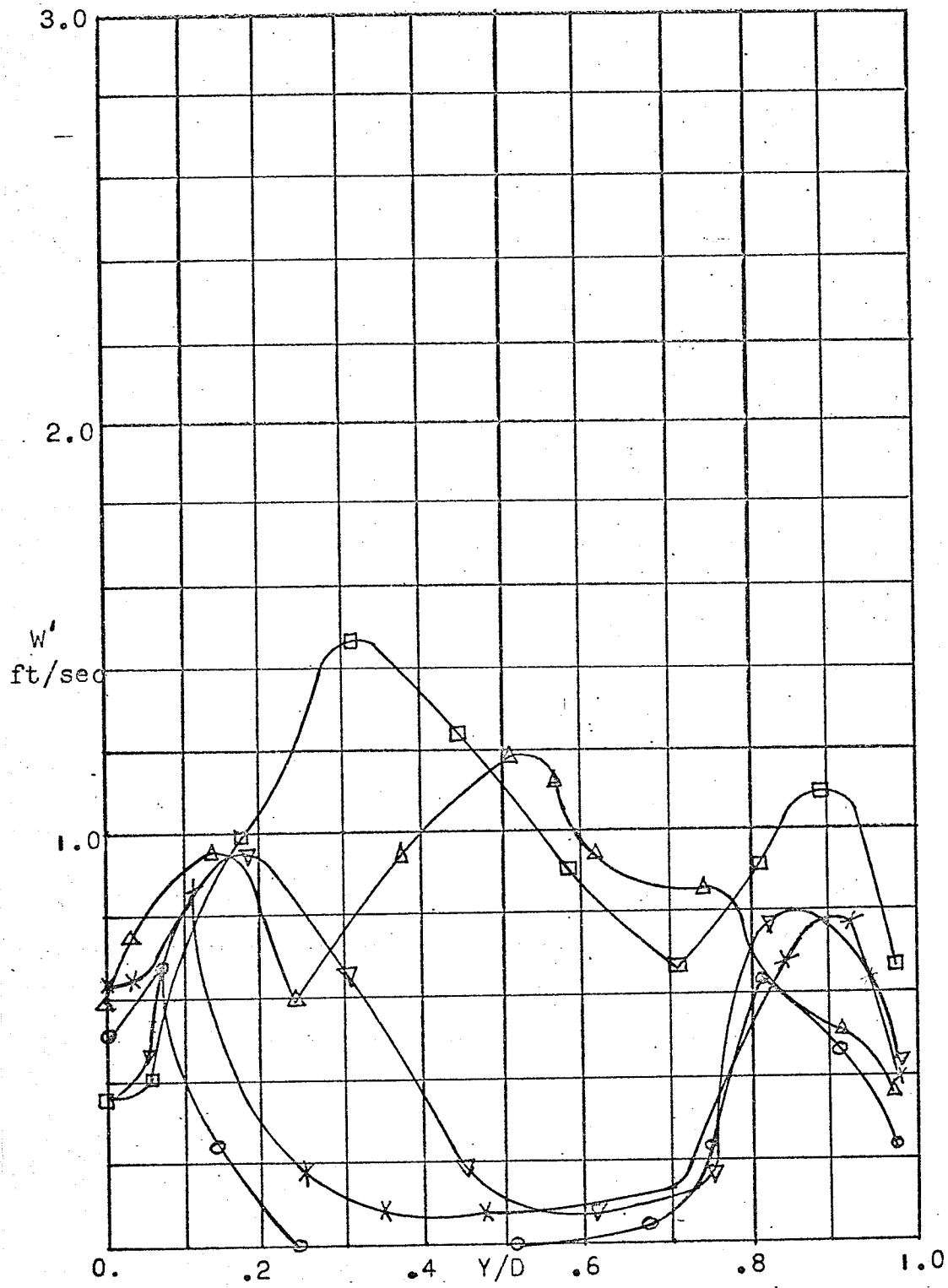
STN. 2

GRAPH 5.15 w' versus Y/D



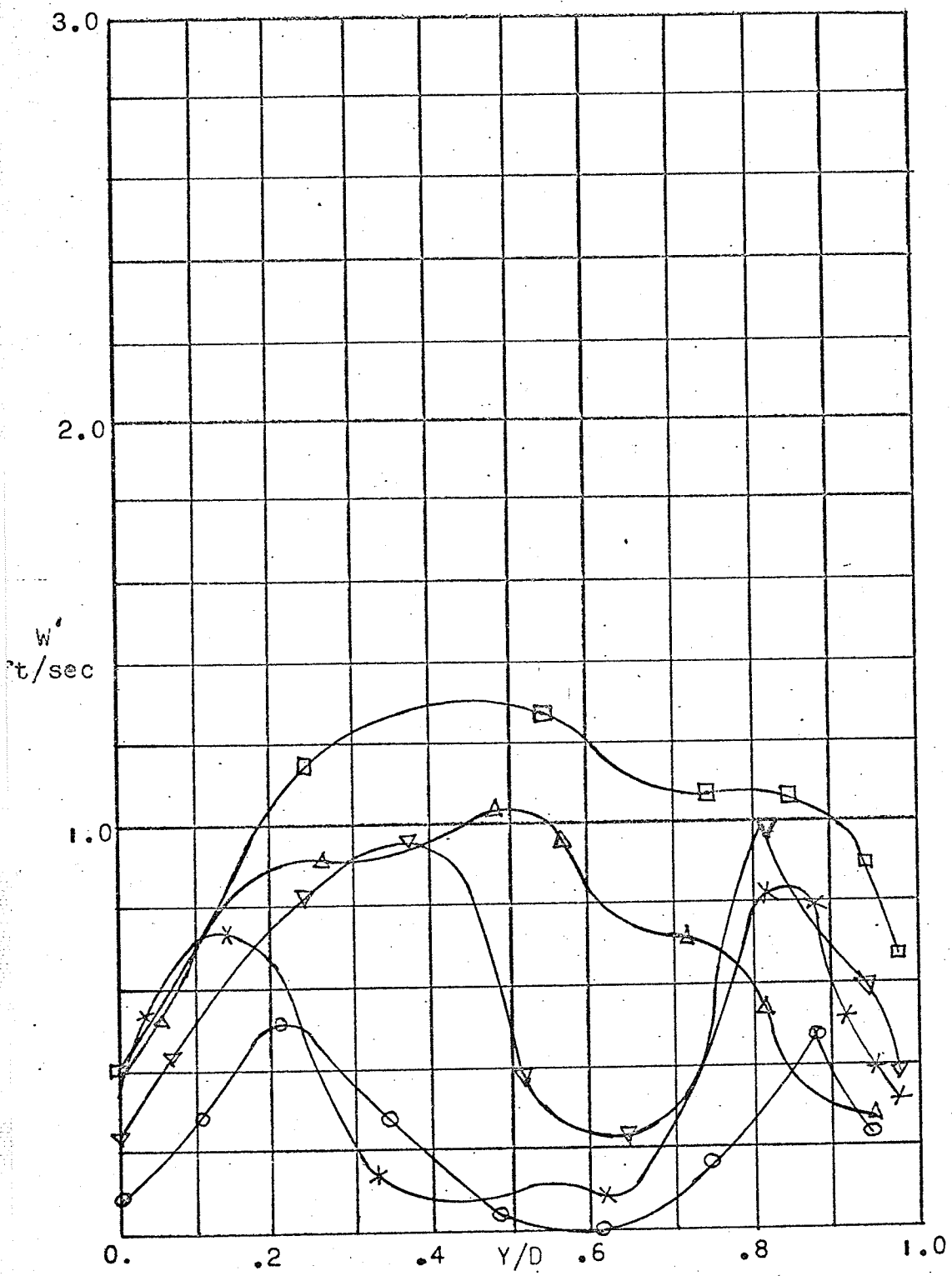
STN. 4

GRAPH 5.16 w' versus Y/D



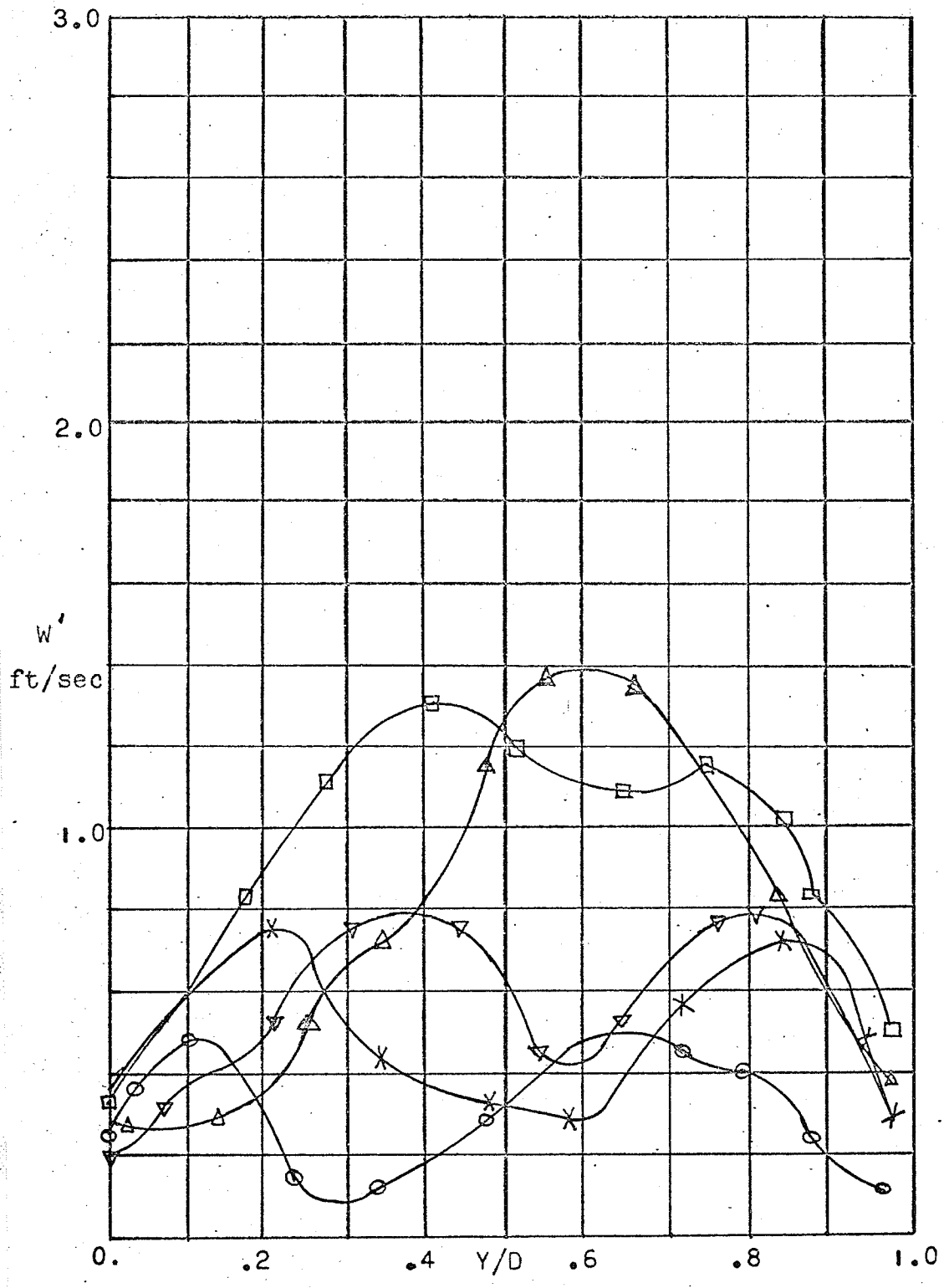
STN. 6

GRAPH 5.17 w' versus Y/D



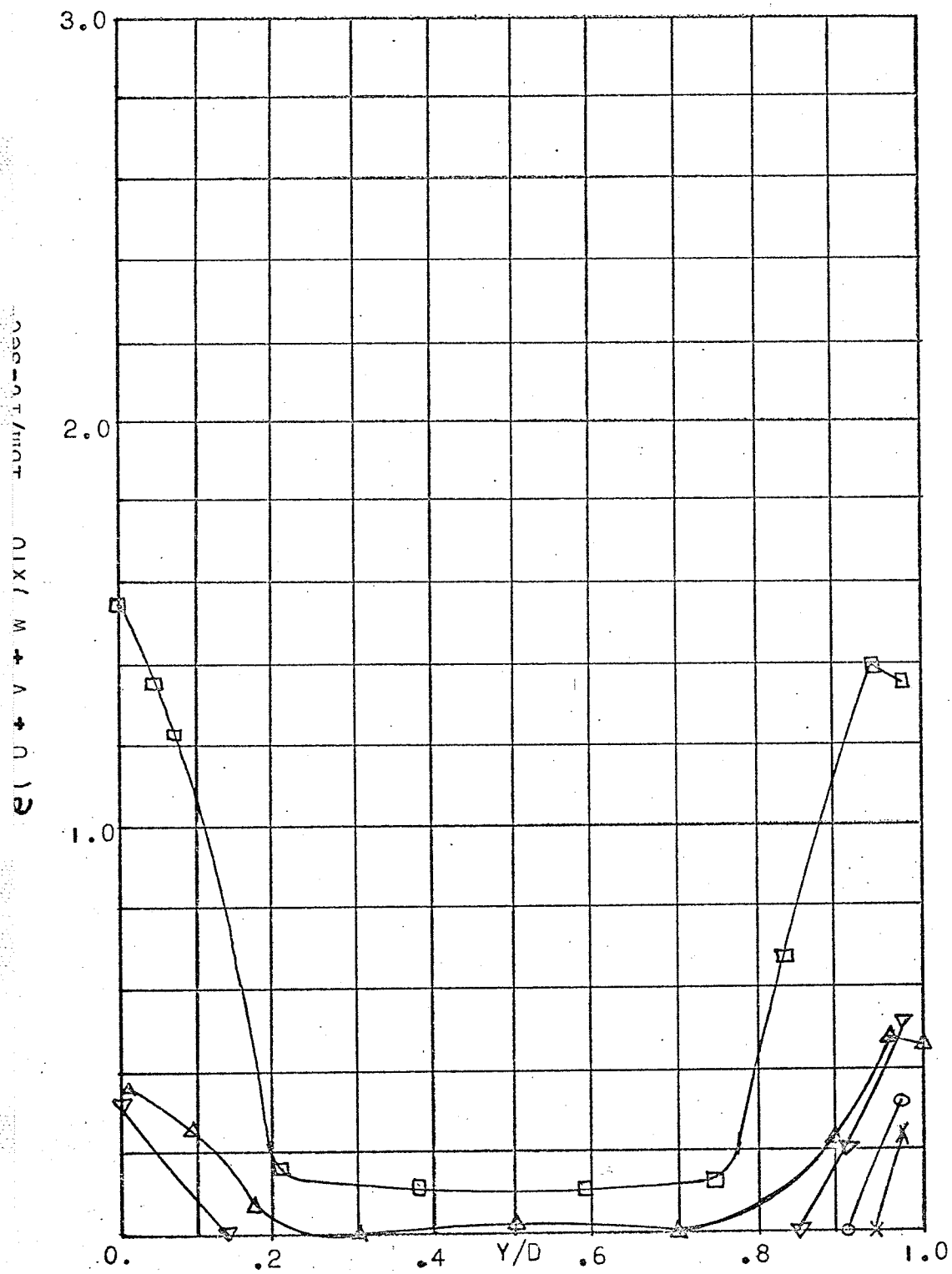
STN. 8

GRAPH 5.18 w' versus Y/D



STN. 10

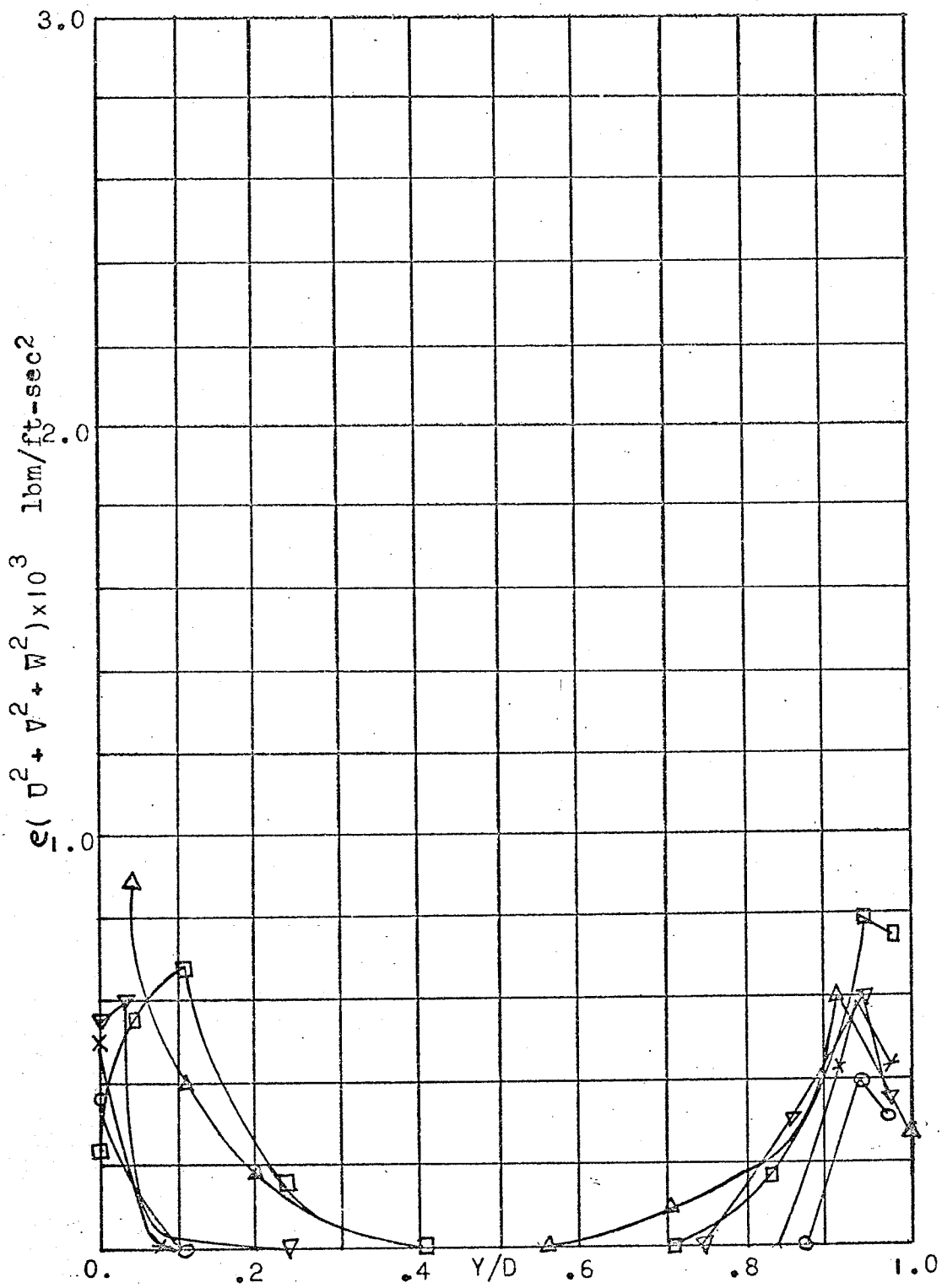
GRAPH 5.19 w' versus Y/D



STATION 0

GRAPH 5.20

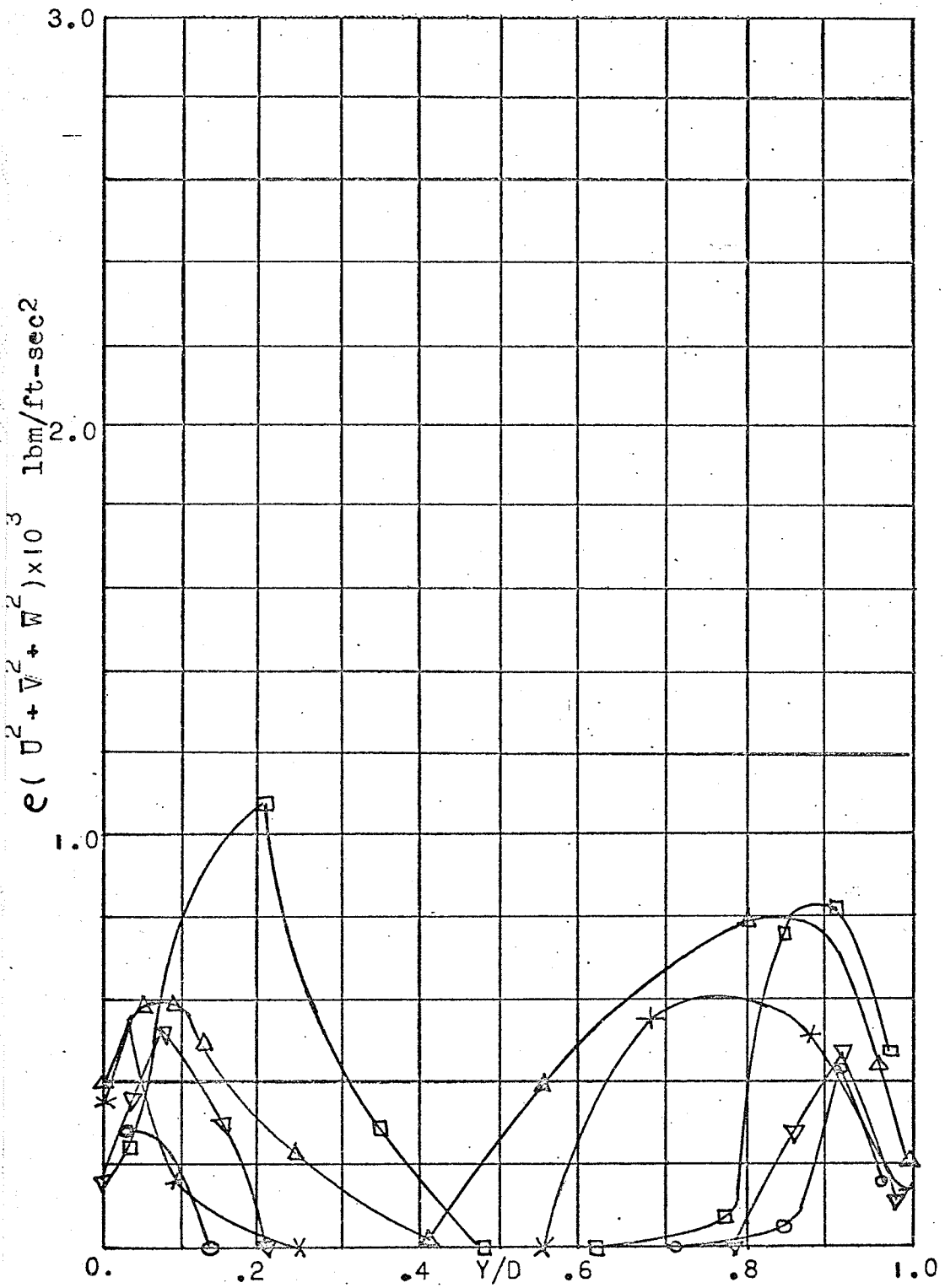
Turbulent Energy versus Y/D



STATION 2

GRAPH 5.21

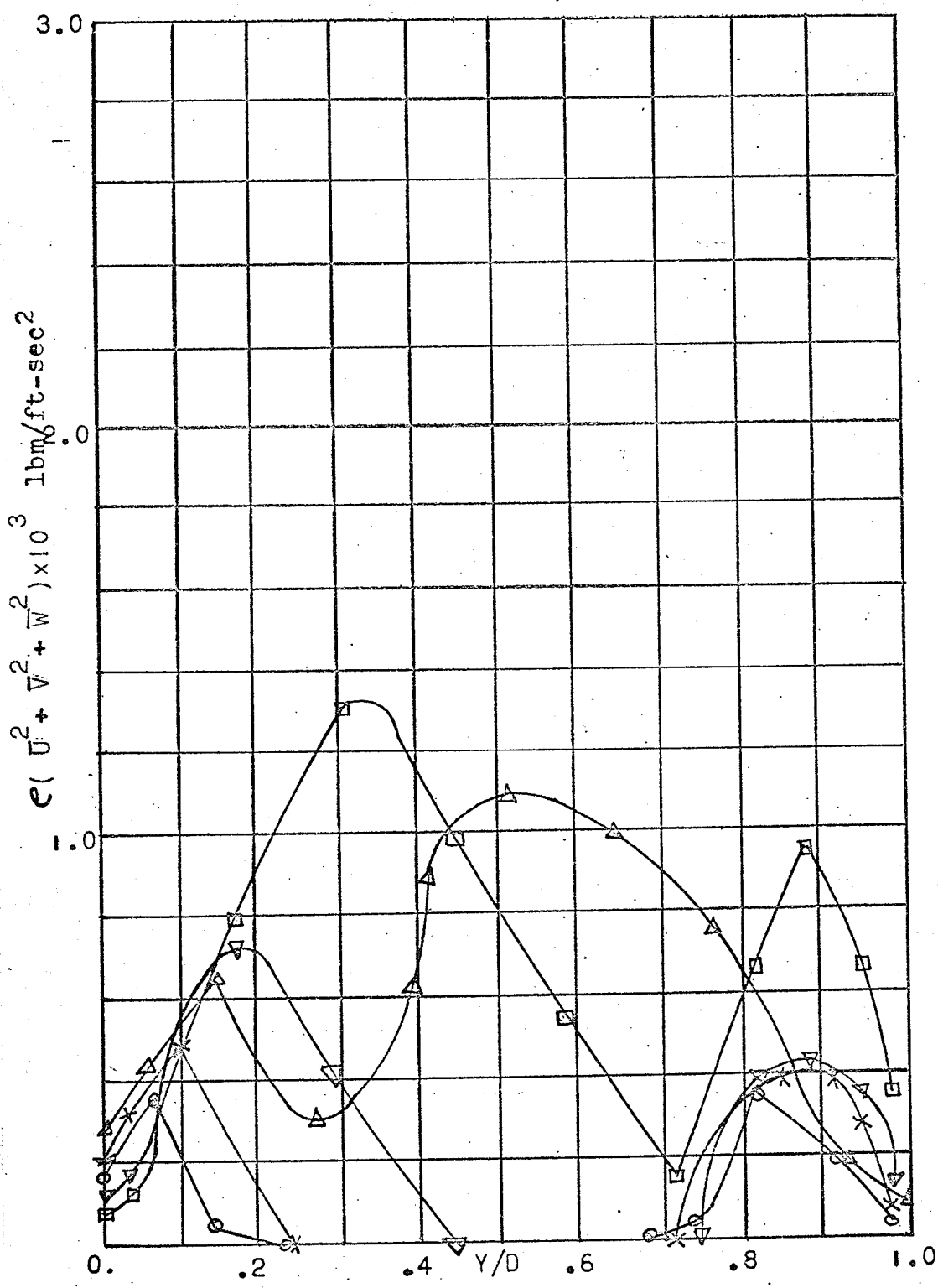
Turbulent Energy versus Y/D



STATION 4

GRAPH 5.22

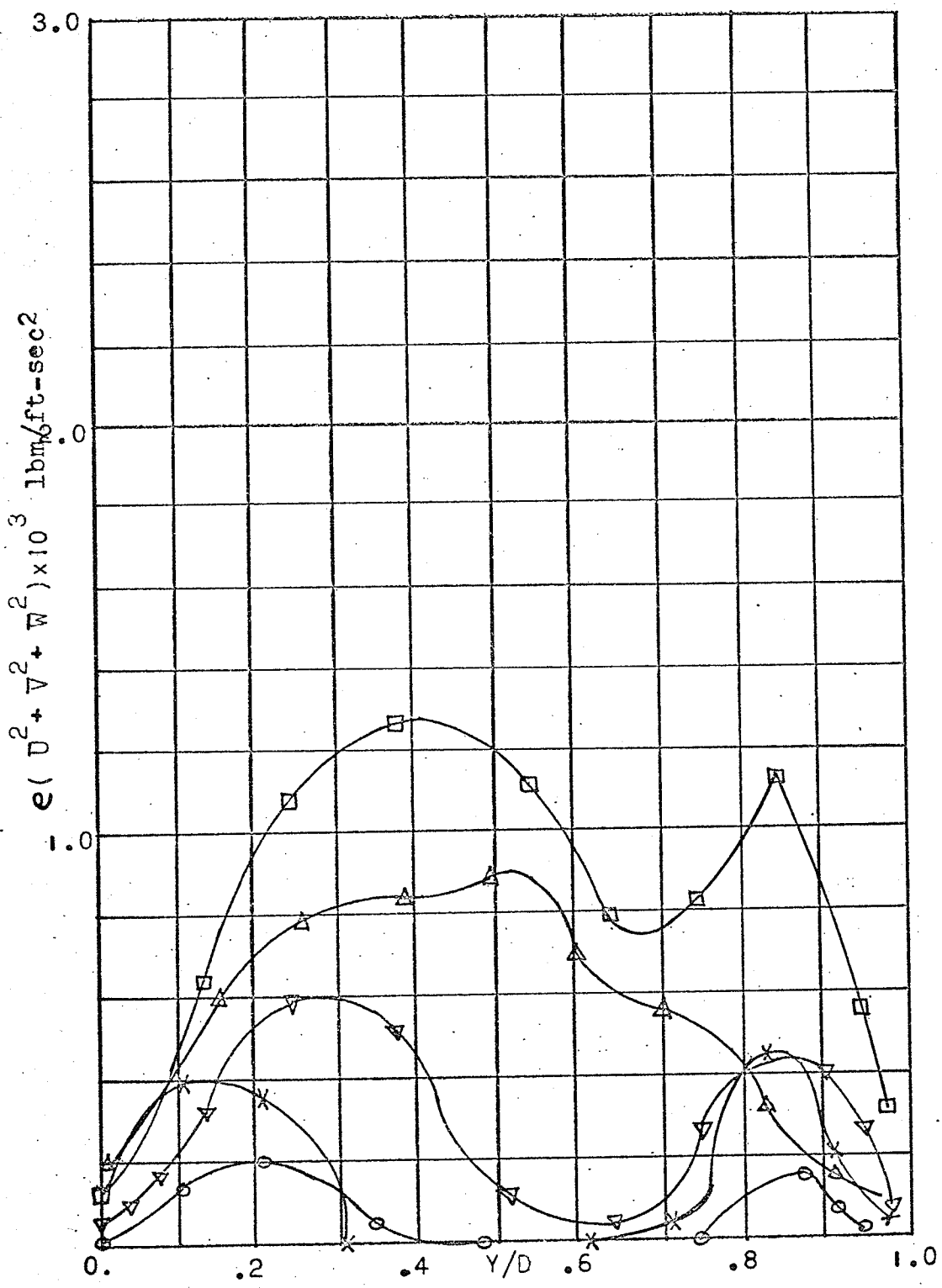
Turbulent Energy versus Y/D



STATION 6

GRAPH 5.23

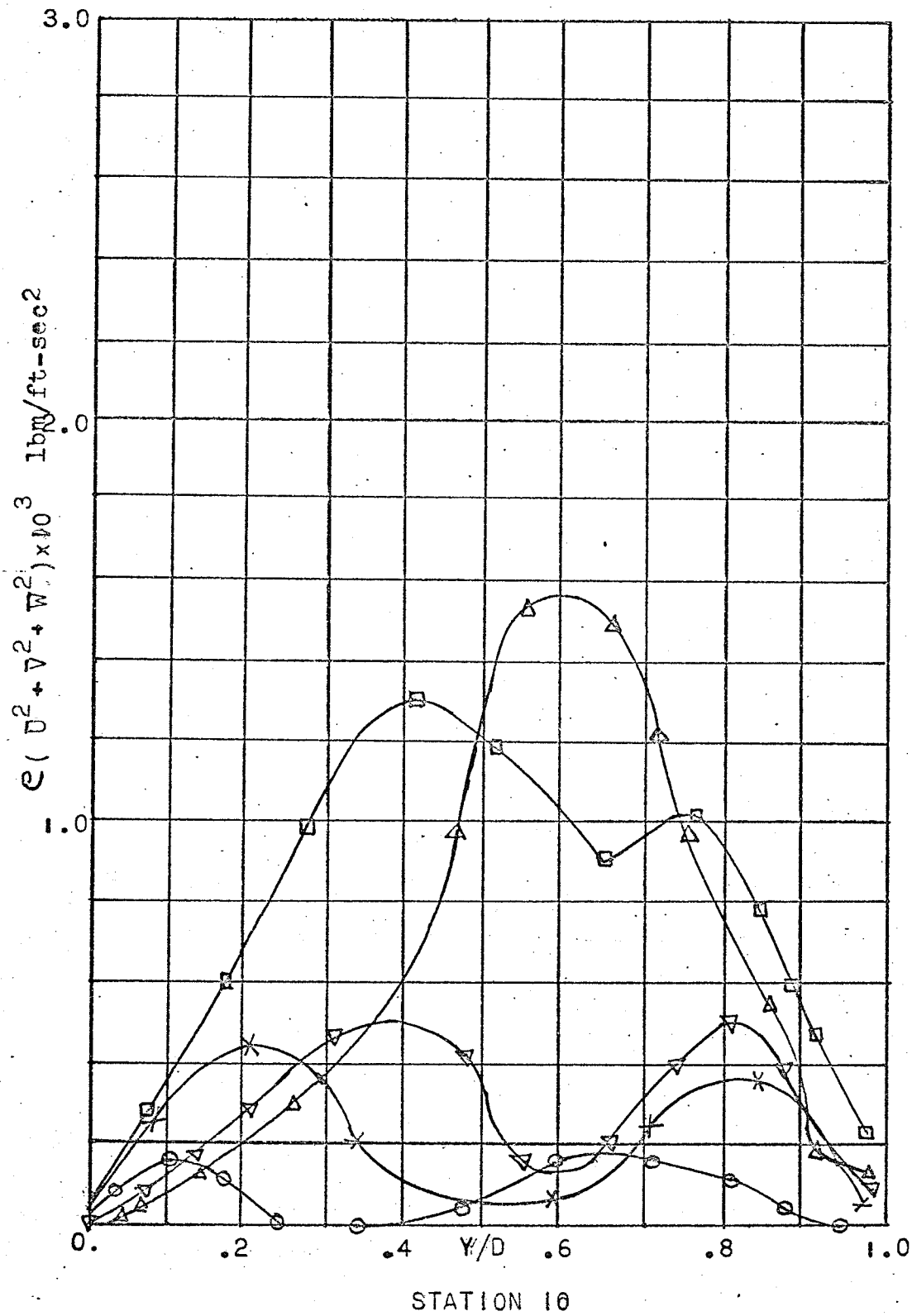
Turbulent Energy versus Y/D



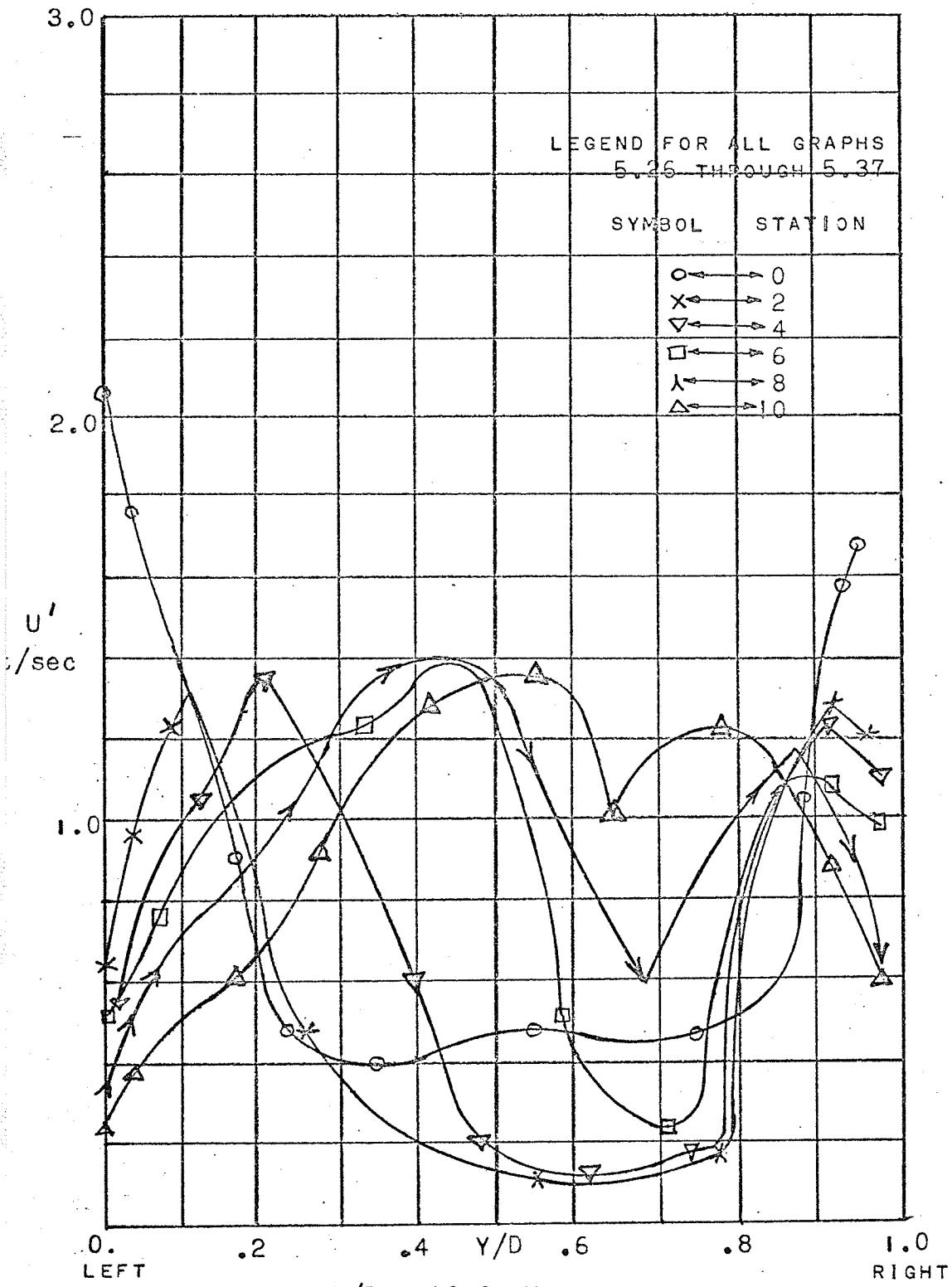
STATION 8

GRAPH 5.24

Turbulent Energy versus Y/D

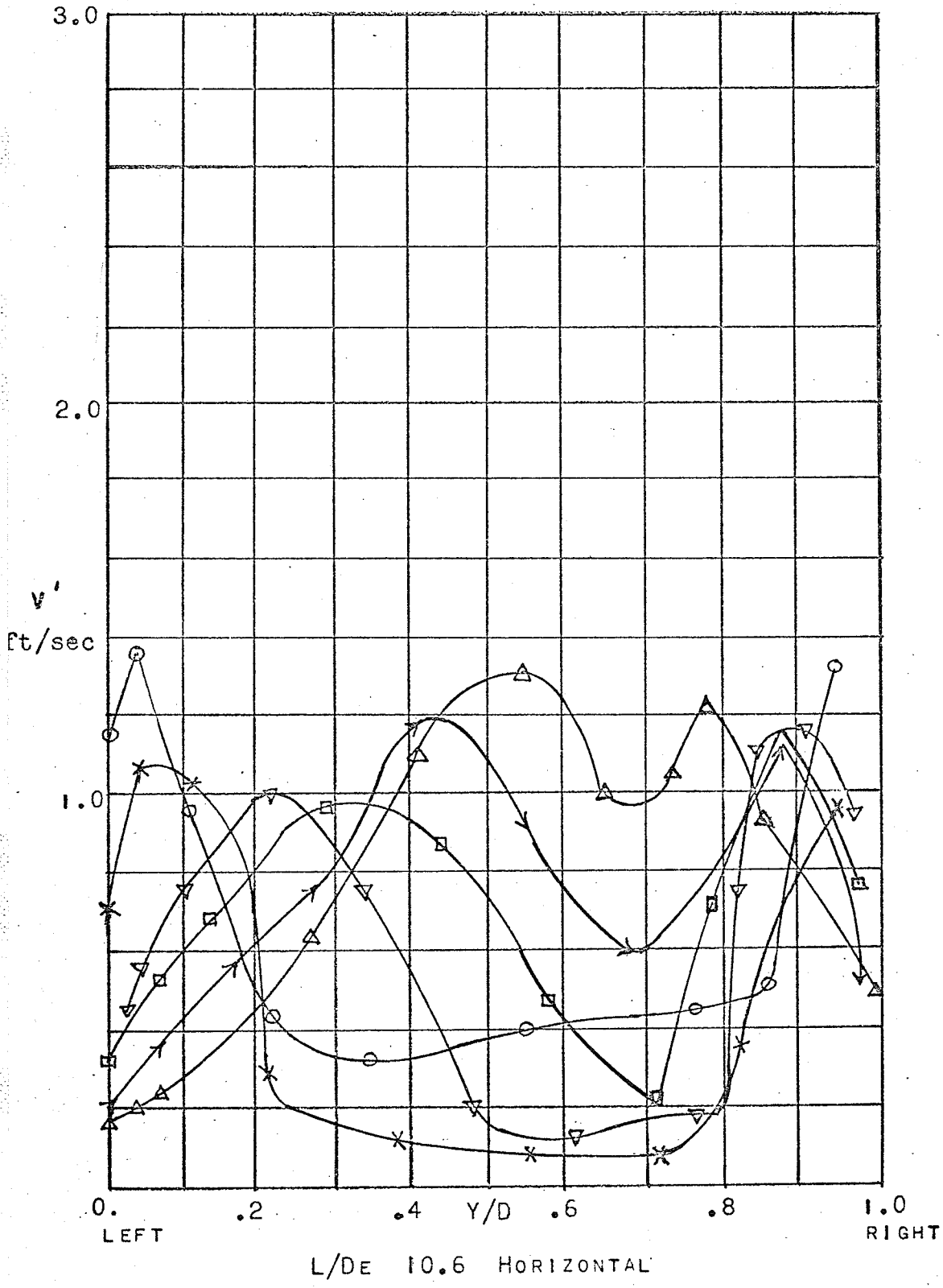


GRAPH 5.25
Turbulent Energy versus Y/D

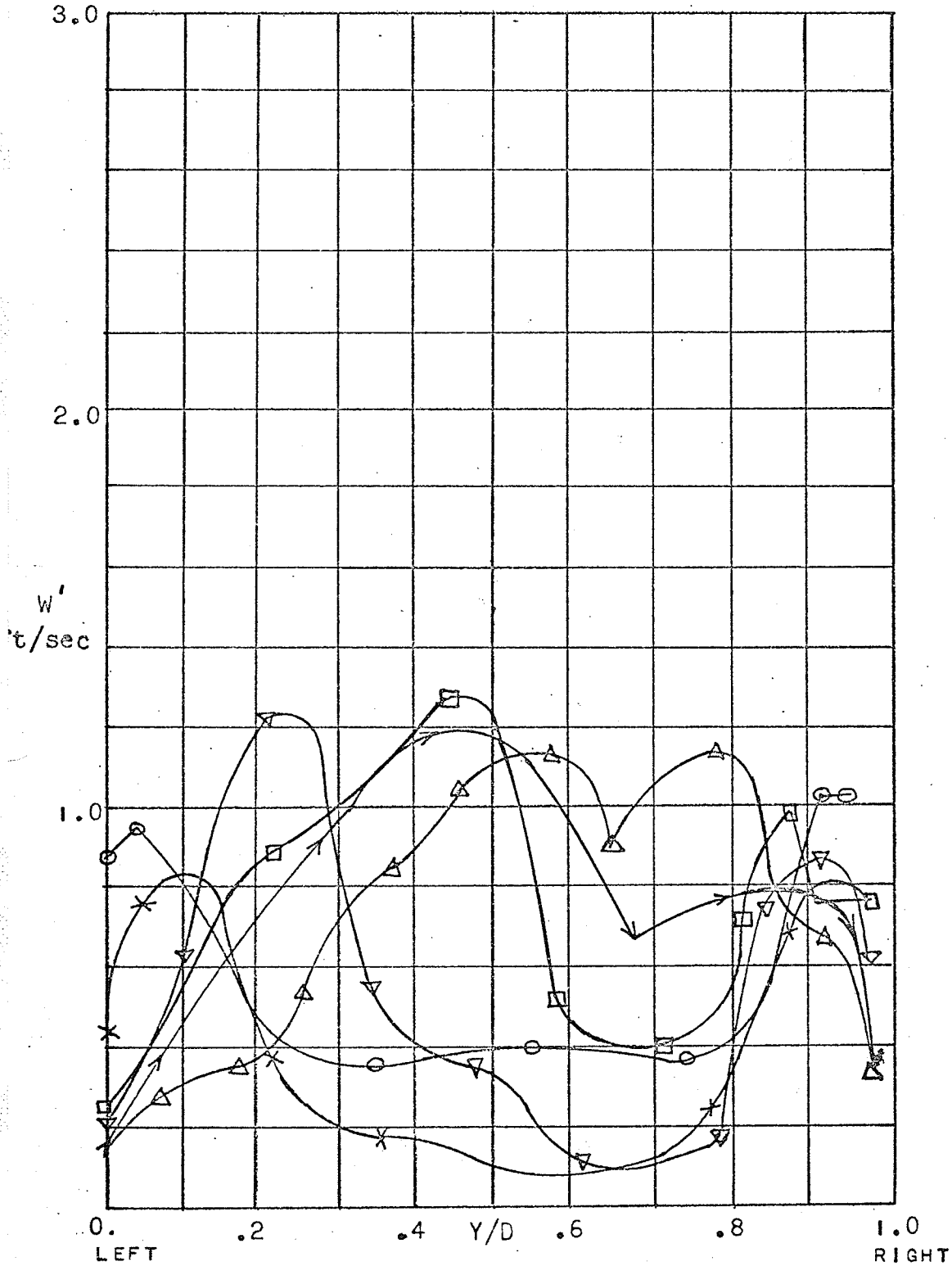


as per Figure 4.1 L/De 10.6 HORIZONTAL as per Figure 4.1

GRAPH 5.26 u' versus Y/D

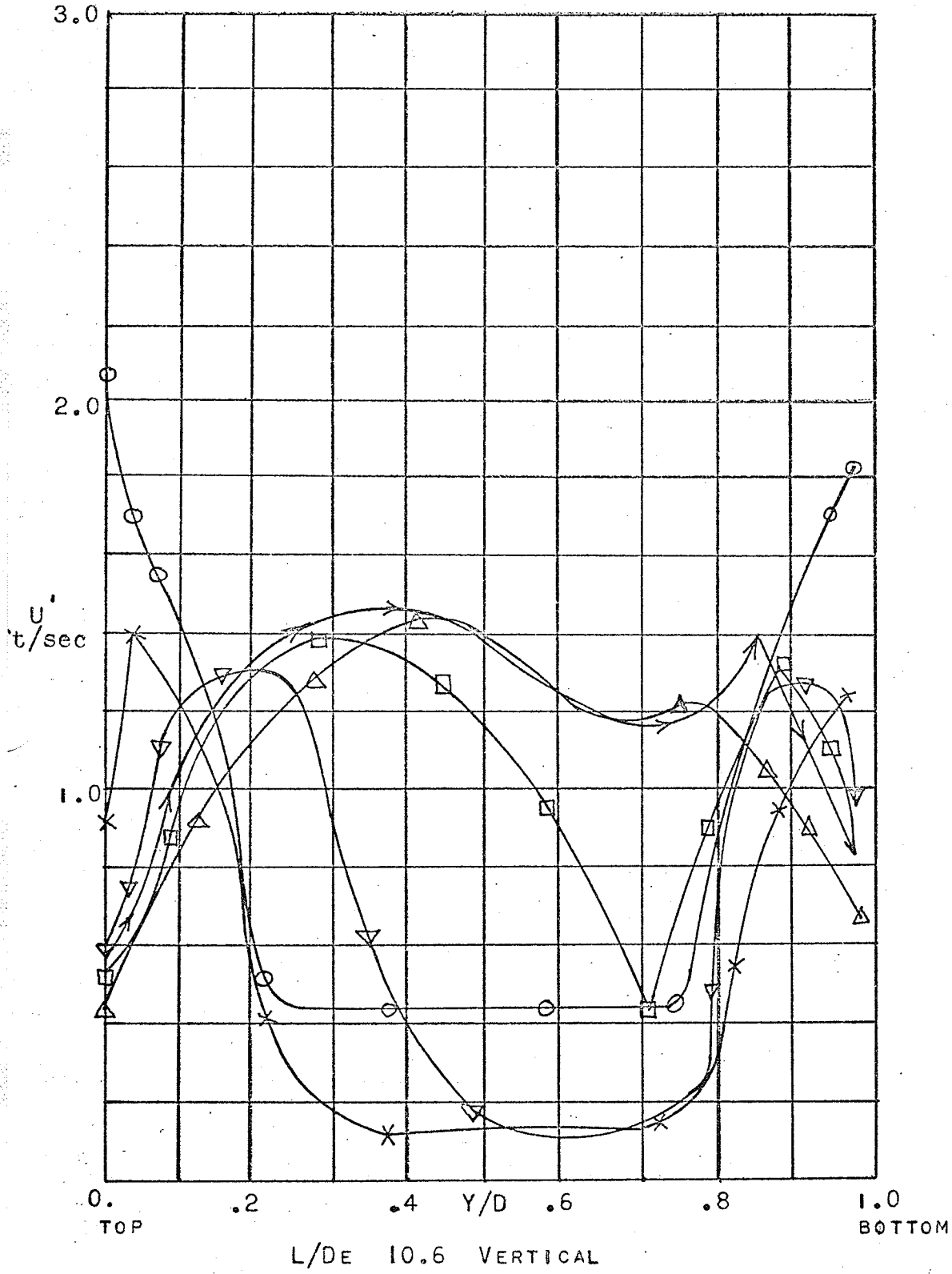


GRAPH 5.27 v' versus Y/D

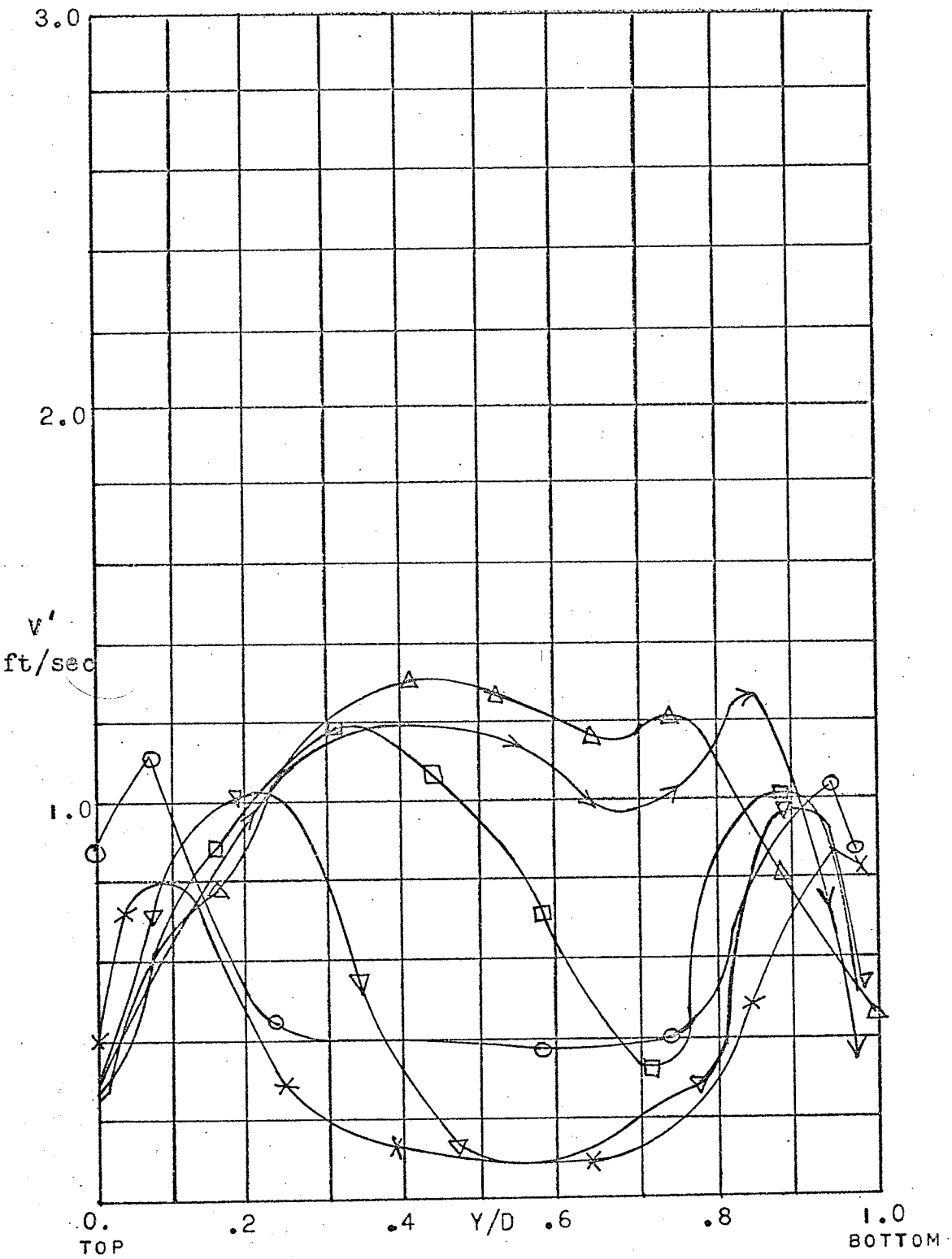


L/De 10.6 HORIZONTAL

GRAPH 5.28 w^r versus Y/D

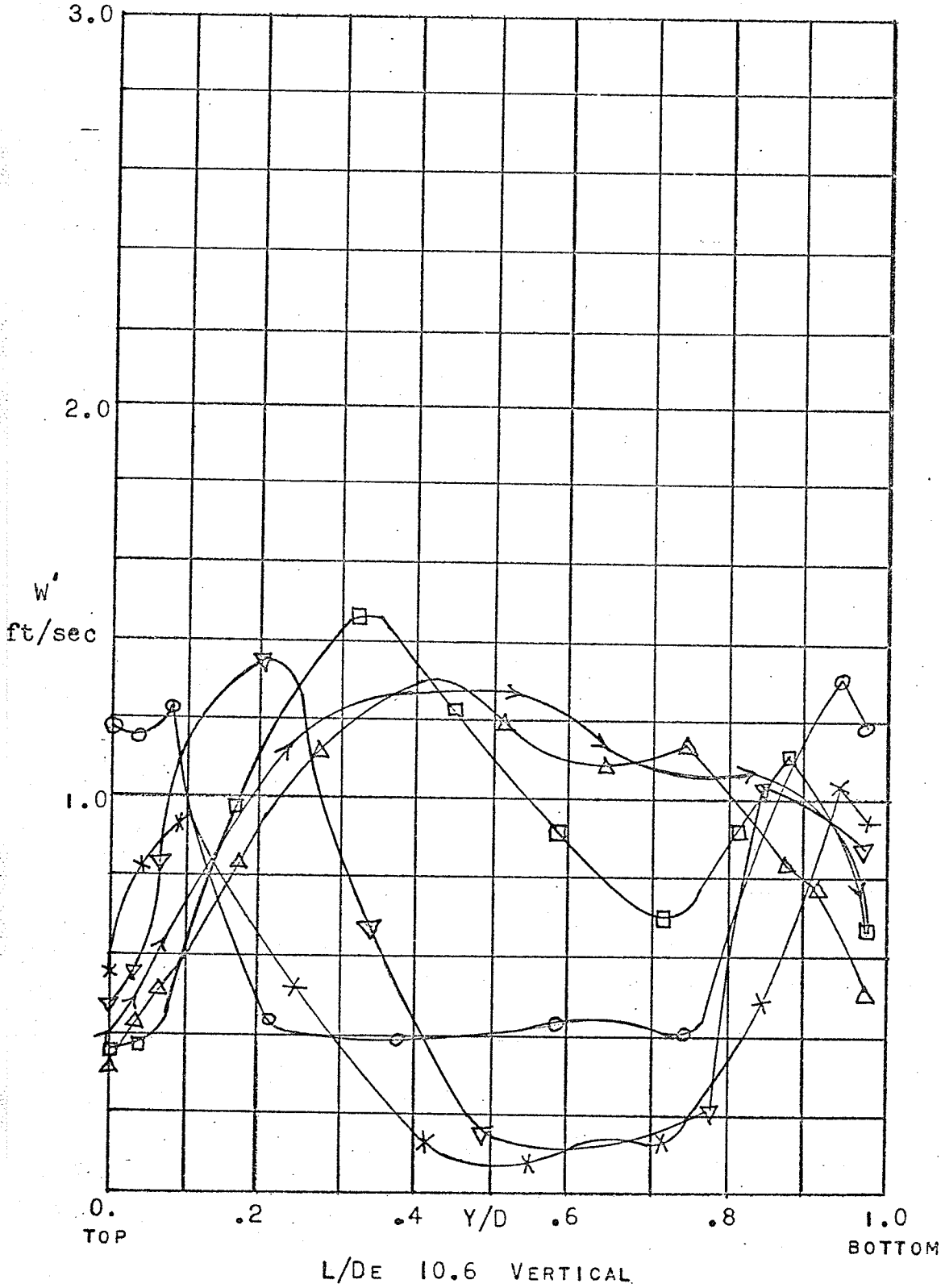


GRAPH 5.29 u' versus Y/D

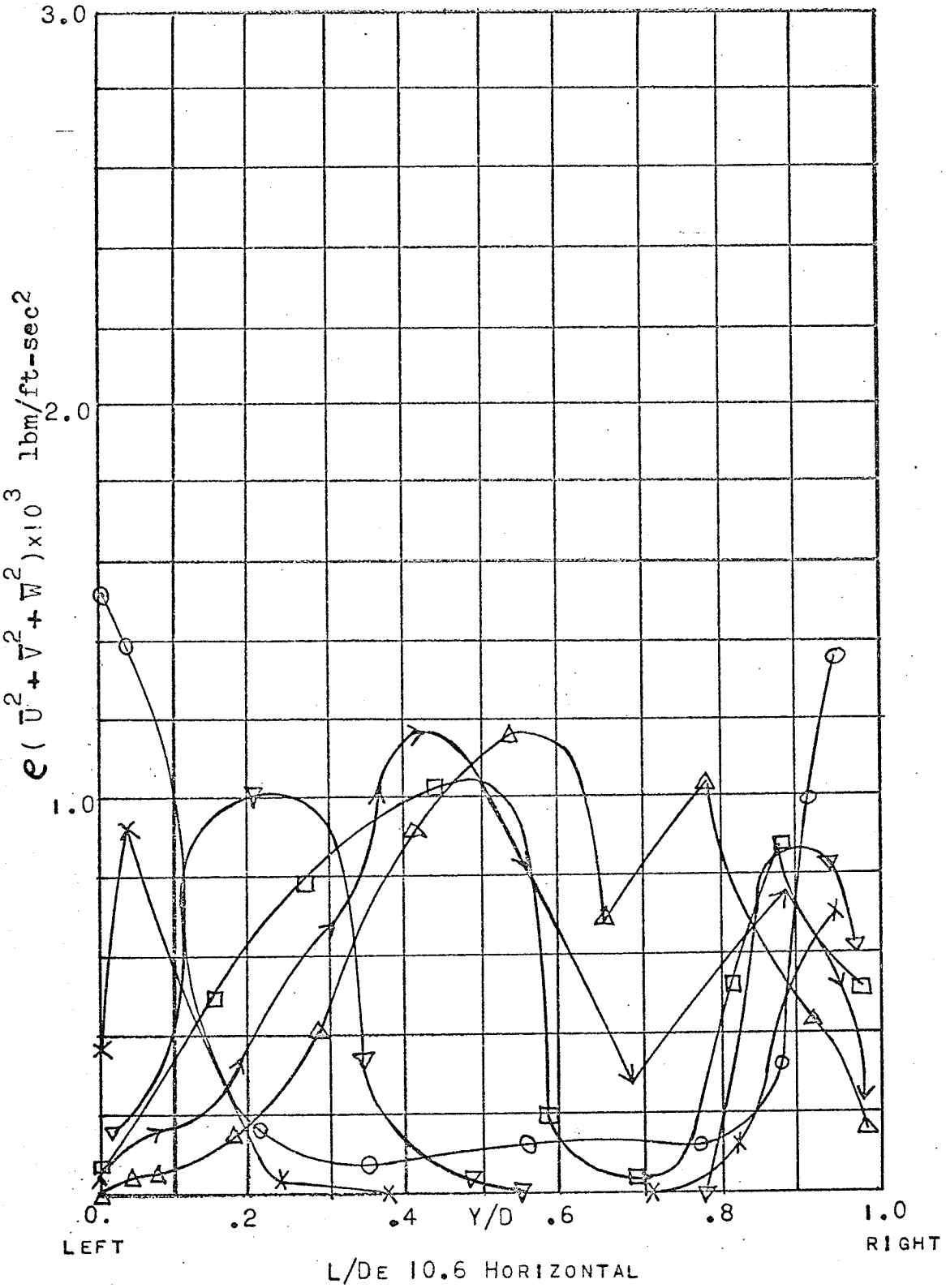


L/De 10.6 Vertical

GRAPH 5.30 v' versus Y/D



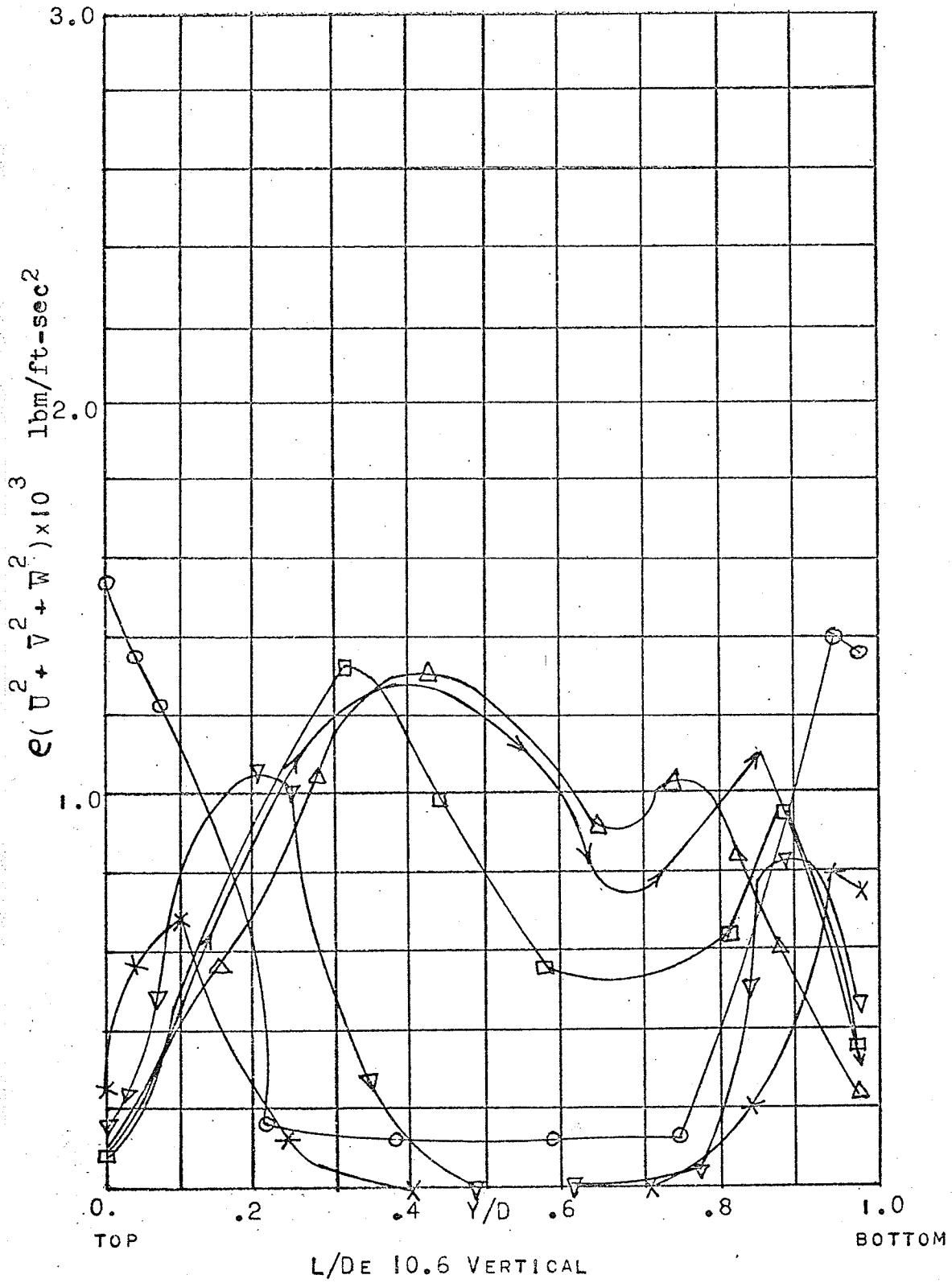
GRAPH 5.31 w' versus Y/D



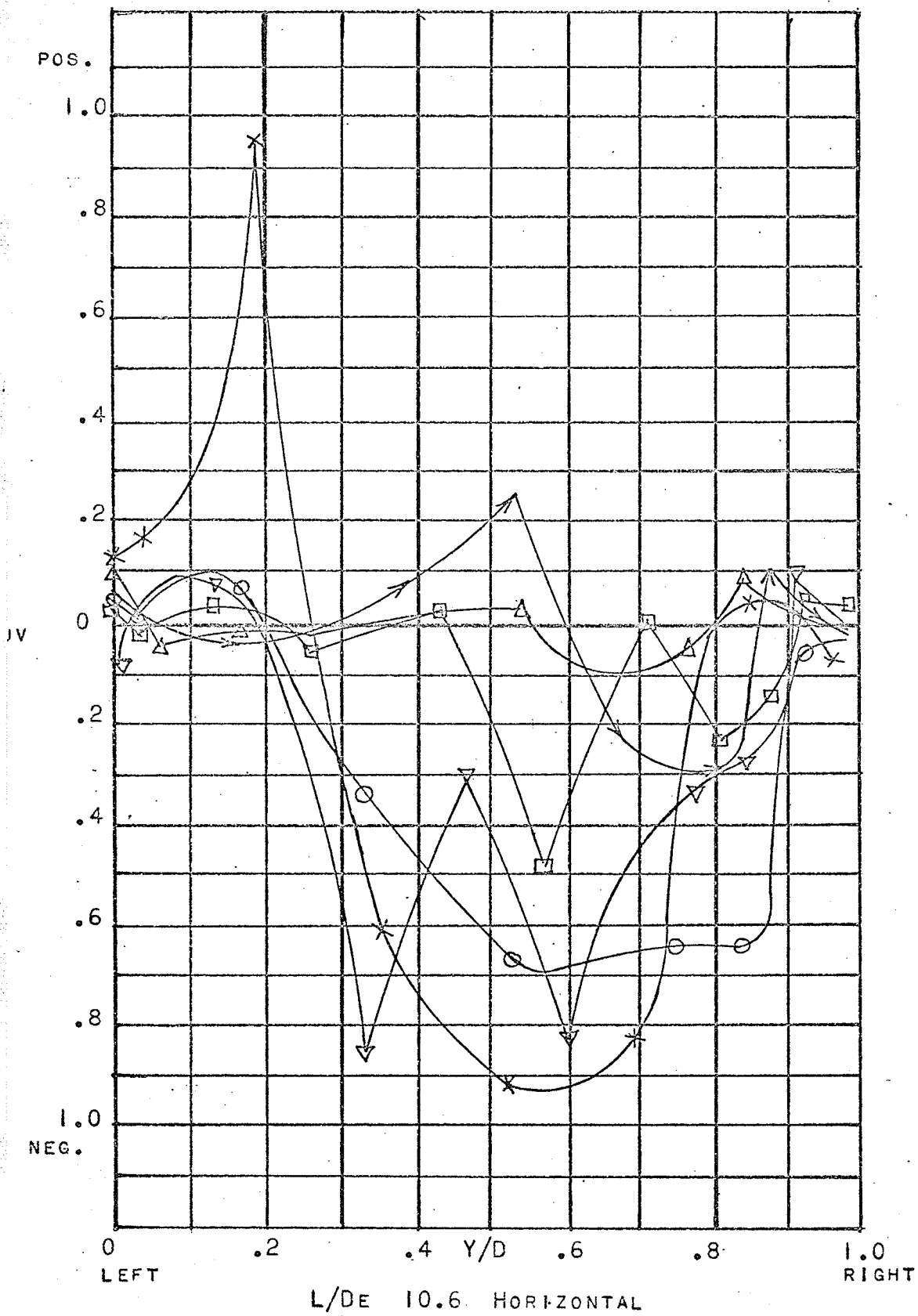
L/De 10.6 Horizontal

GRAPH 5.32

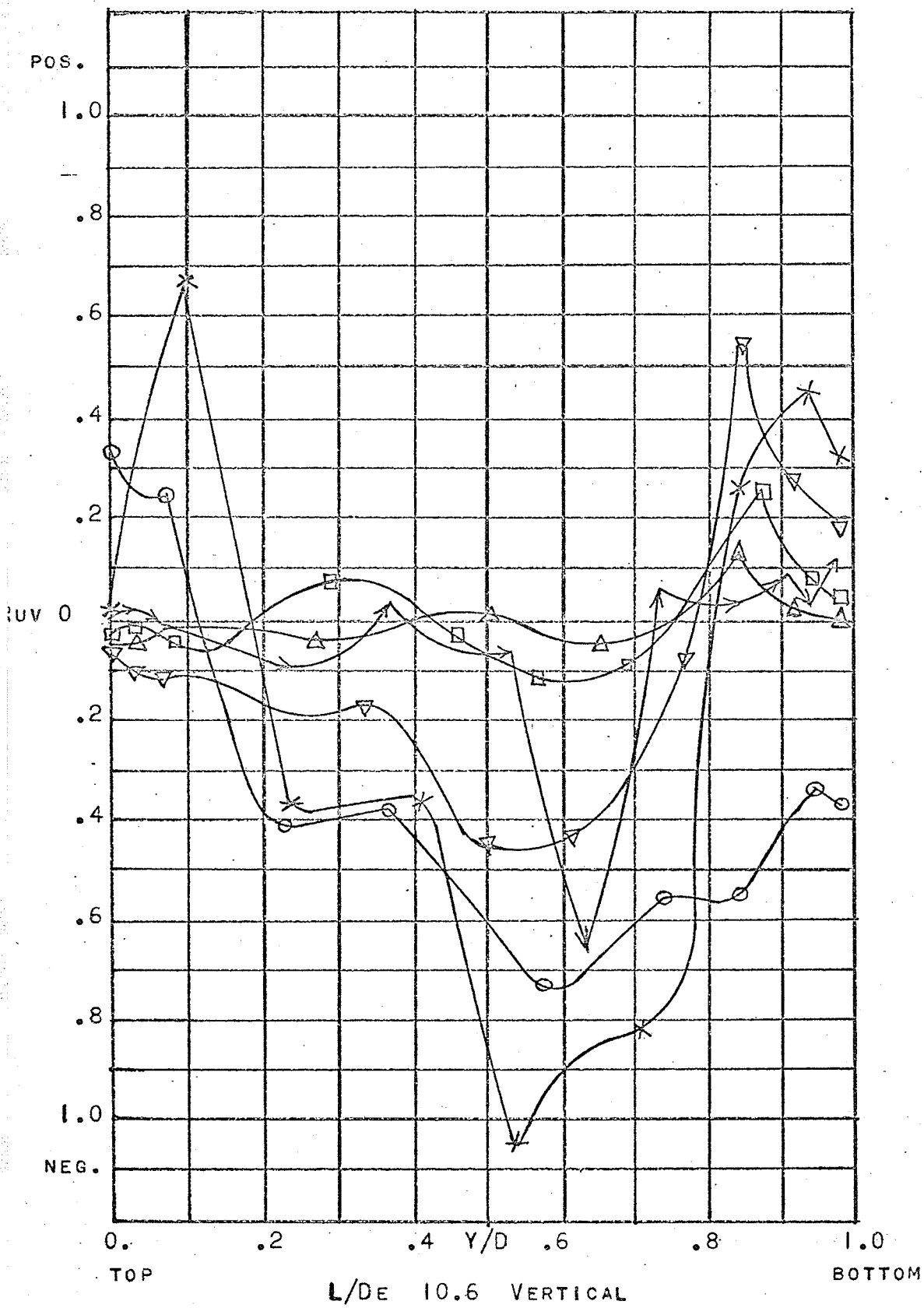
Turbulent Energy versus Y/D



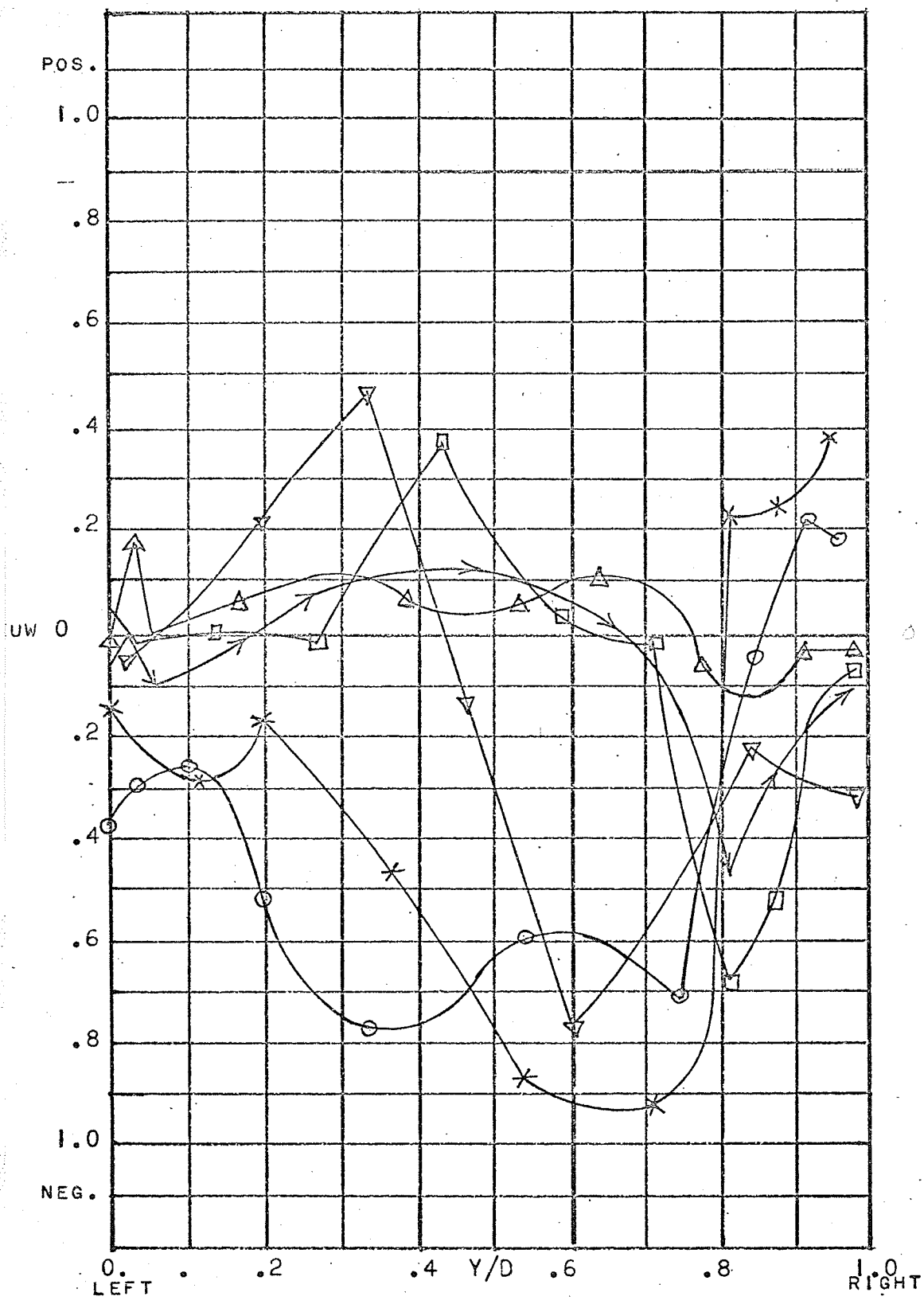
GRAPH 5.33
Turbulent Energy versus Y/D



GRAPH 5.34
Ruv versus Y/D

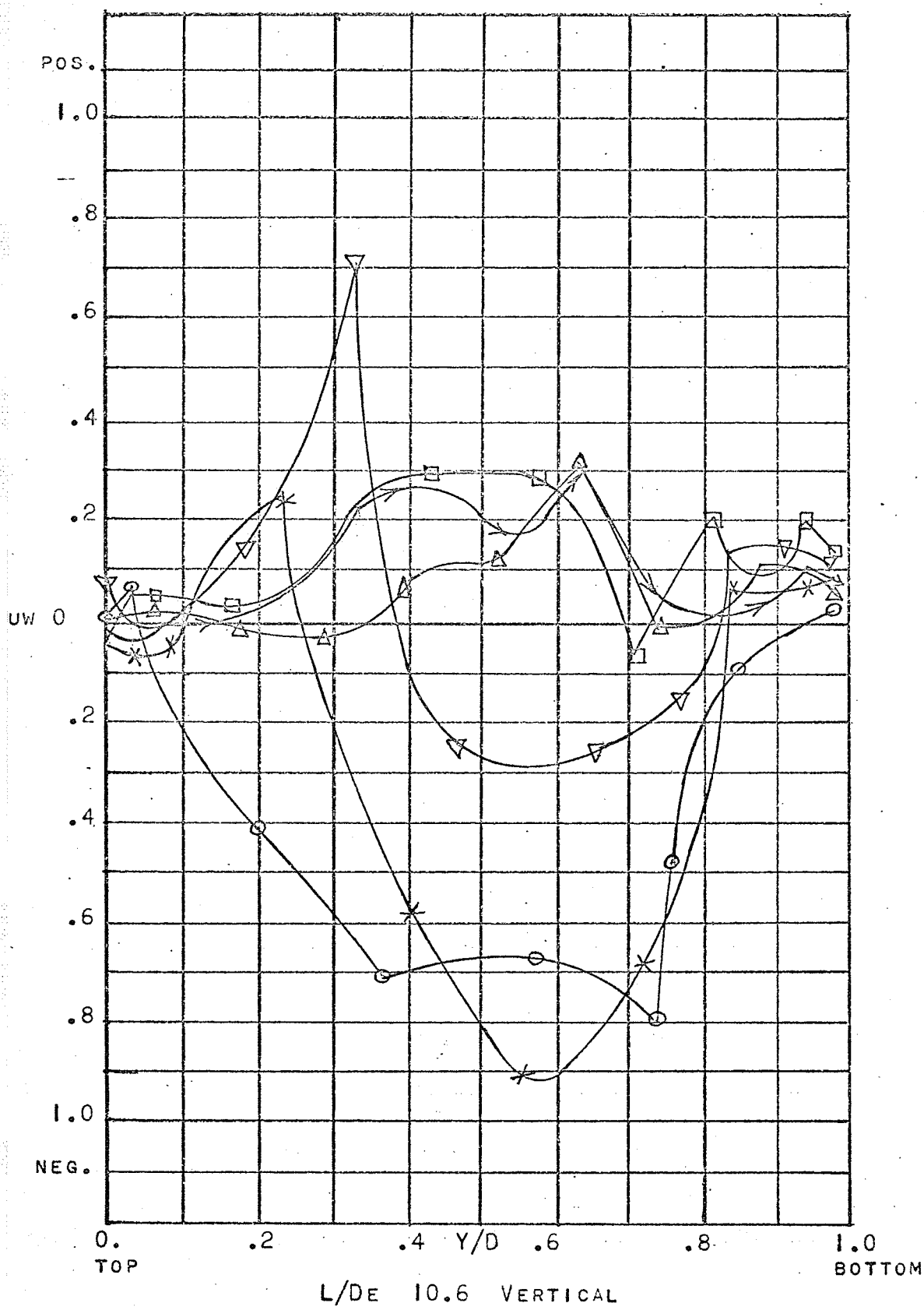


GRAPH 5.35
Ruv versus Y/D



L/DE 10.6 HORIZONTAL

GRAPH 5.36
Ruw versus Y/D



L/De 10.6 VERTICAL

GRAPH 5.37

Ruw versus Y/D

APPENDIX A

TOTAL RESULTS OF EXPERIMENTAL WORK

Explanation of the Coding System

Each table in the following pages has the word "Code", followed by a five digit number, in the upper left hand corner. This code denotes the L/De ratio, the station which was measured, and the traverse which was measured.

This is done as follows:

1. The first two digits denote the L/De ratio.
   16 means L/De = 16.6
   10 means L/De = 10.6
   46 means L/De = 4.6
   15 means L/De = 1.6
   06 means L/De = 0.6

2. The third digit denotes the traverse which was measured. For L/De = 16.6 and 0.6 there were four traverses measured. Facing the outlet of the diffuser and looking in towards the fan these were as follows:

Digit	Traverse	
1	1 - 5	
2	2 - 6	
3	3 - 7	
4	4 - 8	(Cf. Figure 4.1)

For L/De ratios of 10.6, 4.6, and 1.6 the traverses were

Digit	Traverse
1	1 - 5
2	3 - 7

3. The last two digits denote the station at which the measurements were taken.

Digits	Station
00	0
01	1
.	.
.	.
09	9
10	10

As examples,
Code 15203 means that the measurements were carried out at L/De = 1.6 along a vertical traverse at station 3.

or

Code 6410 means that the measurements were carried out at L/De = 0.6 along traverse 4 - 8 at station 10.

The tables themselves are self explanatory:
y = distance from the diffuser wall in cm. and was always taken from top to bottom or from left to right. That is small y is nearer to the top or the left wall of the diffuser. For diagonal traverses y was always measured from the left of centre.

U, V, W = u', v', w' in ft/sec

RUV, RUW = Ruv, Ruw

VEL = local mean velocity in ft/sec

CODE 6100 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.10	0.642	0.307	0.471	-0.181	-0.477	183.680
0.40	0.043	0.019	0.073	-0.154	-0.079	200.080
0.80	0.014	0.010	0.012	-0.217	-0.087	200.080
4.10	0.011	0.008	0.008	-0.127	-0.0	200.080
7.10	0.011	0.005	0.005	-0.194	-0.0	200.080
9.20	0.015	0.011	0.009	-0.0	-0.123	200.080
~~9.70~~	~~0.064~~	~~0.078~~	~~0.037~~	~~59.823~~	~~-0.109~~	~~200.080~~

CODE 6101 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.05	0.925	0.631	0.505	0.126	0.525	123.656
0.40	0.062	0.025	0.090	-0.236	0.050	182.860
0.70	0.021	0.012	0.026	-1.361	-0.034	182.860
3.40	0.010	0.009	0.009	-0.750	-0.121	182.860
5.90	0.009	0.006	0.006	-0.167	-0.0	182.860
8.40	0.009	0.006	0.006	-0.136	-0.349	182.860
10.30	0.088	0.149	0.025	0.258	-0.317	182.860
10.60	0.875	0.643	0.532	0.131	-0.659	132.020

CODE 6102 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.05	0.934	0.683	0.547	0.163	0.422	74.456
0.50	0.494	0.555	0.203	0.447	0.241	150.880
1.00	0.057	0.048	0.037	0.267	0.126	155.800
3.60	0.008	0.006	0.006	-0.125	-0.250	155.800
6.10	0.007	0.006	0.005	-0.123	-0.0	155.800
8.60	0.007	0.004	0.004	-0.321	-0.183	155.800
10.80	0.019	0.008	0.023	-0.077	0.067	155.800
11.30	0.302	0.317	0.212	0.321	-0.074	155.800
11.70	0.977	0.698	0.593	0.185	-0.491	90.200

CUDE o103 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.10	0.809	0.592	0.444	-0.094	0.302	48.380
0.70	1.139	0.846	0.604	0.207	0.402	86.920
1.50	0.316	0.253	0.253	0.569	-0.198	136.120
2.70	0.013	0.007	0.014	-0.077	0.100	136.120
5.20	0.007	0.006	0.007	-0.0	-0.107	136.120
7.70	0.007	0.004	0.004	-0.0	-0.0	136.120
10.20	0.007	0.004	0.005	-0.0	-0.0	136.120
12.00	0.098	0.098	0.075	0.254	0.083	136.120
12.50	0.880	0.760	0.520	0.099	-0.559	111.520
12.90	0.842	0.662	0.532	-0.028	-0.441	68.880

CODE 6104 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.20	0.627	0.473	0.386	0.182	0.234	40.672
0.70	0.941	0.790	0.638	-0.101	0.345	72.160
1.40	0.574	0.328	0.533	-0.247	-0.169	113.980
2.20	0.055	0.273	0.063	-0.0	0.093	119.720
3.70	0.012	0.008	0.010	0.156	0.350	123.656
6.20	0.006	0.005	0.005	-0.0	0.127	123.656
8.70	0.007	0.005	0.004	-0.0	-0.153	123.656
11.20	0.015	0.008	0.015	0.061	0.041	123.656
12.20	0.057	0.030	0.059	-0.028	0.118	123.656
12.90	0.512	0.574	0.307	-0.054	-0.198	113.980
13.50	1.008	0.820	0.632	0.165	0.488	83.640
13.90	0.706	0.547	0.456	0.136	0.368	53.300

CODE 6105 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.10	0.474	0.394	0.257	-0.165	0.111	30.340
0.70	0.746	0.569	0.512	0.152	0.244	53.300
1.90	0.524	0.515	0.439	0.402	-0.062	108.240
2.90	0.102	0.057	0.066	-0.0	-0.217	113.980
3.90	0.029	0.025	0.029	-0.214	-0.107	113.980
5.90	0.009	0.009	0.008	0.059	0.217	111.520
8.40	0.008	0.006	0.006	0.194	-0.096	111.520
10.90	0.013	0.011	0.014	0.050	-0.086	113.980
12.40	0.048	0.036	0.044	0.353	-0.0	111.520
13.40	0.240	0.160	0.280	-0.162	-0.0	111.520
14.40	0.774	0.638	0.607	0.033	0.254	80.360
14.90	0.550	0.453	0.376	0.221	0.287	42.640

CODE 6106 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.10	0.438	0.383	0.268	-0.178	-0.075	27.880
0.80	0.758	0.658	0.572	-0.152	-0.141	55.760
2.00	0.237	0.292	0.182	0.804	-0.0	104.960
3.00	0.164	0.146	0.146	-0.350	-0.0	104.960
5.50	0.038	0.031	0.019	-0.0	-0.220	108.240
8.00	0.016	0.015	0.010	0.270	-0.0	108.240
10.50	0.014	0.012	0.012	0.138	0.150	108.240
12.50	0.063	0.032	0.057	0.165	-0.0	108.240
13.50	0.267	0.191	0.229	-0.233	1.000	108.240
14.50	0.683	0.615	0.581	0.525	-0.238	83.640
15.20	0.607	0.525	0.481	0.113	-0.264	50.840
15.80	0.516	0.424	0.376	0.180	0.223	36.736

CODE 6107 DIAMETER = 17. 154

Y	U	V	W	RUV	RUW	VEL
16.90	0.362	0.288	0.214	-0.0	-0.161	31.160
16.10	0.530	0.460	0.410	-0.039	-0.126	50.840
14.80	0.522	0.477	0.313	-0.072	-0.254	78.720
13.00	0.050	0.037	0.037	0.710	-0.149	87.740
10.50	0.018	0.017	0.015	0.640	0.152	87.740
8.00	0.025	0.025	0.022	0.203	-0.0	82.000
5.50	0.155	0.155	0.186	0.092	-0.0	82.000
3.50	0.345	0.288	0.374	0.277	0.280	75.440
2.00	0.482	0.482	0.463	0.146	0.127	48.380
1.00	0.440	0.384	0.362	0.158	0.080	31.160
0.10	1.111	0.842	0.691	0.068	-0.119	114.800

CODE 6108 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.10	0.273	0.182	0.131	0.101	-0.0	18.040
0.80	0.387	0.253	0.233	-0.043	0.014	25.256
2.30	0.540	0.410	0.410	-0.067	-0.018	45.920
4.30	0.588	0.619	0.495	-0.321	-0.253	82.000
6.80	0.418	0.469	0.201	0.062	0.671	87.740
9.30	0.075	0.105	0.052	-0.300	-0.100	90.200
11.80	0.055	0.057	0.033	-0.0	0.338	87.740
14.30	0.217	0.186	0.232	-0.216	-0.576	82.000
16.30	0.494	0.484	0.442	0.276	0.272	53.300
17.30	0.381	0.369	0.344	0.100	0.170	37.720
17.90	0.306	0.285	0.250	0.139	0.107	27.880

CODE 6109 DIAMETER = 19. 156

Y	U	V	W	RUV	RUW	VEL
0.10	0.243	0.154	0.108	-0.038	-0.085	13.940
0.60	0.322	0.214	0.183	-0.036	-0.0	22.960
1.40	0.417	0.281	0.281	-0.033	0.032	31.160
2.40	0.473	0.335	0.351	0.031	0.031	39.688
3.90	0.618	0.472	0.461	-0.0	-0.0	58.220
5.40	0.574	0.454	0.378	-0.077	0.084	65.600
7.90	0.410	0.394	0.295	-0.565	0.172	85.280
10.40	0.176	0.134	0.100	-0.193	-0.0	87.740
12.90	0.082	0.066	0.049	-0.350	-0.800	85.280
15.40	0.288	0.316	0.259	0.298	-0.136	75.440
16.90	0.459	1.771	0.437	0.068	0.235	55.760
17.90	0.419	0.419	0.374	0.242	0.197	44.280
18.60	0.363	0.336	0.312	0.131	0.156	34.440
18.90	0.281	0.271	0.236	0.076	0.113	27.880

CODE 6110 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
0.10	0.250	0.191	0.152	-0.036	0.129	17.220
0.60	0.303	0.234	0.221	-0.0	0.039	23.944
1.60	0.387	0.304	0.304	-0.033	-0.0	32.800
2.60	0.483	0.383	0.364	-0.063	0.032	44.280
4.20	0.574	0.481	0.448	-0.088	-0.125	55.760
6.10	0.549	0.506	0.494	-0.210	-0.032	63.140
8.10	0.615	0.492	0.492	-0.212	-0.168	85.280
10.10	0.410	0.392	0.285	-0.0	-0.247	93.480
12.30	0.157	0.186	0.134	-0.450	-0.085	96.760
14.30	0.175	0.261	0.112	-0.218	0.271	96.760
16.30	0.426	0.459	0.525	-0.051	0.396	85.280
17.80	0.519	0.519	0.458	0.111	0.237	63.140
18.80	0.424	0.399	0.354	0.063	0.259	45.920
19.50	0.342	0.314	0.257	0.036	0.144	36.080

CODE 6200 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.10	0.024	0.018	0.025	-0.0	-0.0	188.600
0.40	0.020	0.018	0.016	-0.0	-0.072	200.080
0.90	0.014	0.012	0.010	-0.0	-0.093	200.080
3.90	0.011	0.006	0.006	-0.0	-0.170	200.080
7.40	0.011	0.006	0.006	-0.0	-0.0	200.080
9.20	0.045	0.016	0.090	-0.067	0.176	200.080
9.70	0.620	0.642	0.228	-0.439	-0.152	188.600

CODE 6201 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.20	0.699	0.386	0.506	-0.493	-0.301	150.880
0.60	0.176	0.041	0.228	-0.196	-0.0	177.120
1.00	0.015	0.014	0.014	-0.0	0.144	182.860
3.70	0.010	0.007	0.009	-0.0	-0.0	182.860
6.20	0.009	0.005	0.005	-0.357	-0.357	182.860
8.70	0.009	0.005	0.006	-0.357	-0.257	182.860
10.50	0.053	0.047	0.050	-0.176	-0.180	182.860
10.80	0.886	0.635	0.450	-0.417	0.286	155.800

CODE 6202 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.20	0.770	0.631	0.378	0.394	0.339	1.410
0.70	0.082	0.095	0.037	0.548	-0.190	155.800
1.30	0.025	0.019	0.022	0.247	0.219	155.800
3.80	0.008	0.009	0.007	-0.0	0.246	155.800
6.30	0.008	0.005	0.005	-0.240	-0.150	155.800
8.80	0.007	0.005	0.004	-0.135	-0.0	155.800
10.70	0.029	0.028	0.020	-0.027	-0.068	155.800
11.10	0.082	0.090	0.058	-0.083	-0.180	155.800
11.80	0.881	0.592	0.577	-0.349	0.194	80.360

CODE 6203 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.30	0.978	0.604	0.719	0.342	-0.024	68.880
1.00	0.610	0.378	0.589	0.120	0.052	123.656
7.70	0.049	0.047	0.023	-0.475	-0.383	136.120
2.80	0.011	0.011	0.007	14.266	-0.169	136.120
5.30	0.007	0.004	0.004	0.151	-0.0	136.120
7.80	0.006	0.004	0.005	-0.0	-0.131	136.120
10.30	0.020	0.013	0.018	0.129	0.185	136.120
11.30	0.088	0.066	0.094	0.266	0.244	136.120
11.90	0.892	0.636	0.615	0.301	-0.342	113.980
12.60	0.758	0.559	0.460	0.251	-0.264	55.760

CODE 6204 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.05	0.854	0.604	0.592	-0.238	0.137	48.380
0.70	0.957	0.714	0.699	0.309	0.200	80.360
1.30	0.738	0.620	0.656	0.628	-0.160	103.320
2.00	0.252	0.210	0.294	-0.314	-0.0	119.720
2.90	0.038	0.027	0.025	0.321	-0.0	119.720
5.40	0.007	0.006	0.005	0.188	0.113	123.656
7.90	0.006	0.004	0.004	0.893	-0.0	123.656
10.40	0.010	0.008	0.008	-0.0	-0.0	123.656
11.90	0.078	0.050	0.088	-0.145	0.183	123.656
12.70	0.715	0.427	0.648	-0.175	-0.151	108.240
13.70	0.645	0.503	0.437	-0.258	-0.169	45.920

CODE 6205 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.10	0.646	0.454	0.436	-0.137	0.025	34.440
0.80	0.807	0.641	0.692	0.220	0.103	58.220
2.00	0.793	0.692	0.510	0.150	0.092	103.320
2.80	0.246	0.246	0.287	-0.500	-0.0	113.980
3.50	0.088	0.049	0.123	-0.861	-0.042	113.980
5.00	0.019	0.016	0.014	-0.074	-0.137	113.980
7.50	0.009	0.007	0.006	-0.0	-0.161	119.720
10.00	0.012	0.008	0.011	-0.066	0.053	119.720
12.00	0.066	0.057	0.074	-0.281	0.138	113.980
13.00	0.680	0.600	0.520	0.368	0.048	111.520
14.00	0.716	0.600	0.539	0.257	0.151	62.976
14.90	0.553	0.391	0.353	-0.221	12.990	38.540

CODE 6206 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.20	0.378	0.265	0.265	0.089	0.031	20.500
1.10	0.724	0.444	0.492	0.096	0.046	42.640
8.80	0.752	0.581	0.717	-0.415	0.294	83.640
3.80	0.547	0.474	0.474	-0.164	-0.292	104.960
5.30	0.088	0.072	0.095	-0.652	-0.459	108.240
7.30	0.019	0.023	0.011	0.047	0.544	108.240
9.80	0.011	0.009	0.008	0.171	-0.0	108.240
12.30	0.031	0.023	0.031	-0.0	0.049	108.240
13.30	0.082	0.057	0.099	0.120	0.132	108.240
14.30	0.794	0.639	0.570	0.310	0.274	86.920
15.20	0.692	0.564	0.538	0.300	0.125	58.220
15.50	0.516	0.357	0.338	0.168	-0.102	36.736

CODE 6207 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.10	0.290	0.170	0.213	0.070	0.065	15.580
1.00	0.450	0.316	0.302	-0.0	0.059	29.520
2.50	0.610	0.470	0.500	0.221	0.025	50.840
4.50	0.503	0.476	0.555	0.228	0.188	68.880
7.00	0.042	0.060	0.060	-0.171	-0.0	78.720
9.50	0.013	0.014	0.010	0.492	0.683	82.000
12.00	0.019	0.016	0.017	-0.0	0.069	82.000
14.00	0.201	0.172	0.170	-0.0	-0.129	82.000
15.50	0.519	0.405	0.470	-0.210	0.033	55.760
16.30	0.428	0.330	0.365	-0.101	-0.0	42.640
16.80	0.356	0.210	0.254	-0.097	-0.071	30.340

CODE 6208 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.10	0.225	0.120	0.162	0.049	-0.110	14.760
0.70	0.318	0.208	0.214	-0.028	0.068	19.680
2.00	0.439	0.281	0.324	-0.031	0.029	29.520
4.00	0.696	0.472	0.539	-0.076	0.053	58.220
6.50	0.485	0.435	0.335	-0.097	0.230	87.740
9.00	0.059	0.080	0.042	-0.0	-0.120	90.200
11.50	0.023	0.022	0.013	-0.095	-0.531	87.740
14.00	0.077	0.069	0.056	-0.0	-0.213	85.280
16.00	0.562	0.516	0.529	0.225	0.013	68.880
17.10	0.443	0.429	0.373	0.238	-0.013	45.920
17.90	0.332	0.266	0.266	0.093	0.122	31.160

CODE 6209 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.10	0.196	0.119	0.119	0.050	0.051	13.120
0.80	0.262	0.164	0.175	0.081	0.040	16.400
1.80	0.341	0.214	0.221	0.022	0.034	22.960
3.30	0.474	0.330	0.354	-0.0	0.058	36.080
5.30	0.601	0.470	0.481	-0.058	0.090	55.760
7.80	0.525	0.394	0.295	-0.375	-0.396	85.280
10.30	0.090	0.082	0.066	-0.300	-0.672	85.280
12.80	0.034	0.033	0.026	-0.320	-0.0	85.280
14.80	0.155	0.170	0.124	-0.136	-0.350	82.000
16.30	0.437	0.465	0.410	0.490	-0.0	72.160
17.80	0.410	0.392	0.348	0.228	-0.0	42.640
18.40	0.348	0.328	0.312	0.114	0.035	37.720
18.80	0.301	0.247	0.247	0.140	0.144	30.340

CODE 6210 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
19.30	0.335	0.313	0.276	0.200	0.073	39.688
19.00	0.415	0.420	0.370	0.211	0.132	50.840
18.00	0.479	0.492	0.487	0.260	0.185	65.600
16.50	0.340	0.309	0.402	0.158	0.231	82.000
15.00	0.132	0.087	0.100	0.380	-0.241	87.740
13.00	0.056	0.077	0.045	-0.152	-0.379	90.200
11.00	0.183	0.157	0.174	-0.667	-0.0	90.200
9.00	0.492	0.426	0.492	-0.095	-0.250	85.280
7.00	0.591	0.458	0.519	-0.0	-0.067	63.140
5.00	0.485	0.351	0.377	-0.0	-0.0	39.688
3.50	0.381	0.266	0.273	0.034	0.034	29.520
2.00	0.294	0.202	0.202	-0.0	-0.030	19.680
0.80	0.192	0.128	0.128	0.056	-0.049	15.580
0.30	0.172	0.099	0.115	0.181	-0.055	14.760

CODE 6300 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.50	0.023	0.026	0.016	-0.095	0.064	200.080
0.90	0.015	0.013	0.010	-0.0	-0.321	200.080
4.40	0.012	0.008	0.007	-0.0	-0.0	200.080
7.40	0.011	0.006	0.005	-0.0	-0.194	200.080
9.40	0.026	0.023	0.026	53.138	0.170	200.080
9.90	0.820	0.820	0.361	0.608	-0.180	167.280

CODE 6301 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.10	0.216	0.374	0.316	-4.808	-0.252	171.380
0.40	0.149	0.093	0.167	4.738	-0.393	182.860
0.80	0.022	0.024	0.012	0.215	-0.067	182.860
2.00	0.010	0.007	0.007	-0.109	-0.244	182.860
4.50	0.009	0.006	0.006	0.140	-0.0	182.860
7.00	0.009	0.006	0.005	-0.151	-0.170	182.860
9.90	0.018	0.014	0.014	-0.055	0.109	182.860
10.50	0.476	0.151	0.459	-0.0	0.337	194.340
10.80	0.933	0.595	0.615	-0.489	0.165	113.980

CODE 6302 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.40	0.994	0.558	0.750	-0.522	0.059	90.200
0.90	0.482	0.241	0.362	-0.119	0.275	145.960
1.40	0.028	0.032	0.014	-0.0	-0.096	155.800
3.90	0.007	0.005	0.005	-0.0	-0.286	155.800
6.40	0.007	0.004	0.004	-0.0	-0.170	155.800
8.90	0.007	0.005	0.004	-0.135	-0.321	155.800
10.90	0.057	0.035	0.044	0.022	0.260	155.800
11.40	0.967	0.526	0.749	-0.476	0.196	119.720
11.80	0.896	0.531	0.668	-0.486	0.229	74.456

CODE 6303 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.30	0.753	0.591	0.484	-0.136	0.661	65.600
1.00	0.484	0.421	0.294	0.044	1.454	123.656
1.80	0.040	0.030	0.028	0.612	-0.079	136.120
2.80	0.052	0.008	0.008	0.275	-0.026	136.120
5.30	0.006	0.009	0.004	-0.074	-0.0	136.120
7.80	0.007	0.004	0.005	-0.170	-1.857	136.120
10.30	0.011	0.009	0.007	0.136	0.086	136.120
11.30	0.066	0.052	0.052	0.180	0.314	136.120
12.00	0.615	0.453	0.078	0.635	-1.076	127.920
12.80	0.717	0.433	0.569	-0.346	-0.128	53.300

CODE 6304 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.50	0.820	0.514	0.612	0.125	-0.133	45.920
1.30	0.747	0.620	0.583	-0.471	-0.072	104.960
2.10	0.222	0.177	0.105	-0.686	0.118	123.656
2.90	0.030	0.034	0.017	-0.0	-0.068	123.656
5.40	0.008	0.006	0.005	-0.0	0.106	123.656
7.90	0.007	0.004	0.004	-0.0	-0.293	123.656
10.40	0.010	0.009	0.006	-0.0	-0.0	123.656
11.90	0.284	0.278	0.168	-0.293	-0.181	123.656
12.90	0.944	0.610	0.839	-0.307	0.151	108.240
13.80	0.603	0.328	0.473	0.208	0.132	40.672

CODE 6305 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.10	0.532	0.386	0.363	-0.027	0.149	29.520
0.80	0.922	0.638	0.581	0.043	0.192	48.380
2.00	0.784	0.656	0.620	0.073	-0.322	104.960
2.80	0.252	0.168	0.252	-0.292	-0.556	119.720
3.50	0.042	0.029	0.055	-0.0	-0.0	119.720
5.50	0.012	0.008	0.010	0.208	0.406	119.720
8.00	0.018	0.005	0.005	0.123	-0.0	119.720
10.00	0.010	0.008	0.009	0.069	-0.129	119.720
11.50	0.035	0.022	0.029	0.043	0.142	119.720
12.50	0.238	0.126	0.244	-0.0	0.216	119.720
13.50	0.855	0.733	0.715	-0.064	-0.297	90.200
14.60	0.569	0.453	0.338	0.209	-0.174	40.672

CODE 6306 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
15.80	0.369	0.259	0.265	-0.093	-0.032	20.500
15.00	0.715	0.448	0.505	-0.070	0.022	38.540
13.50	0.881	0.638	0.668	-0.300	-0.0	72.160
12.00	0.324	0.343	0.267	-0.593	-0.0	108.240
11.00	0.071	0.095	0.053	0.528	0.185	108.240
8.50	0.016	0.013	0.011	0.168	-0.213	108.240
6.00	0.011	0.008	0.008	0.130	-0.333	108.240
4.00	0.029	0.023	0.026	0.024	-0.0	108.240
2.50	0.237	0.255	0.255	-0.214	0.265	104.960
1.50	0.837	0.683	0.717	-0.096	-0.060	83.640
0.50	0.618	0.405	0.547	0.233	-0.243	45.920
0.10	0.545	0.280	0.415	0.236	0.176	36.736

CODE 6307 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.10	0.261	0.162	0.178	0.039	0.113	14.760
0.80	0.391	0.259	0.252	0.030	0.031	22.960
2.10	0.611	0.410	0.402	0.093	0.050	39.688
4.10	0.547	0.475	0.504	0.446	0.167	75.440
6.10	0.116	0.155	0.108	0.098	-0.0	82.000
8.60	0.017	0.017	0.015	0.347	0.194	82.000
11.10	0.015	0.012	0.012	0.196	0.187	82.000
13.10	0.060	0.053	0.046	0.223	-0.039	82.000
14.60	0.468	0.432	0.475	-0.047	0.279	75.440
15.90	0.450	0.339	0.455	-0.067	0.263	42.640
16.80	0.347	0.201	0.316	-0.083	0.129	29.520

CODE 6308 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.10	0.245	0.151	0.120	0.088	0.174	14.760
0.70	0.340	0.233	0.202	-0.020	0.035	21.320
2.00	0.523	0.386	0.322	-0.0	-0.0	36.080
4.00	0.609	0.555	0.531	-0.032	-0.032	63.140
6.50	0.368	0.234	0.301	-0.074	-0.0	87.740
9.00	0.055	0.044	0.050	-0.363	0.249	87.740
11.50	0.037	0.020	0.030	-0.150	-0.185	87.740
14.00	0.201	0.155	0.186	-0.257	0.104	82.000
16.00	0.580	0.469	0.515	-0.066	0.232	60.680
17.00	0.410	0.328	0.361	-0.063	0.125	37.720
17.50	0.334	0.251	0.261	0.015	0.014	30.340

CODE 6309 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.10	0.225	0.108	0.154	0.108	0.082	13.940
0.90	0.286	0.163	0.202	0.084	-0.0	17.220
2.10	0.387	0.240	0.287	-0.0	0.030	25.256
4.10	0.517	0.391	0.438	-0.030	0.096	45.920
6.60	0.561	0.460	0.489	-0.197	0.170	75.440
9.10	0.234	0.234	0.167	-0.429	-0.440	87.740
11.60	0.075	0.100	0.033	-0.0	-0.0	87.740
14.10	0.124	0.124	0.108	-0.0	-0.229	82.000
16.10	0.542	0.476	0.622	0.079	-0.116	68.880
17.60	0.446	0.401	0.346	0.067	-0.102	44.280
18.60	0.324	0.252	0.230	-0.016	-0.077	29.520

CODE 6310 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
0.30	0.368	0.284	0.276	-0.039	-0.040	39.688
1.20	0.433	0.391	0.373	0.066	-0.034	45.920
2.20	0.555	0.494	0.494	0.202	-0.0	63.140
3.70	0.472	0.495	0.433	0.196	-0.091	82.000
5.20	0.157	0.244	0.140	0.321	-0.0	90.200
7.20	0.174	0.140	0.140	-0.250	-0.0	90.200
9.70	0.349	0.349	0.314	-0.167	-0.162	90.200
12.20	0.552	0.447	0.507	-0.131	-0.094	78.720
14.70	0.573	0.472	0.505	-0.032	0.060	58.220
16.70	0.524	0.383	0.428	-0.0	0.044	44.280
18.20	0.360	0.247	0.267	0.033	0.032	25.256
19.20	0.279	0.172	0.190	-0.0	-0.0	19.680
19.60	0.209	0.125	0.157	0.052	-0.0	14.760

CODE 6400 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.20	0.068	0.070	0.066	0.156	0.193	200.080
0.60	0.020	0.014	0.019	-0.0	-0.0	200.080
1.40	0.012	0.007	0.006	-0.156	-0.158	200.080
4.40	0.011	0.006	0.005	0.158	-0.194	200.080
7.40	0.012	0.006	0.005	-0.158	-0.181	200.080
9.60	0.017	0.016	0.012	-0.0	-0.170	188.600

CODE 6401 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.10	0.904	0.589	0.631	0.308	-0.370	119.720
0.50	0.637	0.688	0.217	-0.248	-0.603	155.800
0.90	0.074	0.065	0.071	0.334	-28.468	182.860
1.30	0.017	0.014	0.014	0.194	0.114	182.860
4.30	0.010	0.009	0.009	0.196	-0.094	182.860
7.30	0.009	0.006	0.006	-0.151	-0.151	182.860
10.30	0.035	0.030	0.032	0.210	0.319	182.860
10.50	0.231	0.287	0.082	-0.098	-0.429	177.120

CUDE 6402 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.40	0.938	0.656	0.565	-0.068	0.410	104.960
0.90	0.057	0.032	0.071	-0.113	0.142	155.800
1.50	0.014	0.011	0.013	-0.120	-0.0	155.800
4.20	0.007	0.004	0.006	-0.393	-0.0	155.800
6.70	0.007	0.005	0.004	0.151	-0.170	155.800
9.20	0.007	0.005	0.005	-0.0	-0.0	155.800
10.50	0.030	0.028	0.024	0.169	0.292	155.800
10.90	0.591	0.241	0.603	0.136	0.567	145.960
11.30	0.831	0.465	0.598	0.329	-0.367	132.020

CODE 6403 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.40	0.807	0.538	0.591	-0.125	-0.260	60.680
1.10	0.171	0.131	0.178	-0.0	-0.374	136.120
1.90	0.027	0.019	0.029	-0.069	0.248	136.120
4.40	0.007	0.006	0.007	-0.106	-0.100	136.120
6.90	0.006	0.004	0.004	-0.0	-0.183	136.120
9.40	0.007	0.005	0.005	-0.0	-0.0	136.120
11.20	0.028	0.023	0.021	-0.054	-0.191	136.120
11.90	0.197	0.131	0.141	-0.097	-0.160	136.120
12.50	0.887	0.629	0.667	0.426	-0.314	108.240

CODE 6404 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.20	0.582	0.391	0.372	0.182	0.192	38.540
0.80	0.906	0.705	0.633	-0.026	0.316	68.880
1.80	0.357	0.286	0.303	-0.058	0.573	119.720
2.80	0.029	0.017	0.031	-0.030	0.072	123.656
5.30	0.007	0.008	0.005	-0.306	0.222	123.656
7.80	0.007	0.005	0.004	0.229	-0.0	123.656
10.30	0.013	0.012	0.009	0.159	0.121	123.656
11.80	0.053	0.046	0.046	-0.264	0.687	119.720
12.80	0.512	0.492	0.369	0.513	-0.058	113.980
13.80	1.017	0.699	0.790	0.360	-0.181	72.160

CODE 6405 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.40	0.478	0.321	0.304	0.099	0.134	32.800
1.10	0.782	0.628	0.589	0.027	0.276	58.220
2.10	0.620	0.510	0.456	0.164	0.511	103.320
3.10	0.074	0.044	0.068	-0.123	0.176	111.520
4.10	0.014	0.015	0.022	-0.099	0.528	111.520
6.60	0.008	0.007	0.007	0.159	0.168	111.520
9.10	0.009	0.008	0.006	-0.075	0.082	111.520
11.60	0.026	0.028	0.016	0.265	-0.0	111.520
12.60	0.140	0.200	0.100	-0.350	-0.400	111.520
13.60	0.583	0.474	0.547	0.869	-0.084	104.960
14.10	0.774	0.681	0.588	0.262	-0.221	77.080
14.50	1.276	0.911	0.911	-0.225	-0.196	103.320

CODE 6407 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.10	0.345	0.273	0.247	-0.0	-0.0	23.944
0.80	0.473	0.402	0.360	0.030	-0.083	39.688
2.30	0.596	0.567	0.447	-0.030	-0.217	78.720
3.80	0.124	0.093	0.077	-0.229	0.300	82.000
6.30	0.021	0.017	0.017	-0.223	-0.021	82.000
8.80	0.014	0.017	0.011	-0.278	0.432	82.000
11.30	0.022	0.022	0.023	-0.381	0.398	82.000
12.80	0.077	0.074	0.124	-0.0	0.975	82.000
14.30	0.485	0.465	0.478	0.161	0.360	72.160
15.30	0.521	0.434	0.492	0.060	0.231	48.380
16.10	0.430	0.344	0.375	0.061	0.132	34.440
16.60	0.319	0.254	0.215	0.176	0.051	23.944

CODE 6408 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
17.90	0.297	0.208	0.208	-0.038	0.037	21.320
17.40	0.403	0.305	0.334	-0.031	0.095	30.340
16.00	0.480	0.420	0.440	0.033	0.232	50.840
14.00	0.361	0.262	0.262	-0.0	0.487	85.280
11.50	0.075	0.100	0.067	0.101	0.248	87.740
9.00	0.054	0.070	0.028	-0.037	-0.273	90.200
6.50	0.044	0.033	0.033	-0.531	-0.146	87.740
4.00	0.318	0.335	0.268	-0.081	-0.350	87.740
2.50	0.609	0.506	0.458	0.064	-0.033	63.140
1.20	0.503	0.401	0.335	0.060	-0.056	45.920
0.10	0.327	0.257	0.181	0.254	-0.0	27.880

CODE 6409 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.10	0.363	0.197	0.190	-0.026	-0.025	29.520
0.60	0.439	0.293	0.310	0.111	-0.060	39.688
1.60	0.540	0.430	0.410	0.093	-0.059	50.840
3.10	0.565	0.557	0.433	0.217	-0.215	82.000
5.30	0.218	0.167	0.167	0.640	0.175	87.740
7.80	0.140	0.105	0.174	-0.0	-0.280	90.200
10.30	0.100	0.100	0.084	0.667	-0.257	87.740
12.80	0.164	0.197	0.213	-0.0	-0.692	85.280
14.80	0.532	0.432	0.460	0.178	0.530	75.440
16.30	0.526	0.473	0.505	0.093	0.317	53.300
17.60	0.422	0.422	0.344	0.097	0.094	34.440
18.30	0.370	0.283	0.268	0.101	0.068	30.340
18.70	0.279	0.196	0.190	0.194	0.031	19.680

CODE 6410 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
0.10	0.334	0.215	0.214	0.063	-0.0	27.880
0.70	0.414	0.297	0.297	0.073	-0.054	36.080
1.30	0.427	0.343	0.335	0.053	-0.026	39.688
2.30	0.530	0.492	0.470	0.080	-0.051	55.760
3.80	0.478	0.492	0.465	0.193	-0.042	72.160
5.80	0.361	0.426	0.262	0.308	0.071	85.280
8.30	0.349	0.384	0.279	-0.0	-0.115	90.200
10.80	0.268	0.234	0.335	-0.0	0.069	87.740
13.30	0.279	0.197	0.328	0.194	-0.066	85.280
15.30	0.477	0.462	0.507	0.278	0.353	78.720
16.80	0.551	0.504	0.527	0.127	0.244	60.680
18.30	0.443	0.351	0.377	0.105	0.176	39.688
19.30	0.344	0.254	0.278	0.124	0.097	27.880
19.80	0.251	0.165	0.182	0.211	-0.0	18.040

CODE 16100 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.05	0.944	0.696	0.562	0.042	0.476	114.800
0.60	0.748	0.696	0.542	0.051	0.245	142.680
1.70	0.676	0.648	0.507	0.056	0.359	152.520
3.20	0.521	0.488	0.436	-0.093	0.235	195.160
5.20	0.234	0.268	0.201	-0.507	-0.177	201.720
7.20	0.212	0.228	0.182	-1.006	-0.087	195.160
8.70	0.636	0.477	0.477	-0.188	-0.279	188.600
9.60	0.879	0.703	0.556	-0.154	-0.533	164.000

CODE 16101 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.05	1.056	0.778	0.556	0.046	0.350	60.680
0.50	1.033	0.850	0.648	0.066	0.304	100.040
1.00	0.927	0.761	0.666	-0.080	0.274	123.000
2.00	0.793	0.711	0.601	-0.101	0.323	147.600
4.00	0.418	0.402	0.402	-0.198	-0.213	175.480
6.00	0.268	0.252	0.252	-0.833	-0.516	182.040
8.00	0.284	0.252	0.252	-0.809	-0.540	182.040
9.00	0.928	0.433	0.495	-0.103	-0.406	175.480
10.00	0.954	0.722	0.567	-0.091	-0.459	142.680
10.50	1.047	3.255	0.580	-0.031	-0.386	132.020

CODE 16102 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.10	0.696	0.489	0.406	-0.021	0.142	28.700
0.70	1.230	0.820	0.754	-0.058	0.143	55.760
1.50	1.273	1.003	0.810	0.135	0.111	95.940
3.50	0.683	0.711	0.574	-0.373	0.286	147.600
4.50	0.512	0.469	0.498	-0.399	0.087	164.000
6.50	0.218	0.268	0.239	-0.667	-0.0	168.920
8.50	0.205	0.211	0.187	-0.489	-0.582	164.000
10.00	0.674	0.439	0.469	-0.016	-0.352	164.000
11.00	1.039	0.808	0.716	-0.0	-0.417	119.720
11.80	1.004	0.782	0.536	-0.231	-0.298	68.880

CODE 16103 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.05	0.600	0.439	0.351	0.021	0.074	23.780
0.70	0.971	0.648	0.616	-0.020	0.039	40.180
1.80	1.410	1.000	0.820	-0.060	0.183	75.440
3.30	1.028	0.970	0.878	-0.072	0.257	119.720
4.80	0.738	0.738	0.629	-0.813	0.059	147.600
6.80	0.425	0.293	0.293	-0.831	0.081	164.000
8.80	0.225	0.225	0.209	-0.137	-0.249	152.520
10.30	0.507	0.423	0.479	-0.155	-0.157	152.520
11.50	1.061	0.897	0.787	-0.068	-0.315	109.880
12.40	0.978	0.804	0.631	-0.249	-0.204	72.160

CODE 16104 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.05	0.489	0.344	0.278	0.049	-0.0	19.680
0.85	0.777	0.475	0.509	0.021	0.019	30.340
2.10	1.055	0.826	0.803	-0.016	0.052	45.920
4.10	1.323	1.118	1.044	-0.173	0.229	88.560
5.60	1.175	1.126	1.028	-0.105	-0.060	127.920
8.10	0.423	0.507	0.395	-0.608	-0.411	152.520
10.10	0.310	0.254	0.282	-0.356	0.294	152.520
12.10	0.845	0.706	0.656	-0.567	-0.205	132.020
13.10	1.032	0.984	0.810	-0.298	-0.426	95.940
13.90	0.813	0.709	0.514	-0.335	-0.225	60.680

CODE 16105 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.05	0.436	0.364	0.221	-0.047	-0.0	18.860
0.55	0.549	0.410	0.395	-0.045	-0.0	23.780
1.05	0.645	0.446	0.430	-0.087	-0.0	27.060
2.10	0.865	0.604	0.624	-0.0	0.040	37.720
4.10	1.293	1.072	1.041	-0.0	0.040	72.160
6.10	1.296	1.215	1.215	-0.303	0.198	100.040
8.10	0.984	0.959	0.858	-0.329	0.173	132.020
10.10	0.464	0.490	0.387	-0.182	0.183	142.680
12.10	0.645	0.490	0.516	-0.137	-0.058	142.680
14.10	1.000	0.918	0.754	-0.318	-0.375	75.440
14.60	0.918	0.873	0.632	-0.239	-0.229	67.240

CODE 16106 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.05	0.390	0.299	0.228	-0.117	-0.035	18.860
0.70	0.613	0.360	0.345	-0.0	-0.026	25.420
2.00	0.865	0.573	0.503	-0.0	-0.0	37.720
4.00	1.190	0.820	0.794	-0.117	0.056	55.760
6.00	1.373	1.068	1.049	-0.095	0.171	91.840
8.00	1.132	1.063	1.063	-0.189	0.328	119.720
10.00	0.619	0.361	0.825	-0.531	0.041	142.680
12.00	0.469	0.469	0.469	-0.136	-0.160	137.760
13.50	1.033	0.854	0.944	-0.150	-0.340	114.800
14.50	1.025	0.932	0.839	-0.326	-0.336	88.560
15.40	0.806	0.751	0.625	-0.204	-0.233	60.680

CODE 16107 DIAMETER = 17. 197

Y	U	V	W	RUV	RUW	VEL
0.05	0.370	0.271	0.191	0.031	-0.0	17.220
0.80	0.556	0.359	0.337	-0.097	-0.047	23.780
1.80	0.747	0.492	0.492	-0.063	-0.065	32.800
3.30	0.948	0.681	0.636	-0.020	-0.0	44.280
5.30	1.293	1.009	0.946	-0.019	0.021	72.160
7.30	1.312	1.003	1.003	-0.255	0.102	95.940
9.30	1.039	0.970	1.063	-0.0	0.086	119.720
11.30	0.673	0.539	0.685	-0.618	0.146	127.920
13.30	0.654	0.713	0.808	-0.241	-0.555	123.000
14.80	1.023	0.888	0.810	-0.254	-0.188	95.940
15.90	0.858	0.812	0.707	-0.206	-0.303	67.240
16.30	0.741	0.675	0.555	-0.240	-0.185	55.760

CODE 16108 DIAMETER = 18.198

Y	U	V	W	RUV	RUW	VEL
0.05	0.377	0.430	0.208	-0.060	-0.075	18.860
0.70	0.542	0.318	0.318	-0.053	-0.049	22.960
2.00	0.708	0.432	0.432	-0.0	-0.067	30.340
4.00	0.975	0.665	0.654	-0.042	-0.020	45.920
6.00	1.287	0.981	0.920	-0.076	-0.021	68.880
8.00	1.370	1.081	1.063	-0.180	0.042	85.280
10.00	1.203	1.093	1.115	-0.287	0.161	109.880
12.00	1.016	0.924	0.901	-0.638	0.268	119.720
14.00	0.866	0.832	0.808	-0.170	-0.149	119.720
15.50	1.022	1.012	0.911	-0.306	-0.387	100.040
17.00	0.778	0.764	0.667	-0.289	-0.305	60.680
17.90	0.614	0.543	0.348	-0.243	-0.234	42.640

CODE 16109 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.05	0.410	0.284	0.212	0.060	-0.068	19.680
0.60	0.512	0.351	0.315	0.050	0.026	23.780
1.80	0.682	0.449	0.423	0.066	-0.0	30.340
4.30	1.089	0.751	0.751	0.020	-0.020	51.660
6.30	1.303	1.104	1.042	-0.035	0.073	68.880
8.30	1.478	1.225	1.225	-0.020	0.035	85.280
10.30	1.557	1.370	1.370	-0.240	0.119	103.320
12.30	1.146	1.168	1.393	-0.103	-0.0	114.800
14.30	1.063	0.970	1.155	-0.176	0.120	119.720
16.30	1.109	1.080	1.003	-0.0	-0.268	95.940
17.50	1.104	0.920	0.797	-0.103	-0.188	68.880
18.30	0.873	0.820	0.648	-0.132	-0.079	55.760
8.90	0.731	0.625	0.413	-0.022	-0.067	44.280

CODE 16200 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.10	0.997	0.706	0.606	0.222	0.421	132.020
0.70	0.902	0.676	0.676	0.210	0.352	152.520
1.50	0.671	0.567	0.596	0.135	0.100	168.920
2.60	0.390	0.325	0.390	0.158	0.132	195.160
4.60	0.385	0.402	0.301	-0.222	-0.172	201.720
6.60	0.181	0.167	0.234	-0.107	0.206	201.720
8.10	0.435	0.321	0.482	-0.676	-0.324	201.720
8.90	0.850	0.567	0.716	-0.322	-0.233	168.920
9.50	0.970	0.574	0.683	-0.410	-0.196	147.600

CODE 16201 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.10	1.033	0.722	0.623	0.178	0.325	75.440
0.50	1.017	0.830	0.664	0.129	0.333	103.320
1.00	0.869	0.685	0.612	-0.0	0.269	127.920
2.00	0.789	0.733	0.620	-0.205	0.252	152.520
4.00	0.634	0.588	0.495	-0.137	0.074	175.480
6.00	0.426	0.442	0.442	-0.0	-0.090	182.040
8.00	0.388	0.318	0.369	-0.327	-0.196	188.600
10.00	1.141	0.570	0.832	-0.354	-0.0	123.000
10.80	1.276	0.769	0.769	-0.280	-0.064	100.040

CODE 16202 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.10	1.183	0.725	0.741	0.158	0.193	72.160
0.80	1.048	0.830	0.830	0.206	0.107	103.320
1.80	0.807	0.677	0.651	0.322	0.153	137.760
2.80	0.532	0.460	0.403	-0.0	0.097	157.440
4.80	0.197	0.197	0.179	-0.425	-0.076	168.920
6.80	0.188	0.131	0.089	-0.599	-0.063	168.920
8.80	0.217	0.173	0.217	-0.0	0.114	175.480
10.30	0.875	0.629	0.738	-0.337	-0.051	147.600
11.30	1.167	0.810	0.849	-0.286	-0.147	95.940
11.70	1.150	0.674	0.705	-0.206	-0.045	68.880

CODE 16203 DIAMETER = 13.203

Y	U	V	W	RUV	RUW	VEL
0.05	1.002	0.651	0.676	-0.067	0.110	51.660
0.60	1.167	0.820	0.915	0.096	-0.097	72.160
1.60	1.006	0.875	0.678	-0.171	0.070	109.880
3.10	0.711	0.765	0.711	0.093	-0.037	147.600
5.60	0.446	0.460	0.374	0.088	0.212	157.440
7.60	0.381	0.410	0.293	-0.506	0.457	164.000
9.60	0.374	0.299	0.374	-0.143	-0.0	157.440
10.90	1.047	0.782	0.908	-0.408	-0.079	132.020
11.80	1.146	0.857	0.895	-0.294	-0.088	88.560
12.40	0.917	0.584	0.625	-0.303	-0.026	60.680

CODE 16204 DIAMETER = 14. 204

Y	U	V	W	RUV	RUW	VEL
0.05	0.891	0.554	0.608	0.023	0.128	42.640
1.25	1.221	1.012	0.803	0.181	0.160	82.000
2.55	0.878	0.785	0.785	0.384	0.102	119.720
4.00	0.632	0.774	0.490	0.039	0.399	142.680
6.00	0.368	0.345	0.403	-0.611	-0.204	157.440
8.00	0.437	0.479	0.395	0.235	-0.0	152.520
10.00	0.380	0.374	0.316	0.148	-0.387	157.440
11.50	0.967	0.808	0.759	-0.235	-0.135	127.920
12.50	1.125	0.915	0.953	-0.141	-0.299	91.840
13.60	0.724	0.431	0.539	-0.239	-0.169	49.200

CODE 16205 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.10	0.549	0.337	0.337	-0.024	-0.111	23.780
0.40	0.621	0.431	0.464	-0.097	-0.136	28.700
2.00	1.139	0.922	0.840	0.078	-0.166	58.220
3.30	1.342	1.118	1.006	-0.045	-0.284	88.560
5.30	1.363	1.321	1.065	-0.204	-0.203	106.600
7.30	1.299	1.150	1.065	-0.228	-0.196	106.600
9.30	1.137	0.875	1.093	0.070	-0.230	109.880
10.80	0.784	0.856	0.618	-0.194	-0.451	123.000
12.30	1.247	0.832	1.155	-0.313	-0.049	119.720
13.50	1.274	0.977	1.047	-0.196	-0.077	82.000
13.90	1.083	0.933	0.903	-0.358	-0.045	67.240
14.60	0.876	0.651	0.751	-0.291	0.096	51.660

CODE 16206 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.05	0.564	0.300	0.366	-0.026	0.023	23.780
0.80	0.758	0.483	0.531	-0.023	0.021	34.440
2.10	1.098	0.826	0.775	0.038	0.060	54.120
4.30	1.370	0.955	0.865	0.024	0.025	85.280
6.30	1.157	0.988	1.033	-0.093	0.259	114.800
8.30	1.093	1.022	0.951	-0.550	0.202	123.000
10.30	0.963	0.523	0.951	-0.344	0.037	123.000
12.30	0.951	0.713	0.951	-0.173	0.126	123.000
13.80	1.144	1.011	1.220	-0.205	-0.205	91.840
14.80	1.084	0.764	0.820	-0.266	-0.0	60.680
15.70	0.869	0.521	0.586	-0.137	0.021	42.640

CODE 16207 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.10	0.527	0.286	0.344	-0.0	-0.0	23.780
0.90	0.656	0.432	0.449	-0.047	0.046	30.340
2.40	1.039	0.739	0.726	0.039	-0.0	51.660
4.40	1.230	0.991	0.888	-0.096	-0.070	78.720
6.40	1.273	1.003	1.042	-0.130	0.070	95.940
8.40	1.373	0.992	1.049	-0.332	0.086	91.840
10.40	1.167	1.003	1.042	-0.146	0.194	95.940
12.40	1.086	0.937	0.895	-0.060	0.240	106.600
14.40	1.144	1.030	1.106	-0.317	-0.026	91.840
15.70	0.924	0.806	0.834	-0.313	-0.072	60.680
16.60	0.881	0.558	0.602	-0.132	-0.045	44.280

CODE 16208 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.05	0.477	0.275	0.311	-0.062	0.088	22.960
0.60	0.621	0.381	0.398	-0.077	0.024	28.700
1.60	0.771	0.537	0.547	-0.042	-0.022	36.080
3.60	1.071	0.807	0.767	-0.042	-0.020	55.760
5.60	1.279	1.000	0.968	-0.020	-0.0	75.440
7.60	1.370	1.081	1.045	-0.230	-0.0	85.280
9.60	1.406	1.081	1.081	-0.235	-0.043	85.280
11.60	1.370	1.045	1.027	-0.128	0.083	85.280
13.60	1.274	1.029	1.012	-0.0	0.131	82.000
15.10	1.104	0.812	0.904	-0.113	-0.023	68.880
16.60	0.981	0.710	0.723	-0.205	-0.042	54.120
17.80	0.683	0.430	0.459	-0.053	0.026	36.080

CODE 16209 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.10	0.446	0.297	0.258	-0.0	-0.0	31.160
0.80	0.522	0.339	0.346	-0.025	-0.022	33.620
2.30	0.811	0.556	0.528	-0.077	-0.128	49.200
4.80	1.584	1.267	1.081	-0.096	-0.120	83.640
6.80	1.523	1.367	1.328	-0.037	-0.111	86.920
8.80	1.603	1.230	1.305	-0.220	-0.069	83.640
10.08	1.303	0.996	0.996	-0.208	-0.018	70.520
12.80	1.244	0.877	0.905	-0.198	-0.019	68.060
14.80	1.245	0.908	0.937	-0.184	-0.019	70.520
16.40	1.201	0.849	0.937	-0.152	-0.039	70.520
17.80	0.885	0.604	0.604	-0.213	-0.068	54.940
18.50	0.703	0.487	0.505	-0.186	0.021	47.560
18.90	0.585	0.342	0.364	-0.048	0.025	39.360

CODE 16210 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
0.30	0.478	0.278	0.232	-0.080	0.059	31.160
0.80	0.468	0.366	0.319	-0.048	-0.054	33.620
1.20	0.518	0.388	0.388	-0.099	-0.0	36.900
2.40	0.640	0.476	0.492	-0.045	-0.085	42.640
4.40	1.012	0.846	0.846	-0.082	-0.0	63.140
6.40	1.378	1.186	1.151	-0.117	-0.084	80.360
7.40	1.435	1.230	1.230	-0.252	-0.083	83.640
9.40	1.396	1.186	1.117	-0.256	-0.132	80.360
11.40	1.238	0.990	1.052	-0.210	-0.0	73.800
13.40	1.186	0.937	0.996	-0.202	-0.0	70.520
15.40	1.003	0.807	0.914	-0.229	-0.130	65.600
17.60	0.987	0.769	0.794	-0.126	-0.088	63.140
18.60	0.742	0.586	0.586	-0.168	-0.416	50.840
19.30	0.617	0.473	0.473	-0.047	-0.047	44.280
19.70	0.524	0.425	0.395	-0.210	-0.105	39.360

CODE 16300 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
9.70	0.849	0.615	0.644	0.419	-0.121	164.000
9.20	0.743	0.588	0.526	0.334	0.072	175.480
8.30	0.351	0.423	0.293	0.322	-0.181	195.160
7.00	0.101	0.111	0.098	0.204	-0.582	195.160
5.00	0.110	0.147	0.154	0.080	-0.0	201.720
3.00	0.261	0.268	0.281	-0.0	0.439	201.720
1.00	0.683	0.445	0.572	-0.323	-0.0	188.600
0.30	1.021	0.547	0.834	-0.387	-0.0	157.440
0.05	1.054	0.495	0.755	-0.616	0.086	137.760

CODE 16301 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
10.60	1.045	0.539	0.741	1.047	-0.037	114.800
10.40	1.010	0.570	0.666	0.272	-0.047	123.000
10.00	0.877	0.567	0.670	0.373	-0.050	142.680
9.00	0.600	0.439	0.469	0.178	-0.0	164.000
7.00	0.278	0.235	0.248	-0.491	-0.707	175.480
5.00	0.388	0.381	0.381	-0.394	0.022	188.600
3.00	0.378	0.442	0.315	-0.304	-0.125	182.040
1.00	0.964	0.575	0.806	-0.368	0.047	157.440
0.05	1.225	0.613	0.829	-0.303	0.113	85.280

CODE 16302 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
11.50	1.407	0.979	1.028	0.301	-0.0	127.920
10.70	0.921	0.782	0.732	0.287	0.152	132.020
9.60	0.561	0.489	0.403	0.146	0.083	157.440
7.60	0.173	0.203	0.137	-0.696	-0.340	168.920
5.60	0.313	0.209	0.358	-1.057	0.089	168.920
3.60	0.447	0.376	0.298	0.233	0.196	168.920
2.10	0.817	0.592	0.648	-0.178	-0.0	152.520
1.10	1.212	0.761	0.998	-0.411	0.276	123.000
0.10	1.084	0.500	0.834	-0.253	0.231	60.680

CODE 16303 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.40	0.965	0.752	0.888	0.233	-0.112	78.720
1.00	1.100	0.872	1.038	0.302	-0.055	103.320
1.80	0.807	0.681	0.732	0.474	-0.0	132.020
2.80	0.434	0.451	0.451	0.172	-0.203	152.520
4.80	0.158	0.146	0.193	0.693	-0.142	164.000
6.80	0.264	0.410	0.351	-0.107	-0.173	164.000
8.80	0.360	0.403	0.403	0.136	0.117	157.440
10.80	0.903	0.722	0.799	-0.441	0.321	142.680
12.00	0.955	0.847	1.045	-0.397	0.300	85.280
12.80	1.058	0.569	0.846	-0.093	0.142	55.760

CODE 16304 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.10	0.858	0.828	0.828	0.136	-0.102	67.240
0.70	1.044	0.801	0.988	0.147	-0.0	88.560
1.80	0.951	0.832	0.784	0.346	0.040	123.000
3.30	0.339	0.897	0.328	-0.064	-0.164	147.600
5.80	0.311	0.230	0.288	-0.829	-0.268	157.440
7.80	0.734	0.748	0.806	-0.0	0.053	157.440
9.80	0.722	0.619	0.593	0.137	0.273	142.680
11.30	1.143	1.155	1.016	-0.304	0.261	119.720
12.60	2.535	1.610	1.968	-0.045	0.112	168.920
13.30	1.009	0.631	0.734	-0.044	0.135	45.920
13.95	0.787	0.322	0.531	-0.115	0.045	34.440

CODE 16305 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.40	0.757	0.538	0.726	0.092	0.079	51.660
1.10	1.059	0.726	0.900	0.229	0.123	63.960
2.80	0.934	0.913	0.810	0.064	-0.056	103.320
4.60	0.732	0.656	0.555	-0.339	0.159	132.020
6.60	0.959	0.858	0.908	-0.173	0.164	132.020
8.60	1.191	1.078	0.899	-0.174	-0.0	114.800
10.60	1.158	1.119	0.810	-0.106	0.349	95.940
12.10	1.496	0.793	1.009	-0.132	0.041	85.280
13.60	1.162	0.749	0.736	-0.080	0.020	54.120
14.80	0.430	0.342	0.398	-0.0	0.071	27.060

CODE 16306 DIAMETER = 16. **217**

Y	U	V	W	RUV	RUW	VEL
0.30	0.757	0.482	0.631	-0.0	0.025	45.920
1.00	0.917	0.620	0.775	0.079	-0.020	54.120
2.30	1.153	0.667	0.991	0.270	-0.200	85.280
4.30	0.725	0.642	0.618	0.364	0.337	123.000
6.30	1.004	0.881	0.979	-0.117	0.332	127.920
8.30	1.406	1.108	1.235	-0.268	0.221	106.600
10.30	1.442	1.153	1.009	-0.019	0.270	85.280
12.30	1.287	0.889	0.889	-0.065	-0.0	68.880
13.80	1.053	0.718	0.646	-0.057	0.044	49.200
15.00	0.806	0.493	0.531	-0.092	0.063	34.440
15.90	0.605	0.268	0.399	-0.0	0.066	25.420

CODE 16307 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.10	0.594	0.332	0.563	0.114	0.025	37.720
0.90	0.814	0.505	0.654	-0.109	-0.021	45.920
2.10	0.987	0.695	0.764	-0.0	-0.024	60.680
4.10	1.174	0.931	0.931	0.247	0.102	100.040
6.10	1.045	0.944	0.899	-0.036	0.288	114.800
8.10	1.331	1.042	1.080	-0.245	-0.022	95.940
10.10	1.257	0.904	0.920	-0.165	0.021	68.880
12.10	1.140	0.834	0.778	-0.080	0.065	60.680
14.10	0.994	0.646	0.622	-0.062	0.023	49.200
15.60	0.749	0.531	0.540	-0.022	0.020	34.440
16.80	0.544	0.307	0.399	-0.0	-0.046	25.420

CODE 16308 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.50	0.664	0.342	0.523	0.033	0.048	37.720
1.40	0.791	0.550	0.642	0.026	0.023	45.920
2.90	1.038	0.828	0.873	-0.0	-0.0	67.240
4.90	1.114	1.093	0.931	-0.061	-0.0	100.040
6.90	1.137	1.093	1.050	-0.163	0.059	109.880
8.90	1.189	1.063	1.081	-0.296	0.046	85.280
10.90	1.204	0.888	0.888	-0.144	0.021	67.240
12.90	1.098	0.762	0.736	-0.020	-0.0	54.120
14.90	0.880	0.565	0.576	-0.022	-0.067	42.640
16.40	0.605	0.366	0.342	-0.0	0.026	27.060
17.50	0.403	0.225	0.291	-0.0	-0.0	19.680

CODE 16309 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.40	0.529	0.312	0.443	-0.0	-0.181	42.640
1.00	0.694	0.487	0.541	-0.099	-0.039	47.560
1.70	0.974	0.661	0.759	-0.181	-0.084	60.680
3.20	1.145	0.928	0.990	0.040	-0.145	73.800
5.20	1.442	1.216	1.527	-0.0	-0.289	118.080
7.20	1.640	1.581	1.581	0.028	-0.263	123.000
9.20	1.773	1.463	1.463	-0.0	-0.114	95.120
11.20	1.183	0.941	0.968	0.017	-0.098	65.600
13.20	0.949	0.755	0.712	-0.033	0.018	54.940
15.20	0.689	0.459	0.492	-0.065	0.056	42.640
16.70	0.631	0.465	0.457	-0.039	-0.041	41.000
17.70	0.508	0.312	0.339	-0.051	-0.066	33.620
18.40	0.439	0.278	0.297	-0.027	-0.107	31.160
18.90	0.335	0.196	0.277	-0.079	0.199	25.420

CODE 16310 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
19.50	0.560	0.315	0.410	-0.106	-0.048	41.000
19.20	0.582	0.344	0.459	-0.082	-0.022	42.640
18.40	0.707	0.481	0.547	-0.0	-0.108	49.200
17.20	1.049	0.753	0.833	-0.281	-0.058	65.600
15.20	1.291	1.066	1.189	-0.373	-0.172	90.200
13.20	1.589	1.435	1.384	-0.075	-0.047	108.240
11.20	1.568	1.495	1.399	0.045	-0.096	103.320
9.20	1.378	1.082	1.082	-0.184	-0.072	77.080
7.20	0.979	0.729	0.752	-0.109	-0.075	57.400
5.20	0.748	0.523	0.523	-0.021	-0.142	47.560
3.20	0.526	0.350	0.301	-0.0	-0.056	35.260
1.20	0.430	0.285	0.298	-0.123	0.060	33.620
0.70	0.380	0.262	0.276	-0.0	-0.0	31.980
0.10	0.362	0.271	0.284	-0.175	-0.170	31.160

CODE 16400 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.10	0.932	0.562	0.584	-0.203	0.327	114.800
0.80	0.761	0.620	0.648	-0.065	0.172	152.520
2.00	0.650	0.588	0.464	-0.0	0.187	175.480
4.00	0.335	0.301	0.355	-0.167	-0.127	201.720
6.00	0.241	0.215	0.234	-0.852	-0.772	195.160
7.50	0.251	0.229	0.636	-0.678	-0.289	188.600
8.80	0.599	0.536	0.442	0.168	-0.361	182.040
9.60	0.775	0.626	0.567	0.185	-0.406	168.920

CODE 16401 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.05	1.084	0.705	0.895	0.129	0.171	58.220
0.50	1.145	0.854	0.683	-0.0	0.258	78.720
1.00	0.958	0.724	0.618	-0.079	0.235	106.600
2.00	0.833	0.732	0.580	-0.137	0.348	132.020
4.00	0.641	0.537	0.507	-0.283	0.081	168.920
6.00	0.291	0.272	0.272	-0.621	-0.593	175.480
8.00	0.537	0.477	0.417	0.014	-0.393	168.920
9.00	0.793	0.547	0.656	0.136	-0.200	147.600
9.80	0.959	0.631	0.706	0.288	-0.272	132.020
10.10	0.959	0.580	0.732	0.255	-0.161	132.020

CODE 16402 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.30	0.677	0.422	0.358	0.021	0.051	27.060
1.00	1.162	0.801	0.775	0.020	0.083	54.120
2.20	0.955	0.789	0.996	-0.203	0.370	103.320
4.20	0.645	0.696	0.567	-0.501	0.350	142.680
5.20	0.498	0.527	0.469	-0.178	0.184	164.000
7.20	0.221	0.209	0.191	-1.099	-0.455	168.920
9.20	0.259	0.276	0.242	-0.299	-0.442	157.440
10.70	0.833	0.677	0.625	-0.056	-0.229	137.760
11.50	1.080	0.752	0.810	0.297	-0.225	95.940

CODE 16403 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.20	0.542	0.324	0.265	0.045	-0.028	19.680
1.00	0.936	0.594	0.594	-0.042	0.038	37.720
1.80	1.214	0.904	0.852	-0.017	0.097	54.120
3.80	1.214	1.108	1.108	-0.155	0.198	106.600
5.30	0.761	0.774	0.670	-0.228	0.191	142.680
7.30	0.259	0.230	0.288	-0.903	-0.144	157.440
9.30	0.217	0.225	0.225	-0.516	-0.422	152.520
10.80	0.658	0.567	0.490	0.059	-0.117	142.680
11.80	1.038	0.872	0.830	0.131	-0.386	103.320
12.50	1.008	0.786	0.803	0.230	-0.214	78.720

CODE 16404 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.05	0.443	0.311	0.258	0.143	-0.130	19.680
1.25	0.729	0.431	0.431	-0.0	-0.021	28.700
1.95	1.003	0.616	0.627	-0.0	0.040	40.180
5.30	1.496	1.081	1.153	-0.150	0.063	85.280
7.30	0.478	0.601	0.601	-0.128	0.078	147.600
9.30	0.299	0.259	0.282	-0.794	-0.345	152.520
11.30	0.599	0.547	0.547	0.058	-0.333	137.760
12.50	1.001	0.852	0.895	0.068	-0.340	106.600
13.40	0.948	0.837	0.769	0.114	-0.245	78.720

CODE 16405 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.05	0.407	0.296	0.222	0.053	-0.0	17.220
0.50	0.517	0.331	0.317	-0.0	-0.0	21.320
1.00	0.605	0.414	0.368	-0.047	-0.0	25.420
2.00	0.784	0.492	0.528	-0.046	0.044	32.800
4.00	1.220	0.922	0.922	-0.039	0.076	58.220
6.00	1.379	1.230	1.193	-0.168	0.089	88.560
8.00	0.885	0.833	0.833	-0.247	0.200	137.760
10.00	0.335	0.309	0.309	-0.339	-0.250	142.680
12.00	0.631	0.656	0.404	0.189	-0.198	132.020
14.00	0.991	0.854	0.922	0.164	-0.221	78.720
14.50	0.867	0.757	0.757	0.165	-0.259	72.160

COLF 16406 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.40	0.403	0.286	0.215	-0.0	-0.070	18.860
1.30	0.556	0.337	0.322	-0.0	-0.0	23.780
2.80	0.784	0.492	0.474	-0.0	-0.023	32.800
4.80	1.077	0.754	0.706	-0.058	-0.0	49.200
7.30	1.454	1.193	1.062	-0.175	-0.0	88.560
9.30	0.857	0.881	0.832	-0.660	0.401	127.920
11.30	0.417	0.338	0.495	0.211	-0.389	137.760
13.30	0.786	0.674	0.741	0.168	-0.394	114.800
14.80	0.883	0.811	0.901	0.126	-0.056	85.280
15.50	0.767	0.662	0.782	0.070	-0.369	67.240

CODE 16407 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.10	0.340	0.234	0.199	0.064	-0.259	15.580
0.90	0.503	0.310	0.317	-0.052	-0.0	21.320
1.90	0.629	0.398	0.366	-0.022	-0.025	27.060
3.90	0.849	0.527	0.517	-0.044	-0.021	36.080
5.90	1.166	0.813	0.813	-0.059	-0.021	58.220
7.90	1.380	1.081	1.045	-0.326	0.043	85.280
9.90	1.022	0.903	0.903	-0.272	-0.0	123.000
11.90	0.551	0.539	0.514	-0.134	-0.0	127.920
13.90	0.854	0.764	0.719	0.244	-0.224	114.800
15.40	0.880	0.820	0.820	0.058	-0.233	78.720
16.40	0.684	0.637	0.637	0.030	-0.201	58.220

CODE 16408 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.05	0.325	0.228	0.187	0.099	-0.193	15.580
0.50	0.441	0.289	0.248	-0.0	-0.032	21.320
1.80	0.590	0.353	0.353	-0.025	-0.0	25.420
3.80	0.849	0.537	0.508	-0.0	-0.044	36.080
5.80	1.152	0.789	0.764	-0.018	-0.0	51.660
8.50	1.466	1.186	1.134	-0.056	0.056	82.000
10.30	1.505	1.078	1.078	-0.147	0.051	114.800
12.30	0.918	0.930	0.906	-0.075	0.175	127.920
14.30	1.115	0.853	0.875	0.248	-0.262	109.880
15.80	1.045	0.901	0.883	0.059	-0.131	85.280
17.00	0.757	0.723	0.737	0.089	-0.249	60.680
17.90	0.625	0.459	0.493	0.124	-0.092	45.920

CODE 16409 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.10	0.282	0.202	0.164	0.075	-0.207	13.120
0.70	0.400	0.258	0.231	-0.034	-0.0	19.680
2.10	0.571	0.322	0.315	-0.0	-0.026	23.780
4.10	0.765	0.456	0.456	-0.023	-0.0	32.800
6.10	1.089	0.730	0.682	-0.018	-0.021	49.200
8.10	1.339	1.053	0.978	-0.107	-0.0	67.240
10.10	1.486	1.196	1.158	-0.079	-0.0	95.940
12.10	1.168	1.123	1.123	-0.150	0.061	114.800
14.10	1.033	0.988	0.988	0.035	-0.105	114.800
16.10	1.081	0.988	0.988	0.122	-0.104	88.560
17.60	0.987	0.769	0.827	0.069	-0.182	63.960
18.50	0.846	0.675	0.688	-0.0	-0.124	55.760
19.90	0.692	0.457	0.524	0.089	-0.136	44.280

CODE 16410 DIAMETER = 20. 232

Y	U	V	W	RUV	RUW	VEL
0.30	0.279	0.225	0.213	0.038	-0.079	29.520
0.60	0.291	0.200	0.213	-0.107	-0.079	29.520
1.20	0.291	0.213	0.213	-0.039	-0.080	29.520
2.30	0.387	0.265	0.271	-0.032	-0.084	31.160
4.30	0.569	0.340	0.377	-0.0	-0.023	37.720
6.30	0.801	0.528	0.528	-0.060	-0.107	49.200
8.30	1.289	0.952	0.937	-0.019	-0.072	70.520
10.30	2.024	1.640	1.537	0.020	-0.0	108.240
12.30	2.198	1.640	1.640	-0.346	-0.311	139.400
14.30	1.783	1.640	1.569	-0.227	-0.229	152.520
16.30	1.409	1.332	1.332	-0.440	-0.409	108.240
17.50	1.495	1.278	1.399	-0.226	-0.049	103.320
18.30	1.174	1.025	1.062	-0.048	-0.0	83.640
18.90	0.961	0.749	0.806	-0.078	-0.226	68.060
19.70	0.658	0.432	0.507	-0.185	-0.220	54.940

DE 10100 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.10	2.109	1.201	0.908	0.056	-0.370	157.440
0.60	1.808	1.379	1.006	0.034	-0.263	190.240
1.10	1.373	0.984	0.820	0.114	-0.237	213.200
2.10	0.553	0.451	0.451	0.034	-0.503	213.200
3.60	0.406	0.353	0.369	-0.319	-0.758	213.200
5.60	0.488	0.443	0.435	-0.667	-0.590	213.200
7.60	0.492	0.451	0.394	-0.636	-0.684	213.200
8.60	0.615	0.492	0.574	-0.643	-0.020	213.200
9.20	1.517	1.025	1.066	-0.048	0.236	213.200
9.70	1.715	1.342	1.081	-0.034	0.209	190.240

)E 10101 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.05	2.299	1.319	0.981	0.324	-0.252	89.380
0.60	2.252	1.251	1.028	0.091	-0.141	152.520
1.30	1.588	1.117	0.977	0.127	-0.242	183.680
2.60	0.648	0.574	0.476	-0.129	-0.588	213.200
4.30	0.512	0.508	0.467	-0.654	-0.743	213.200
6.30	0.554	0.492	0.467	-0.762	-0.998	205.000
8.30	0.539	0.469	0.492	-0.891	-0.727	196.800
9.20	0.727	0.634	0.656	-0.161	-0.170	190.240
9.90	1.415	1.061	0.900	-0.083	0.188	172.200
10.30	1.816	1.201	1.025	-0.030	0.230	157.440

)DE 10102 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.05	0.948	0.759	0.446	0.153	-0.119	50.840
0.60	1.454	1.116	0.795	0.195	-0.270	89.380
1.30	1.237	1.067	0.859	0.241	-0.284	142.680
2.60	0.418	0.301	0.402	0.972	-0.160	177.940
4.60	0.153	0.134	0.179	-0.603	-0.446	190.240
6.60	0.122	0.112	0.119	-0.908	-0.892	183.680
8.60	0.131	0.120	0.127	-0.831	-0.900	177.940
10.10	0.434	0.373	0.418	-0.0	0.229	172.200
10.80	0.973	0.751	0.778	0.054	0.248	152.520
11.40	1.240	0.984	0.820	-0.028	0.395	111.520

DE 10103 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.05	0.653	0.427	0.303	-0.0	0.055	28.700
0.60	0.976	0.745	0.573	-0.0	0.060	42.640
1.40	1.333	1.134	1.012	-0.018	0.169	78.720
2.70	0.699	0.627	0.724	0.137	-0.0	132.840
4.40	0.328	0.239	0.417	-1.061	0.527	162.360
6.40	0.125	0.116	0.109	-0.275	-0.269	172.200
8.40	0.097	0.100	0.094	-0.800	-0.872	177.940
10.20	0.167	0.174	0.154	-0.168	-0.306	183.680
11.40	1.083	0.990	0.743	-0.120	-0.333	167.280
12.20	1.323	1.093	0.875	-0.053	-0.386	120.540
12.70	1.263	1.115	0.738	0.142	-0.218	85.280

DE 10104 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.50	0.605	0.466	0.262	0.071	-0.028	25.420
0.60	0.756	0.578	0.357	-0.068	0.052	33.620
1.50	1.028	0.787	0.667	0.078	0.059	49.200
3.00	1.388	1.045	1.262	0.018	0.234	96.760
5.00	0.859	0.781	0.573	-0.853	0.485	142.680
7.00	0.224	0.209	0.388	-0.309	-0.111	162.360
9.00	0.132	0.141	0.122	-0.824	-0.762	172.200
11.00	0.215	0.199	0.193	-0.341	-0.406	172.200
12.30	1.075	1.156	0.807	-0.287	-0.203	147.600
13.00	1.268	1.181	0.918	0.080	-0.274	120.540
13.80	1.167	1.009	0.678	-0.0	-0.295	82.000

DE 10105 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.05	0.556	0.342	0.278	-0.027	0.025	24.600
0.70	0.731	0.459	0.476	-0.064	0.054	33.620
1.40	0.926	0.664	0.624	-0.0	0.038	44.280
2.90	1.260	0.945	0.827	-0.065	0.093	63.960
4.80	1.148	0.779	1.230	-0.211	0.295	111.520
6.80	0.928	0.591	0.807	-0.664	-1.042	147.600
9.30	0.173	0.167	0.209	-0.392	-0.0	162.360
11.80	0.611	0.477	0.388	-0.288	-0.138	162.360
13.30	1.230	1.066	1.025	-0.294	-0.109	111.520
14.00	1.167	0.725	0.773	0.081	-0.109	82.000
14.50	0.918	0.787	0.682	0.021	-0.208	63.960

DE 10106 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.05	0.528	0.328	0.250	0.031	0.054	24.600
0.60	0.648	0.480	0.352	-0.037	-0.0	30.340
1.30	0.771	0.556	0.484	-0.0	-0.0	36.900
2.50	1.039	0.722	0.700	0.018	0.018	49.200
4.60	1.251	1.001	1.001	-0.050	-0.0	68.880
7.10	1.430	0.925	1.304	0.034	0.390	115.620
9.60	0.556	0.500	0.556	-0.477	0.069	152.520
11.60	0.253	0.239	0.417	-0.0	-0.0	162.360
13.10	0.911	0.859	0.755	-0.253	-0.653	142.680
14.30	1.168	1.191	1.033	-0.142	-0.529	124.640
15.10	1.104	1.104	0.804	0.019	-0.138	82.000
15.80	1.013	0.773	0.800	0.020	-0.053	66.420

DE 10107 DIAMETER = 17. 240

Y	U	V	W	RUV	RUW	VEL
0.05	0.488	0.352	0.258	-0.0	0.027	22.140
0.60	0.624	0.424	0.352	0.020	-0.0	30.340
1.40	0.746	0.503	0.408	-0.040	0.097	35.260
2.90	0.961	0.585	0.669	-0.0	0.071	46.740
4.10	1.168	0.971	0.813	-0.051	0.020	63.960
6.60	1.556	1.346	1.514	-0.045	0.159	115.620
9.10	0.847	0.591	0.914	-0.059	0.318	147.600
11.10	0.498	0.381	0.527	-0.444	-0.198	157.440
13.10	1.136	0.890	0.961	-0.155	-0.557	128.740
14.30	1.225	1.117	0.955	-0.0	-0.198	96.760
15.10	1.050	0.892	0.834	0.038	-0.161	72.160
15.80	0.814	0.740	0.617	-0.0	-0.183	58.220

ODE 10108 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.05	0.398	0.240	0.182	0.053	-0.035	17.220
0.80	0.559	0.393	0.302	-0.0	-0.0	27.060
1.80	0.672	0.394	0.402	-0.0	-0.098	31.980
3.30	0.854	0.575	0.614	-0.039	-0.0	41.000
5.30	1.195	0.788	0.941	-0.0	0.078	60.680
7.80	1.420	1.217	1.251	0.100	0.133	89.380
10.30	1.206	0.965	1.134	0.263	0.123	132.840
12.80	0.639	0.612	0.695	-0.205	-0.0	152.520
14.80	1.054	0.890	0.843	-0.287	-0.493	128.740
16.30	1.184	1.150	0.812	0.125	-0.262	89.380
17.20	0.960	0.907	0.773	0.018	-0.127	66.420
17.80	0.684	0.563	0.382	-0.0	-0.111	44.280

IDE 10109 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.05	0.310	0.211	0.170	-0.0	-0.123	17.220
0.70	0.499	0.292	0.264	-0.056	-0.029	24.600
1.50	0.574	0.348	0.302	-0.049	-0.0	27.060
3.00	0.705	0.408	0.399	-0.047	-0.0	33.620
5.20	0.971	0.627	0.710	-0.058	0.048	46.740
8.00	1.327	1.073	1.073	0.034	0.116	75.440
10.50	1.304	1.093	1.304	0.053	0.227	115.620
13.00	0.963	0.937	0.885	-0.243	0.047	142.680
15.20	1.009	0.967	1.072	-0.142	-0.203	115.620
17.00	1.150	1.042	1.012	0.039	-0.155	78.720
18.00	0.937	0.838	0.765	-0.0	-0.166	58.220
18.70	0.798	0.722	0.536	0.052	-0.074	49.200

DDE 10110 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
0.05	0.278	0.176	0.190	0.149	-0.0	22.140
0.70	0.364	0.228	0.250	-0.077	0.184	24.600
1.70	0.405	0.255	0.284	-0.035	-0.0	25.420
3.40	0.633	0.408	0.399	-0.0	0.051	35.260
5.90	0.929	0.678	0.656	-0.0	0.117	49.200
8.40	1.325	1.135	0.993	0.034	0.063	82.000
10.90	1.399	1.356	1.181	0.069	0.063	120.540
13.40	1.037	1.013	0.965	-0.101	0.106	132.840
15.90	1.278	1.259	1.182	-0.017	-0.073	103.320
17.40	1.065	0.949	0.921	0.081	-0.116	72.160
18.60	0.925	0.838	0.715	0.035	-0.041	58.220
19.70	0.633	0.556	0.374	-0.0	-0.031	41.000

DE 10200 DIAMETER = 10. 244

Y	U	V	W	RUV	RUW	VEL
0.05	2.138	0.908	1.230	0.349	0.027	157.440
0.50	1.762	1.186	1.186	0.271	0.077	183.680
1.00	1.599	1.148	1.271	0.282	-0.084	205.000
2.20	0.533	0.492	0.451	-0.394	-0.393	213.200
4.00	0.451	0.410	0.410	-0.372	-0.694	213.200
6.00	0.451	0.394	0.451	-0.738	-0.659	213.200
7.70	0.459	0.410	0.426	-0.533	-0.779	213.200
8.80	1.209	0.820	0.943	-0.543	-0.101	213.200
9.50	1.770	1.081	1.342	-0.344	-0.0	190.240
9.90	1.872	0.928	1.238	-0.373	0.030	167.280

DE 10201 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.05	1.953	1.014	1.252	0.345	0.057	75.440
0.50	2.219	1.109	1.206	0.406	0.043	132.840
1.00	1.879	1.073	1.133	0.089	0.035	162.360
2.00	1.132	0.859	0.820	-0.0	-0.122	196.800
3.50	0.541	0.451	0.525	-0.722	-0.523	205.000
5.50	0.500	0.476	0.476	-0.826	-0.881	205.000
7.50	0.545	0.492	0.492	-0.563	-0.891	205.000
9.00	0.566	0.492	0.541	-0.662	-0.720	205.000
10.00	1.495	0.933	1.190	-0.302	-0.111	172.200
10.80	2.079	0.839	1.220	-0.486	-0.037	103.320

DE 10202 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.05	0.781	0.425	0.590	0.022	-0.037	35.260
0.50	1.065	0.766	0.862	0.335	-0.066	55.760
1.40	1.158	0.820	0.984	0.682	-0.0	111.520
2.90	0.480	0.309	0.557	-0.367	0.272	167.280
4.90	0.129	0.135	0.135	-0.338	-0.580	172.200
6.90	0.122	0.119	0.112	-1.019	-0.896	183.680
8.90	0.136	0.140	0.126	-0.812	-0.740	183.680
10.40	0.611	0.515	0.515	0.266	0.052	172.200
11.40	1.258	0.899	1.056	0.480	0.054	124.640
11.80	1.312	0.853	1.000	0.348	0.099	85.280

IDE 10203 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.05	0.739	0.340	0.561	-0.051	0.144	33.620
0.60	0.959	0.714	0.848	-0.129	0.084	50.840
1.50	1.361	0.942	1.082	-0.216	0.102	93.480
2.90	0.963	0.677	0.937	-0.481	0.209	142.680
4.90	0.278	0.248	0.248	-0.203	-0.0	167.280
6.90	0.135	0.129	0.129	-0.608	-0.255	172.200
8.90	0.114	0.120	0.107	-0.583	-0.688	177.940
10.40	0.224	0.268	0.234	-0.220	-0.039	177.940
11.60	1.304	0.780	1.049	0.571	-0.0	147.600
12.20	1.423	0.889	1.067	0.291	0.159	107.420
12.80	1.165	0.705	1.012	0.310	0.286	78.720

DE 10204 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.05	0.637	0.326	0.497	-0.026	0.093	28.700
0.60	0.780	0.502	0.574	-0.079	-0.0	36.900
1.30	1.161	0.742	0.886	-0.098	0.033	55.760
3.20	1.346	1.051	1.388	-0.161	0.182	115.620
5.00	0.686	0.596	0.716	-0.144	0.720	162.360
7.00	0.173	0.142	0.167	-0.435	-0.231	167.280
9.00	0.158	0.148	0.129	-0.422	-0.260	172.200
11.00	0.280	0.289	0.225	-0.064	-0.146	172.200
12.30	1.230	0.916	1.085	0.550	0.146	132.840
13.20	1.309	1.012	1.012	0.298	0.141	93.480
13.80	1.015	0.584	0.917	0.206	0.128	68.880

DE 10205 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.05	0.589	0.325	0.469	-0.049	0.090	27.060
0.60	0.697	0.459	0.508	-0.0	0.038	31.980
1.40	0.892	0.633	0.633	-0.070	0.070	41.000
2.60	1.367	1.036	1.122	-0.094	0.016	72.160
4.50	1.393	0.899	1.438	-0.171	0.242	124.640
6.50	0.860	0.753	0.941	-0.274	0.460	147.600
9.00	0.429	0.239	0.328	0.430	-0.0	162.360
11.00	0.265	0.239	0.227	-0.256	-0.431	162.360
12.50	1.028	0.885	0.937	0.263	-0.0	142.680
13.70	1.274	1.082	1.151	0.189	0.150	93.480
14.40	1.050	0.719	0.921	0.217	0.184	72.160
14.80	0.900	0.580	0.703	0.050	0.170	58.220

'DE 10206 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.05	0.547	0.284	0.364	-0.027	-0.026	25.420
0.60	0.632	0.392	0.368	-0.0	0.054	30.340
1.40	0.863	0.633	0.575	-0.034	0.059	41.000
2.90	1.253	0.960	1.013	-0.034	0.016	66.420
5.10	1.430	1.219	1.514	0.081	0.195	115.620
7.10	1.305	1.093	1.267	-0.0	0.307	137.760
9.60	0.995	0.753	0.968	-0.124	0.313	147.600
11.60	0.483	0.351	0.703	-0.106	-0.072	157.440
13.30	1.054	0.937	0.937	0.128	0.219	142.680
14.60	1.334	1.081	1.153	0.262	0.100	96.760
15.40	1.140	0.917	0.945	0.086	0.221	68.880
15.80	0.910	0.539	0.694	0.075	0.166	55.760

DE 10207 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.05	0.561	0.328	0.423	-0.0	0.077	25.420
0.60	0.689	0.394	0.451	-0.024	0.041	31.980
1.40	0.848	0.512	0.634	-0.134	0.016	39.360
2.90	1.208	0.941	0.864	-0.0	-0.066	60.680
4.90	1.518	1.082	1.326	-0.0	0.066	93.480
7.40	1.471	0.916	1.182	0.070	0.318	132.840
9.90	1.093	0.989	1.276	-0.257	-0.022	142.680
12.40	0.968	0.860	0.591	0.080	0.186	147.600
14.40	1.316	0.744	1.259	0.308	0.037	103.320
15.60	1.165	1.007	1.093	0.109	0.095	72.160
16.50	0.966	0.598	0.915	0.076	0.089	60.680
16.80	0.814	0.402	0.625	0.033	0.089	50.840

IDE 10208 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.05	0.567	0.287	0.423	-0.0	0.041	27.060
0.70	0.697	0.459	0.493	0.021	-0.041	33.620
1.50	0.906	0.584	0.664	-0.0	-0.0	42.640
2.80	1.134	0.838	0.888	-0.018	-0.0	58.220
4.80	1.460	1.115	1.181	-0.087	0.052	85.280
7.30	1.535	1.241	1.304	0.023	0.267	115.620
9.80	1.348	1.191	1.325	-0.061	0.196	124.640
11.80	1.007	1.031	1.171	-0.672	0.312	128.740
13.80	1.206	1.061	1.109	0.061	0.056	132.840
15.30	1.423	1.304	1.107	0.040	0.024	107.420
16.60	1.180	1.036	1.036	0.105	0.088	72.160
17.30	1.030	0.788	0.941	0.040	0.134	60.680
17.80	0.866	0.393	0.716	0.133	0.101	53.300

DE 10209 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.05	0.539	0.284	0.364	0.028	-0.024	25.420
0.70	0.648	0.443	0.476	0.043	-0.040	31.980
1.70	0.764	0.559	0.540	-0.020	-0.0	39.360
3.30	1.106	0.864	0.890	0.073	-0.0	60.680
5.50	1.410	1.148	1.181	0.070	-0.017	85.280
8.00	1.521	1.225	1.146	0.021	-0.102	107.420
10.50	1.487	1.312	0.984	-0.0	-0.341	120.540
13.00	1.191	1.258	1.123	0.157	-0.216	124.640
15.00	1.312	1.107	1.312	-0.049	-0.134	111.520
16.50	1.319	1.150	1.116	-0.055	-0.0	89.380
17.50	1.080	0.853	0.907	-0.053	-0.019	66.420
18.20	0.946	0.718	0.814	-0.020	-0.072	55.760
18.90	0.729	0.278	0.614	-0.074	-0.039	41.000

IDE 10210 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
0.05	0.466	0.277	0.357	-0.032	-0.026	25.420
0.80	0.629	0.399	0.459	-0.026	0.022	33.620
1.80	0.796	0.575	0.556	-0.0	0.020	41.000
3.50	1.093	0.814	0.864	-0.0	-0.0	60.680
5.80	1.312	1.181	1.148	-0.017	-0.020	85.280
8.30	1.487	1.335	1.335	0.037	0.103	103.320
10.80	1.442	1.304	1.225	0.039	0.127	107.420
13.30	1.189	1.189	1.107	-0.055	0.329	111.520
15.30	1.278	1.259	1.182	-0.0	-0.0	103.320
17.10	1.165	1.042	1.073	0.143	0.018	78.720
18.00	1.053	0.880	0.880	0.057	0.112	66.420
18.80	0.962	0.789	0.838	0.038	0.108	58.220
19.70	0.714	0.563	0.563	0.021	0.069	44.280

CODE 46100 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.05	1.025	0.732	0.556	-0.047	0.474	157.440
0.50	1.014	0.626	0.626	-0.0	0.556	162.360
1.50	0.193	0.176	0.184	-0.918	-0.779	205.000
3.50	0.189	0.168	0.164	-1.057	-0.944	205.000
5.50	0.184	0.172	0.164	-0.991	-0.986	213.200
7.50	0.160	0.139	0.139	-1.035	-0.891	213.200
8.50	0.164	0.262	0.148	-0.596	-0.744	213.200
9.30	0.189	0.172	0.176	-0.800	-0.829	205.000
9.95	1.044	0.716	0.596	0.053	-0.611	162.360

DE 46101 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.05	1.014	0.745	0.537	-0.046	0.450	75.440
0.50	1.148	0.703	0.679	-0.085	0.519	128.740
1.00	0.424	0.272	0.347	-0.198	0.152	167.280
2.50	0.157	0.141	0.147	-1.074	-0.902	177.940
4.50	0.167	0.157	0.150	-0.865	-0.982	183.680
6.50	0.179	0.160	0.160	-1.102	-1.012	190.240
8.50	0.153	0.127	0.134	-0.662	-1.034	190.240
9.50	0.194	0.171	0.171	-0.795	-0.812	190.240
10.50	1.093	0.937	0.573	0.075	-0.506	142.680
10.80	1.182	0.801	0.458	0.030	-0.654	103.320

DE 46102 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.05	0.878	0.762	0.577	-0.106	0.347	53.300
0.50	1.104	0.858	0.766	-0.023	0.355	78.720
1.00	0.781	0.599	0.573	-0.061	0.334	142.680
3.00	0.152	0.134	0.140	-1.001	-0.880	162.360
5.00	0.146	0.146	0.128	-0.892	-0.999	162.360
7.00	0.150	0.149	0.136	-1.028	-0.869	167.280
9.00	0.141	0.130	0.130	-0.975	-0.990	167.280
10.00	0.152	0.142	0.145	-0.896	-0.813	167.280
11.00	0.982	0.820	0.721	0.042	-0.660	137.760
11.80	0.806	0.671	0.499	-0.0	-0.165	41.000

DE 46103 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.05	0.699	0.596	0.466	-0.112	0.210	39.360
0.50	1.036	0.892	0.777	-0.130	0.383	72.160
1.00	0.982	0.839	0.706	-0.155	0.434	103.320
2.00	0.174	0.154	0.184	-0.726	-0.727	137.760
4.00	0.134	0.129	0.124	-1.013	-1.012	137.760
6.00	0.135	0.129	0.129	-0.978	-0.959	137.760
8.00	0.138	0.134	0.132	-0.977	-1.010	137.760
10.00	0.152	0.149	0.154	-0.824	-0.861	137.760
11.00	0.543	0.531	0.386	-0.271	-0.289	132.840
12.00	1.053	0.880	0.800	0.064	-0.252	66.420
12.50	0.729	0.607	0.486	-0.0	-0.177	35.260
12.95	0.503	0.386	0.317	-0.126	-0.105	22.960

DE 46104 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.05	0.517	0.459	0.394	-0.048	0.204	31.980
0.50	0.736	0.669	0.591	-0.070	0.355	50.840
1.00	0.849	0.806	0.662	-0.047	0.354	72.160
2.00	0.369	0.369	0.369	-0.160	0.173	111.520
5.00	0.105	0.102	0.098	-0.927	-1.008	111.520
8.00	0.111	0.107	0.109	-0.994	-0.903	115.620
11.00	0.569	0.481	0.481	-1.322	-0.105	120.540
12.00	1.133	1.082	0.913	-0.0	-0.275	89.380
13.00	0.783	0.634	0.540	-0.0	-0.184	39.360
13.80	0.468	0.352	0.285	-0.109	-0.0	22.140

DF 46105 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.05	0.476	0.435	0.254	-0.100	-0.121	31.980
0.50	0.678	0.601	0.525	-0.135	-0.106	49.200
1.00	0.813	0.787	0.669	-0.091	-0.508	63.960
2.00	0.772	0.648	0.648	-0.284	-0.159	103.320
3.30	0.180	0.157	0.189	-0.982	-0.386	124.640
5.30	0.130	0.121	0.126	-0.997	-0.958	124.640
7.30	0.121	0.117	0.112	-1.043	-0.942	124.640
9.30	0.171	0.150	0.159	-0.108	-0.512	128.740
11.30	0.700	0.700	0.612	-0.059	-0.0	120.540
12.50	1.237	1.014	0.924	-0.0	0.288	75.440
13.50	0.926	0.745	0.684	0.050	0.140	44.280
14.30	0.630	0.451	0.435	-0.0	0.139	28.700
14.80	0.470	0.317	0.436	-0.0	0.048	21.320

DE 46106 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.05	0.476	0.424	0.344	-0.026	0.059	30.340
0.60	0.704	0.573	0.543	-0.109	0.158	44.280
1.60	0.949	0.892	0.806	0.041	0.179	72.160
3.10	0.420	0.389	0.574	0.307	0.276	111.520
5.10	0.137	0.126	0.139	-0.812	-0.532	115.620
7.60	0.151	0.136	0.136	-0.771	-0.659	120.540
10.10	0.337	0.297	0.045	-0.0	-0.0	124.640
12.10	0.950	1.044	0.895	0.138	0.188	100.040
13.40	1.115	0.997	0.840	0.145	-0.039	63.960
14.30	0.863	0.614	0.595	0.019	-0.0	41.000
15.10	0.627	0.423	0.423	-0.0	0.040	27.060
15.70	0.482	0.345	0.317	-0.025	0.050	22.960

DE 46107 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.05	0.524	0.432	0.360	-0.049	0.056	30.340
0.70	0.803	0.759	0.647	0.166	0.127	50.840
1.40	0.960	0.933	0.800	0.162	-0.106	66.420
2.80	0.877	0.896	0.839	-0.032	-0.096	103.320
5.00	0.195	0.171	0.184	-0.265	-0.133	124.640
7.50	0.184	0.189	0.189	-0.0	-0.122	124.640
10.00	0.514	0.481	0.525	-0.130	0.327	120.540
12.00	0.973	0.883	0.901	0.119	0.074	96.760
13.50	1.070	1.001	0.917	-0.0	0.223	68.880
15.00	0.834	0.614	0.633	0.092	0.070	41.000
15.80	0.656	0.496	0.448	0.074	0.082	30.340
16.70	0.510	0.324	0.303	0.025	0.025	22.960

DE 46108 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.05	0.568	0.443	0.260	0.112	-0.072	35.260
0.70	0.745	0.584	0.483	0.106	-0.0	44.280
1.50	0.889	0.808	0.624	0.128	0.022	53.300
2.80	1.104	0.867	0.820	0.045	-0.100	82.000
4.80	0.568	0.526	0.547	0.186	-0.300	115.620
6.80	0.281	0.292	0.270	0.023	0.282	124.640
9.30	0.481	0.612	0.437	0.061	0.550	120.540
11.30	0.800	0.771	0.711	0.219	0.191	107.420
13.30	1.134	0.981	0.981	0.076	0.277	78.720
14.60	1.017	0.864	0.864	0.095	0.146	60.680
15.70	0.835	0.664	0.644	0.055	0.135	42.640
16.50	0.712	0.503	0.521	0.041	0.078	35.260
17.30	0.576	0.364	0.394	0.068	0.041	25.420
17.80	0.456	0.304	0.251	0.025	0.028	21.320

DE 46109 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.05	0.518	0.425	0.229	0.085	-0.042	33.620
0.70	0.724	0.604	0.453	0.205	0.024	42.640
1.50	0.820	0.743	0.634	0.125	-0.0	49.200
2.90	1.050	0.949	0.762	0.135	-0.085	72.160
4.90	0.881	0.820	0.820	0.356	-0.108	111.520
7.40	0.601	0.656	0.569	0.094	0.231	120.540
9.90	0.697	0.738	0.697	0.176	0.255	111.520
11.90	0.867	0.950	0.857	0.075	0.396	100.040
13.90	1.006	0.924	0.865	0.075	0.086	75.440
14.40	0.889	0.808	0.785	0.037	0.146	53.300
15.50	0.815	0.644	0.624	0.054	0.113	42.640
16.40	0.680	0.493	0.459	0.040	0.065	33.620
17.30	0.552	0.408	0.355	0.064	0.049	27.060
18.70	0.413	0.271	0.212	-0.0	0.064	21.320

DE 46110 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
0.20	0.465	0.355	0.325	-0.0	0.085	27.060
1.00	0.645	0.448	0.439	-0.074	0.024	36.900
1.80	0.794	0.585	0.554	-0.021	0.046	46.740
3.00	0.984	0.761	0.735	-0.0	0.023	63.960
4.50	0.959	0.820	0.886	-0.0	0.124	85.280
6.50	0.790	0.692	0.790	-0.389	0.232	107.420
9.00	0.761	0.751	0.830	-0.349	-0.061	107.420
11.50	0.895	0.857	0.876	-0.268	-0.060	100.040
13.50	1.050	0.902	0.935	-0.048	-0.141	85.280
15.50	1.023	0.813	0.735	-0.0	-0.041	63.960
17.00	0.853	0.612	0.579	0.043	-0.024	49.200
18.00	0.729	0.480	0.480	0.048	0.024	41.000
18.80	0.599	0.394	0.377	0.025	-0.025	31.980
19.80	0.393	0.303	0.262	-0.029	-0.0	22.960

DE 46200 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.05	0.887	0.469	0.636	-0.473	-0.0	177.940
1.50	0.174	0.160	0.164	-1.041	-1.039	205.000
3.50	0.176	0.172	0.164	-0.944	-1.040	205.000
5.50	0.172	0.172	0.156	-0.948	-1.040	205.000
7.00	0.164	0.164	0.143	-1.050	-0.857	205.000
8.50	0.172	0.176	0.148	-0.845	-0.965	205.000
9.20	0.738	0.549	0.377	0.425	-0.0	205.000
9.95	1.160	0.681	0.743	0.502	0.051	167.280

DE 46201 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.20	1.049	0.555	0.724	-0.398	-0.044	132.840
0.70	0.731	0.370	0.656	-0.361	-0.0	162.360
2.70	0.152	0.134	0.147	-0.909	-1.076	177.940
4.70	0.147	0.137	0.134	-1.053	-0.893	177.940
6.70	0.161	0.157	0.136	-0.887	-1.007	183.680
8.70	0.148	0.140	0.140	-0.997	-0.881	183.680
9.70	0.244	0.286	0.161	-0.101	-0.635	183.680
10.70	1.334	0.787	0.897	0.425	0.190	120.540
10.95	1.072	0.568	0.788	0.399	0.192	82.000

DE 46202 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.20	1.093	0.691	0.892	-0.345	-0.135	72.160
0.60	1.126	0.722	0.984	-0.500	0.030	120.540
1.10	0.310	0.246	0.293	-0.319	-0.164	157.440
3.10	0.140	0.125	0.137	-1.015	-0.903	162.360
5.10	0.148	0.137	0.134	-0.750	-1.025	162.360
7.10	0.158	0.149	0.146	-0.989	-0.711	162.360
9.10	0.146	0.143	0.128	-0.862	-0.988	162.360
11.10	1.013	0.699	0.820	0.431	0.211	132.840
11.60	1.150	0.766	0.920	0.428	0.061	78.720
11.95	0.859	0.536	0.781	0.340	0.115	50.840

DE 46203 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.20	0.690	0.522	0.559	-0.150	-0.144	39.360
0.70	0.945	0.656	0.840	-0.381	-0.128	63.960
1.20	1.082	0.715	0.872	-0.355	-0.164	93.480
2.20	0.258	0.270	0.247	2.489	-0.129	124.640
4.20	0.121	0.117	0.112	-0.953	-0.953	124.640
7.20	0.115	0.107	0.114	-0.976	-0.977	120.540
9.20	0.107	0.105	0.105	-0.991	-1.033	115.620
11.20	0.252	0.279	0.202	0.071	-0.149	124.640
12.20	0.876	0.667	0.723	0.337	-0.0	68.880
12.70	0.700	0.525	0.612	0.215	0.049	49.200
12.95	0.583	0.376	0.538	0.290	0.045	36.900

DE 46204 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.20	0.602	0.404	0.451	0.046	-0.069	28.700
0.70	0.864	0.612	0.743	-0.094	0.039	49.200
1.20	1.015	0.723	0.889	-0.144	-0.045	68.880
2.20	0.857	0.615	0.783	-0.506	0.064	100.040
3.20	0.231	0.126	0.252	0.467	0.132	115.620
6.20	0.112	0.105	0.103	-0.964	-0.965	115.620
9.20	0.108	0.105	0.105	-0.937	-1.002	115.620
11.20	0.164	0.168	0.135	-0.347	-0.377	115.620
12.10	0.745	0.652	0.634	0.500	-0.0	100.040
13.10	0.945	0.723	0.834	0.424	0.081	68.880
13.95	0.533	0.328	0.492	0.329	0.049	31.980

DE 46205 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.20	0.552	0.257	0.355	-0.0	0.026	27.060
0.90	0.681	0.459	0.508	-0.0	0.035	31.980
1.60	0.898	0.669	0.710	-0.054	0.109	46.740
2.90	1.025	0.883	0.915	-0.358	0.121	82.000
4.40	0.741	0.584	0.517	-0.163	-0.322	124.640
6.40	0.148	0.127	0.141	-0.677	-0.545	128.740
8.90	0.122	0.117	0.117	-0.847	-0.951	124.640
10.90	0.127	0.121	0.121	-0.930	-0.815	124.640
12.40	0.219	0.262	0.197	0.273	-0.400	120.540
13.60	0.890	0.768	0.837	0.420	0.135	93.480
14.40	0.814	0.703	0.765	0.319	0.118	58.220
14.95	0.538	0.466	0.520	0.235	0.051	36.900

DE 46206 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.20	0.559	0.317	0.393	-0.0	-0.0	27.060
0.70	0.664	0.426	0.443	-0.023	0.064	31.980
1.50	0.855	0.563	0.604	-0.021	0.020	42.640
2.80	1.194	0.921	0.978	-0.0	0.074	72.160
5.00	0.852	0.631	0.715	-0.243	0.272	115.620
7.50	0.195	0.261	0.202	-0.169	0.366	124.640
10.00	0.128	0.118	0.120	-0.782	-0.817	120.540
12.00	0.186	0.197	0.157	-0.254	-0.684	120.540
13.50	0.848	0.745	0.783	0.620	0.089	100.040
14.50	0.853	0.733	0.827	0.307	-0.023	66.420
15.20	0.809	0.634	0.722	0.246	-0.0	49.200
15.95	0.514	0.423	0.469	0.169	0.040	27.060

DE 46207 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.30	0.496	0.221	0.345	0.032	-0.0	22.960
0.80	0.597	0.363	0.355	-0.0	-0.024	27.060
1.50	0.745	0.578	0.540	0.018	0.022	39.360
2.60	0.877	0.669	0.710	-0.0	0.035	46.740
4.30	1.167	0.820	1.041	-0.081	-0.021	82.000
6.80	0.593	0.751	0.593	-0.0	-0.100	107.420
9.30	0.172	0.168	0.168	-0.750	-0.610	115.620
11.80	0.166	0.175	0.166	-0.543	-0.365	120.540
13.60	0.574	0.656	0.615	0.422	-0.046	111.520
15.00	0.866	0.782	0.858	0.319	0.141	78.720
15.90	0.855	0.601	0.716	0.248	0.124	53.300
16.95	0.569	0.382	0.433	0.132	0.123	33.620

DE 46208 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.20	0.403	0.217	0.278	-0.039	0.089	22.140
0.80	0.539	0.313	0.350	0.026	0.023	25.420
1.60	0.640	0.476	0.459	-0.020	0.042	31.980
2.80	0.845	0.584	0.644	-0.0	0.036	42.640
4.80	1.080	0.853	0.880	-0.037	0.019	66.420
6.80	0.913	0.778	0.981	-0.354	-0.095	89.380
9.30	0.492	0.492	0.410	-0.107	0.400	111.520
11.80	0.225	0.284	0.280	-0.128	-0.0	120.540
13.60	0.666	0.697	0.553	0.280	0.128	111.520
15.10	1.082	0.984	1.050	0.391	0.162	85.280
16.30	0.886	0.766	0.790	0.216	0.115	55.760
17.10	0.714	0.584	0.644	0.189	0.078	42.640
17.95	0.457	0.265	0.408	0.176	0.025	27.060

DE 46209 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.20	0.374	0.178	0.232	0.033	-0.029	18.860
0.90	0.525	0.284	0.313	-0.028	-0.0	25.420
1.70	0.598	0.319	0.396	0.084	-0.0	28.700
2.80	0.755	0.475	0.578	-0.0	0.057	39.360
4.20	0.982	0.742	0.730	-0.0	-0.0	55.760
6.20	0.973	0.806	0.764	-0.0	-0.052	68.880
8.70	0.801	0.725	0.877	-0.259	-0.089	103.320
11.20	0.394	0.350	0.437	-0.172	-0.212	120.540
13.20	0.421	0.484	0.357	0.123	0.114	115.620
15.20	0.904	0.895	0.988	0.190	0.029	100.040
16.70	0.945	0.778	0.917	0.136	0.139	68.880
17.70	0.781	0.692	0.759	0.163	0.057	50.840
18.30	0.671	0.470	0.575	0.120	0.124	41.000
18.95	0.443	0.295	0.404	0.068	0.080	28.700

DE 46210 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
0.20	0.270	0.214	0.202	0.039	-0.181	18.860
1.00	0.379	0.248	0.248	0.039	-0.031	22.960
1.80	0.514	0.302	0.333	-0.0	0.054	27.060
3.00	0.654	0.399	0.425	0.024	-0.065	33.620
4.60	0.795	0.543	0.553	-0.022	0.022	44.280
6.50	0.973	0.747	0.787	-0.069	-0.022	66.420
9.00	0.856	0.901	0.793	-0.106	0.154	96.760
11.50	0.526	0.547	0.463	-0.288	-0.144	115.620
13.50	0.494	0.547	0.547	0.061	-0.208	115.620
15.30	0.773	0.745	0.783	0.133	-0.080	100.040
16.60	0.904	0.858	0.843	0.211	0.076	78.720
17.80	0.851	0.765	0.740	0.210	0.065	58.220
18.80	0.731	0.522	0.575	0.101	0.068	46.740
19.80	0.472	0.344	0.440	0.147	0.050	30.340

DE 15100 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.05	0.770	0.502	0.469	-0.075	0.506	177.940
0.50	0.482	0.154	0.523	-0.511	0.679	183.680
1.00	0.051	0.053	0.053	-0.479	-0.0	196.800
3.00	0.098	0.016	0.023	-0.450	-0.037	205.000
5.50	0.027	0.023	0.025	-0.486	-0.692	213.200
8.00	0.015	0.013	0.013	-0.389	-0.333	213.200
9.00	0.016	0.017	0.015	-0.145	-0.346	205.000
9.70	0.512	0.492	0.234	0.194	-0.356	196.800

DE 15101 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.05	0.935	0.672	0.558	-0.060	0.505	85.280
1.00	0.037	0.025	0.065	-0.095	-0.178	167.280
3.00	0.013	0.012	0.014	-0.691	-0.529	172.200
5.00	0.013	0.012	0.014	-0.519	-0.449	172.200
7.00	0.015	0.014	0.014	-0.797	-0.557	183.680
9.00	0.017	0.015	0.020	-0.478	-1.038	183.680
10.60	0.732	1.054	0.176	0.184	-0.467	157.440
10.80	1.044	0.770	0.621	0.123	-0.373	137.760

DE 15102 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.05	0.874	0.694	0.527	-0.068	0.345	55.760
0.50	0.831	0.459	0.700	-0.114	0.486	120.540
1.00	0.071	0.032	0.113	-0.195	-0.079	147.600
3.00	0.019	0.017	0.020	-0.533	-0.626	152.520
5.00	0.029	0.018	0.035	-0.560	-0.731	157.440
7.00	0.080	0.062	0.093	-0.831	-0.627	167.280
9.00	0.013	0.012	0.015	-0.510	-0.896	162.360
10.00	0.028	0.024	0.024	-0.030	-0.165	162.360
11.00	0.570	0.667	1.929	0.151	-0.010	152.520
11.80	1.079	0.863	0.949	0.173	-0.351	72.160

DE 15103 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.05	0.729	0.614	0.422	-0.075	0.362	41.000
0.50	1.041	0.788	0.788	-0.078	0.422	82.000
1.00	0.841	0.526	0.694	-0.105	0.439	115.620
2.00	0.078	0.063	0.082	-0.650	-0.541	132.840
4.00	0.065	0.058	0.065	-0.915	-0.911	132.840
6.00	0.056	0.035	0.075	-0.274	-0.860	137.760
8.00	0.065	0.047	0.089	-0.080	-0.969	142.680
10.00	0.029	0.031	0.031	-0.444	-0.900	142.680
11.00	0.125	0.156	0.109	0.187	-0.230	142.680
12.00	1.335	1.144	0.572	-0.0	-0.638	103.320
12.80	0.661	0.497	0.451	0.081	-0.248	28.700

DE 15104 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.05	0.607	0.525	0.394	-0.040	0.306	31.980
0.50	0.932	0.866	0.761	-0.081	0.347	63.960
1.50	0.437	0.306	0.547	-0.110	0.315	120.540
2.50	0.111	0.094	0.108	-0.845	-0.656	124.640
4.50	0.099	0.092	0.090	-1.053	-1.023	124.640
6.50	0.100	0.091	0.096	-0.978	-0.914	128.740
8.50	0.101	0.091	0.098	-0.831	-1.052	128.740
10.50	0.125	0.101	0.113	-0.600	-0.528	132.840
12.50	1.151	1.072	0.820	0.145	-0.441	82.000
13.50	0.730	0.476	0.492	-0.044	-0.113	31.980
13.95	0.452	0.309	0.285	-0.0	0.024	18.860

DE 15105 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.05	0.510	0.452	0.306	-0.041	0.212	25.420
0.50	0.724	0.664	0.584	-0.062	0.236	44.280
1.50	0.886	0.754	0.738	-0.093	0.322	85.280
3.50	0.105	0.093	0.105	-0.931	-0.686	115.620
5.50	0.094	0.086	0.086	-0.885	-1.046	115.620
7.50	0.099	0.085	0.090	-1.049	-0.979	120.540
9.50	0.105	0.096	0.098	-0.767	-1.045	120.540
11.50	0.394	0.394	0.394	-0.231	-0.519	120.540
12.50	1.064	1.047	0.768	0.143	-0.359	93.480
13.50	1.089	0.886	0.814	0.070	-0.130	55.760
14.50	0.590	0.364	0.408	-0.0	-0.088	25.420
14.80	0.416	0.273	0.238	-0.0	-0.0	18.860

DE 15106 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.05	0.471	0.414	0.285	-0.043	0.173	24.600
0.50	0.704	0.644	0.563	-0.080	0.201	42.640
1.50	0.924	0.835	0.805	-0.089	0.255	75.440
2.50	0.572	0.534	0.610	-0.132	0.245	103.320
4.50	0.101	0.088	0.094	-0.855	-0.822	111.520
6.50	0.094	0.084	0.086	-0.993	-0.974	111.520
8.50	0.103	0.088	0.097	-0.857	-0.898	115.620
10.50	0.214	0.166	0.192	-0.408	-0.150	120.540
11.50	0.481	0.350	0.437	0.183	-0.211	120.540
12.50	0.913	0.932	0.932	-0.0	-0.432	100.040
13.50	1.208	1.093	0.892	0.033	-0.164	72.160
14.50	0.906	0.684	0.644	0.019	-0.087	44.280
15.50	0.570	0.371	0.342	-0.0	-0.0	24.600
15.70	0.456	0.304	0.291	-0.0	-0.0	21.320

DE 15107 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.05	0.446	0.385	0.265	-0.053	0.101	27.060
0.50	0.578	0.540	0.485	-0.047	0.097	39.360
1.00	0.704	0.644	0.563	-0.055	0.187	44.280
2.00	0.909	0.835	0.805	-0.046	0.299	75.440
4.00	0.207	0.158	0.217	-0.240	-0.074	107.420
6.00	0.094	0.086	0.086	-0.901	-0.915	111.520
8.00	0.098	0.086	0.086	-0.791	-0.907	111.520
10.00	0.164	0.118	0.135	-0.977	-0.810	115.620
12.00	0.697	0.656	0.676	0.270	-0.558	111.520
14.00	1.122	1.036	0.892	-0.0	-0.186	72.160
15.00	0.855	0.684	0.604	0.018	-0.060	44.280
16.00	0.640	0.432	0.448	-0.023	-0.040	30.340
16.95	0.423	0.304	0.265	-0.052	-0.030	21.320

DE 15108 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.05	0.412	0.350	0.241	-0.109	0.102	25.420
0.30	0.531	0.485	0.419	-0.103	0.122	39.360
1.00	0.634	0.604	0.543	-0.087	0.148	44.280
2.00	0.771	0.792	0.709	-0.104	0.281	68.880
3.00	0.689	0.803	0.663	-0.033	0.253	93.480
5.50	0.099	0.071	0.099	-0.453	-0.230	107.420
9.00	0.113	0.079	0.111	-0.213	-0.774	107.420
11.50	0.514	0.514	0.514	-0.0	-0.404	107.420
14.00	1.001	0.917	0.778	-0.0	-0.138	68.880
16.50	0.654	0.476	0.476	0.042	-0.0	33.620
17.00	0.539	0.364	0.335	-0.0	-0.0	25.420
17.70	0.433	0.291	0.265	-0.0	-0.0	21.320
17.95	0.300	0.232	0.170	-0.0	-0.0	16.400

DE 15109 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.05	0.389	0.335	0.228	-0.055	0.074	24.600
0.30	0.443	0.402	0.344	-0.172	0.062	31.980
0.80	0.578	0.540	0.485	-0.109	0.146	39.360
1.80	0.658	0.647	0.601	-0.080	0.190	53.300
4.30	0.451	0.415	0.469	-0.055	0.053	96.760
6.80	0.124	0.095	0.130	-0.247	-0.221	103.320
9.30	0.114	0.088	0.103	-0.522	-0.563	103.320
11.80	0.400	0.420	0.381	-0.060	-0.390	103.320
13.30	0.869	0.886	0.754	0.056	-0.200	85.280
15.80	0.783	0.648	0.606	0.021	-0.041	46.740
17.70	0.503	0.364	0.321	0.023	0.026	25.420
18.70	0.336	0.244	0.214	-0.0	0.021	18.860
18.95	0.267	0.206	0.141	-0.0	-0.046	15.580

DE 15110 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
0.20	0.420	0.358	0.280	-0.110	0.068	28.700
0.60	0.459	0.410	0.377	-0.161	-0.0	31.980
1.60	0.627	0.585	0.543	-0.100	0.103	46.740
2.60	0.708	0.735	0.656	-0.129	0.375	63.960
5.00	0.466	0.466	0.466	-0.178	0.280	100.040
7.50	0.135	0.126	0.145	-0.491	-0.346	103.320
10.00	0.267	0.237	0.336	-0.213	-0.527	107.420
12.50	0.712	0.739	0.649	-0.218	0.102	96.760
15.00	0.884	0.826	0.712	0.019	-0.097	60.680
17.50	0.616	0.469	0.434	-0.0	-0.0	35.260
18.50	0.499	0.363	0.333	0.052	-0.0	27.060
19.10	0.420	0.312	0.271	-0.0	-0.0	22.140
19.60	0.345	0.238	0.202	-0.0	-0.0	18.860
19.90	0.269	0.212	0.174	-0.068	0.039	15.580

)E 15200 DIAMETER = 10.

Y	U	V	W	RUV	RUW	VEL
0.50	0.024	0.028	0.023	-0.251	-0.339	190.240
2.50	0.019	0.015	0.034	-0.875	-0.417	205.000
5.00	0.046	0.074	0.020	-0.741	-0.371	205.000
7.50	0.020	0.022	0.025	-0.759	-0.350	213.200
9.50	0.335	0.066	0.090	0.046	-0.0	213.200
9.95	0.727	0.559	0.485	0.600	0.295	190.240

DE 15201 DIAMETER = 11.

Y	U	V	W	RUV	RUW	VEL
0.50	0.297	0.199	0.296	-0.271	-0.293	172.200
1.00	0.264	0.116	0.309	-0.190	-0.158	172.200
2.00	0.014	0.012	0.013	-0.386	-0.490	177.940
4.00	0.029	0.011	0.047	-0.434	-0.653	177.940
6.00	0.057	0.087	0.013	-0.219	29.348	177.940
8.00	0.016	0.018	0.013	-0.658	-0.421	177.940
10.00	0.022	0.031	0.021	-0.259	-0.387	177.940
10.95	0.829	0.652	0.410	0.469	0.235	100.040

DE 15202 DIAMETER = 12.

Y	U	V	W	RUV	RUW	VEL
0.40	1.071	0.569	0.918	-0.521	-0.149	120.540
0.90	0.256	0.183	0.278	-0.053	-0.183	152.520
1.40	0.064	0.053	0.070	-0.170	-0.556	157.440
3.40	0.067	0.010	0.108	-0.206	-1.050	157.440
5.40	0.026	0.047	0.023	-0.425	-0.473	157.440
7.40	0.064	0.105	0.018	-1.091	-0.427	157.440
9.40	0.016	0.021	0.015	-0.300	-0.384	157.440
10.40	0.031	0.040	0.019	-0.184	-0.083	157.440
11.40	1.135	0.820	0.820	0.500	0.149	103.320
11.95	1.023	0.630	0.774	0.368	0.082	63.960

DE 15203 DIAMETER = 13.

Y	U	V	W	RUV	RUW	VEL
0.50	1.013	0.072	0.853	-3.054	-0.061	66.420
1.00	1.151	0.663	1.012	-0.441	-0.073	93.480
2.00	0.117	0.099	0.117	-0.195	-0.577	137.760
4.00	0.082	0.045	0.099	-0.800	-1.036	137.760
6.00	0.089	0.075	0.082	-0.800	-1.061	137.760
8.00	0.099	0.104	0.077	-0.941	-0.817	137.760
10.00	0.092	0.084	0.082	-0.815	-0.904	137.760
11.00	0.104	0.102	0.089	-0.727	-0.919	137.760
12.00	0.696	0.741	0.382	0.559	0.081	124.640
12.50	1.134	0.837	0.837	0.418	0.054	93.480
12.95	0.745	0.483	0.644	0.311	-0.0	42.640

DE 15204 DIAMETER = 14.

Y	U	V	W	RUV	RUW	VEL
0.20	0.875	0.656	0.722	-0.209	-0.118	49.200
0.70	1.067	0.693	0.987	-0.313	-0.081	66.420
1.70	0.465	0.404	0.539	-0.493	-0.109	124.640
3.70	0.101	0.084	0.101	-0.844	-1.000	128.740
5.70	0.102	0.091	0.094	-0.881	-1.037	128.740
7.70	0.101	0.092	0.094	-0.780	-0.989	124.640
9.70	0.932	0.944	0.854	-0.008	-1.052	124.640
11.70	0.207	0.247	0.135	-0.166	-0.140	124.640
12.70	0.994	0.837	0.837	0.425	0.027	93.480
13.70	0.717	0.485	0.652	0.223	-0.035	39.360
13.95	0.623	0.394	0.525	0.159	0.008	31.980

DE 15205 DIAMETER = 15.

Y	U	V	W	RUV	RUW	VEL
0.20	0.795	0.604	0.644	-0.174	-0.118	42.640
0.70	0.785	0.563	0.664	-0.192	-0.076	42.640
1.70	0.960	0.733	0.942	-0.361	-0.053	93.480
3.70	0.118	0.105	0.114	-0.616	-0.591	115.620
5.70	0.099	0.090	0.092	-0.826	-1.009	120.540
7.70	0.092	0.092	0.092	-0.972	-0.887	120.540
9.70	0.097	0.098	0.087	-0.912	-0.997	120.540
11.70	0.114	0.114	0.096	-0.611	-0.716	120.540
13.70	0.984	0.820	0.820	0.450	0.114	85.280
14.70	0.804	0.606	0.710	0.171	-0.0	46.740
14.95	0.544	0.311	0.482	0.203	-0.0	28.700

DE 15206 DIAMETER = 16.

Y	U	V	W	RUV	RUW	VEL
0.20	0.637	0.476	0.510	-0.077	-0.043	33.620
0.90	0.775	0.584	0.684	-0.131	-0.053	42.640
1.90	0.899	0.725	0.883	-0.361	-0.079	82.000
3.90	0.164	0.143	0.164	-0.112	-0.281	111.520
5.90	0.094	0.084	0.086	-0.852	-0.889	111.520
7.90	0.088	0.078	0.086	3.694	-0.828	111.520
9.90	0.093	0.090	0.082	-0.892	-1.031	111.520
11.90	0.126	0.105	0.147	-0.538	-0.478	115.620
13.90	0.855	0.803	0.698	0.414	0.125	93.480
14.90	0.866	0.693	0.808	0.243	0.037	53.300
15.40	0.755	0.604	0.664	0.140	0.077	42.640
15.95	0.481	0.277	0.437	0.154	-0.0	25.420

DE 15207 DIAMETER = 17.

Y	U	V	W	RUV	RUW	VEL
0.50	0.560	0.389	0.420	-0.027	-0.041	28.700
1.00	0.699	0.540	0.578	-0.086	-0.040	39.360
2.00	0.915	0.763	0.864	-0.194	0.020	60.680
3.00	0.890	0.733	0.872	-0.327	-0.139	93.480
5.00	0.228	0.189	0.184	-0.089	-0.175	111.520
7.00	0.119	0.094	0.107	-0.564	-0.450	111.520
9.00	0.111	0.098	0.102	-0.553	-0.576	111.520
11.00	0.111	0.105	0.101	-0.604	-0.646	115.620
13.00	0.315	0.378	0.294	0.302	-0.184	115.620
15.00	0.964	0.863	1.007	0.255	0.020	72.160
16.00	0.734	0.604	0.664	0.161	0.021	44.280
16.40	0.566	0.426	0.508	0.070	0.037	31.980
16.90	0.455	0.248	0.386	0.072	0.061	22.960

DE 15208 DIAMETER = 18.

Y	U	V	W	RUV	RUW	VEL
0.05	0.434	0.258	0.298	-0.028	0.058	22.140
0.30	0.514	0.333	0.423	-0.027	-0.052	27.060
1.00	0.663	0.502	0.538	-0.064	-0.021	36.900
2.00	0.866	0.670	0.762	-0.148	-0.0	53.300
4.00	0.802	0.757	0.649	-0.254	-0.283	96.760
6.00	0.237	0.178	0.198	-0.333	-0.708	107.420
8.00	0.130	0.107	0.115	-0.031	-0.375	107.420
9.00	0.101	0.087	0.111	-0.451	-0.163	107.420
11.00	0.103	0.111	0.095	-0.204	-0.354	107.420
13.00	0.316	0.217	0.356	-0.0	-0.0	107.420
15.00	0.852	0.788	0.852	0.253	0.054	82.000
16.00	0.888	0.740	0.814	0.186	0.039	58.220
17.00	0.627	0.502	0.538	0.103	0.021	36.900
17.50	0.513	0.342	0.435	0.038	0.022	28.700
17.95	0.413	0.217	0.339	0.107	0.026	22.140

DE 15209 DIAMETER = 19.

Y	U	V	W	RUV	RUW	VEL
0.05	0.393	0.210	0.305	-0.037	-0.030	22.140
0.30	0.462	0.303	0.358	-0.026	-0.071	22.960
0.80	0.582	0.426	0.459	0.037	-0.058	31.980
1.80	0.745	0.563	0.624	-0.054	-0.020	44.280
4.30	0.828	0.676	0.744	-0.248	-0.092	89.380
6.80	0.362	0.381	0.400	-0.337	-0.230	103.320
9.30	0.181	0.153	0.229	-0.343	-0.212	103.320
11.80	0.198	0.158	0.217	0.190	-0.177	107.420
14.30	0.676	0.613	0.757	0.170	0.034	96.760
16.80	0.694	0.584	0.644	0.140	0.041	44.280
17.80	0.528	0.432	0.448	0.076	0.047	30.340
18.30	0.456	0.342	0.385	0.052	-0.0	24.600
18.90	0.327	0.178	0.273	0.116	0.018	18.860

DE 15210 DIAMETER = 20.

Y	U	V	W	RUV	RUW	VEL
0.20	0.377	0.218	0.291	-0.0	-0.029	21.320
0.80	0.552	0.384	0.448	-0.0	-0.041	30.340
1.00	0.525	0.410	0.410	-0.054	-0.082	31.980
2.00	0.724	0.543	0.543	-0.067	-0.023	42.640
4.50	0.842	0.775	0.790	-0.167	-0.102	75.440
7.00	0.649	0.613	0.451	-0.161	-0.091	96.760
9.50	0.324	0.343	0.343	-0.093	-0.237	103.320
12.00	0.316	0.257	0.296	0.231	-0.238	107.420
14.50	0.634	0.634	0.578	0.380	-0.087	100.040
17.00	0.777	0.715	0.765	0.125	0.065	58.220
19.50	0.583	0.484	0.502	0.097	0.023	36.900
19.80	0.419	0.350	0.306	-0.0	0.029	25.420
19.95	0.359	0.230	0.305	0.070	-0.032	22.140

APPENDIX B

COMPUTER PROGRAMMES USED TO CALCULATE TURBULENCE PARAMETERS

CONTENTS

NOTE: Main programme calculated the following:
u', v', w', $\overline{u}^2$, $\overline{v}^2$, $\overline{w}^2$, $\frac{1}{2}\rho(\overline{u}^2 + \overline{v}^2 + \overline{w}^2)$,
Ruv, Ruw, $\overline{uv}$, $\overline{uw}$, Y/D.

Subroutine Readin was the calibration curve for the probe in use at the time of testing.

Subroutine Uplot plotted the calculated parameters versus Y/D.

Data Printout programme printed out the data in Appendix A.

```
 DIMENSION AV)20*,BV)20*,ABPV)20*,ABNV)20*,AW)20*,BW)20*,ABPW)20*,
1ABNW)20*,E)20*,UTV)20*,UTW)20*,UTM)20*,VT)20*,WT)20*,U)20*,V)20*,
2W)20*,X)20*,ENERG)20*,RUV)20*,RUW)20*,UMEAN)200*,EM)200*,SL)200*
3,VEL)200*,UU)200*,UV)200*,UW)200*,DIMDIS)200*
4,VV)20*,WW)20*,R)20*,PK)20*,Y)20*
  COMMON EM,UMEAN,SL
```

NOTE: *=)
)=(in this printout

```
  CALL READIN)N*
 WRITE)6,1*
 FORMAT)'     TURBULENT VELOCITY PARAMETERS'//*
 INPUTS
 READ)5,100,END=99*NCODE,NUMB,DIA
 FORMAT)I5,5X,I2,5X,F5.2*
 WRITE)6,2*NCODE,NUMB,DIA
 FORMAT)5X,'CODE',I5,5X,'NUMBER',I2,5X,'DIAMETER',F3.0//*
 READ)5,200*)AV)I*,BV)I*,ABPV)I*,ABNV)I*,AW)I*,BW)I*,ABPW)I*,
1ABNW)I*,E)I*,X)I*,I=1,NUMB*
    FORMAT)10F8.5*
 CALCULATIONS
 DO 600 I=1,NUMB
 DO 222 J=1,N
 IF)ABS)E)I*-EM)J**.LT.0.001* GO TO 700
  CONTINUE
 UTV)I*=ABPV)I**100./)UMEAN)J**SL)J**2.*
 UTW)I*=ABPW)I**100./)UMEAN)J**SL)J**2.*
 UTM)I*=)UTV)I*.UTW)I**/2.
 VT)I*=ABNV)I**100./)UMEAN)J**SL)J**2.*
 WT)I*=ABNW)I**100./)UMEAN)J**SL)J**2.*
 U)I*=.0328*UTM)I**UMEAN)J*
 V)I*=.0328*VT)I**UMEAN)J*
 W)I*=.0328*WT)I**UMEAN)J*
 ENERG)I*=.001165*)U)I***2.V)I***2.W)I***2*
 RUV)I*=)AV)I***2-BV)I***2*/)ABPV)I**ABNV)I**
 RUW)I*=)AW)I***2-BW)I***2*/)ABPW)I**ABNW)I**
 UU)I*=U)I***2
 UV)I*=RUV)I**U)I**V)I*
 UW)I*=RUW)I**U)I**W)I*
 VEL)I*=UMEAN)J*
 VV)I*=V)I***2
 WW)I*=W)I***2
 PK)I*=)VV)I*-WW)I**/)VV)I*.WW)I**
 DIMDIS)I*=X)I*/DIA
 CONTINUE
 WRITE)6,800*
 FORMAT)12X,'X',9X,'UTM',10X,'VT',10X,'WT',11X,'U',11X,
1'V',11X,'W',7X,'ENERG',9X,'RUV',9X,'RUW',7X,'UMEAN'/*
 WRITE)6,900*)X)I*,UTM)I*,VT)I*,WT)I*,U)I*,V)I*,W)I*,ENERG)I*,RUV)I
1*,RUW)I*,VEL)I*,I=1,NUMB*
 WRITE)6,111*
 FORMAT)10X,'UU',10X,'VV',10X,'WW',10X,'UV',10X,'UW',10X,'K1',
14X,'Y OVER D'//*
 WRITE)6,333*)UU)I*,VV)I*,WW)I*,UV)I*,UW)I*,PK)I*,DIMDIS)I*,
1I=1,NUMB*
 FORMAT)7F12.6////*
 CALL UPLOT)DIMDIS,2.,0.,UTM,4.,0.,NUMB,0.,0.*
 CALL UPLOT)DIMDIS,2.,0.,VT,4.,0.,NUMB,0.,0.*
 CALL UPLOT)DIMDIS,2.,0.,WT,4.,0.,NUMB,0.,0.*
 CALL UPLOT)DIMDIS,2.,0.,U,4.,0.,NUMB,0.,0.*
 CALL UPLOT)DIMDIS,2.,0.,V,4.,0.,NUMB,0.,0.*
 CALL UPLOT)DIMDIS,2.,0.,W,4.,0.,NUMB,0.,0.*
```

```
CALL UPLOT)DIMDIS,2.,0.,UU,4.,0.,NUMB,0.,0.*
CALL UPLOT)DIMDIS,2.,0.,VV,4.,0.,NUMB,0.,0.*
CALL UPLOT)DIMDIS,2.,0.,WW,4.,0.,NUMB,0.,0.*
CALL UPLOT)DIMDIS,2.,0.,ENERG,.02,0.,NUMB,0.,0.*
CALL UPLOT)DIMDIS,2.,0.,RUV,1.5,-1.5,NUMB,0.,-1.5*
CALL UPLOT)DIMDIS,2.,0.,RUW,1.5,-1.5,NUMB,0.,-1.5*
CALL UPLOT)DIMDIS,2.,0.,UV,.5,-.5,NUMB,0.,-.5*
CALL UPLOT)DIMDIS,2.,0.,UW,.5,-.5,NUMB,0.,-.5*
CALL UPLOT)DIMDIS,2.,0.,PK,1.,-1.,NUMB,0.,-1.*
GO TO 11
STOP
END
```

```
      DIMENSION AV(20),BV(20),ABPV(20),ABNV(20),AW(20),BW(20),ABPW(20),
     1ABNW(20),E(20),UTV(20),UTW(20),UTM(20),VT(20),WT(20),U(20),V(20),
     2W(20),X(20),ENERG(20),RUV(20),RUW(20),UMEAN(200),EM(200),SL(200)
     3,VEL(200),UU(200),UV(200),UW(200),DIMDIS(200)
     4,VV(20),WW(20),R(20),PK(20),Y(20)
       COMMON EM,UMEAN,SL
C
       CALL READIN(N)
      WRITE(6,1)
1     FORMAT('     TURBULENT VELOCITY PARAMETERS'//)
C     INPUTS
11    READ(5,100,END=99)NCODE,NUMB,DIA
100   FORMAT(I5,5X,I2,5X,F5.2)
      READ(5,200)(AV(I),BV(I),ABPV(I),ABNV(I),AW(I),BW(I),ABPW(I),
     1ABNW(I),E(I),X(I),I=1,NUMB)
200      FORMAT(10F8.5)
C     CALCULATIONS
      DO 600 I=1,NUMB
      DO 222 J=1,N
      IF(ABS(E(I)-EM(J)).LT.0.001) GO TO 700
222    CONTINUE
700   UTV(I)=ABPV(I)*100./(UMEAN(J)*SL(J)*2.)
      UTW(I)=ABPW(I)*100./(UMEAN(J)*SL(J)*2.)
      UTM(I)=(UTV(I)+UTW(I))/2.
      VT(I)=ABNV(I)*100./(UMEAN(J)*SL(J)*2.)
      WT(I)=ABNW(I)*100./(UMEAN(J)*SL(J)*2.)
      U(I)=.0328*UTM(I)*UMEAN(J)
      V(I)=.0328*VT(I)*UMEAN(J)
      W(I)=.0328*WT(I)*UMEAN(J)
      RUV(I)=(AV(I)**2-BV(I)**2)/(ABPV(I)*ABNV(I))
      RUW(I)=(AW(I)**2-BW(I)**2)/(ABPW(I)*ABNW(I))
      VEL(I)=UMEAN(J)
      VEL(I)=3.28*VEL(I)
600   CONTINUE
      WRITE(6,2)NCODE,DIA
2     FORMAT('1',5X,'CODE  ',I5,'   DIAMETER = ',F3.0//)
      WRITE(6,800)
800   FORMAT(16X,'Y',7X,'U',7X,'V',7X,'W',5X,'RUV',5X,'RUW',5X,'VEL
     1'//)
      WRITE(6,900)(X(I),U(I),V(I),W(I),RUV(I),RUW(I),VEL(I),I=1,NUMB)
900   FORMAT(12X,F5.2,6F8.3/)
      WRITE(6,3)NCODE,DIA
3     FORMAT('1',5X,'CODE  ',I5,'   DIAMETER =  ',F3.0//)
      WRITE(6,801)
801   FORMAT(16X,'Y',7X,'U',7X,'V',7X,'W',5X,'RUV',5X,'RUW',5X,'VEL
     1'//)
      WRITE(6,901)(X(I),U(I),V(I),W(I),RUV(I),RUW(I),VEL(I),I=1,NUMB)
901   FORMAT(12X,F5.2,6F8.3/)
      GO TO 11
99    STOP
      END
```

```
      SUBROUTINE READIN(N)
      COMMON XX,YY,ZZ
      DIMENSION XX(200),YY(200),ZZ(200)
     READ(5,400)N
      READ(5,500)(XX(J),YY(J),ZZ(J),J=1,N)
400  FORMAT(I2)
500  FORMAT(3F7.5)
999  RETURN
     END
```

```
      SUBROUTINE UPLOT)X,XMX,XMN,Y,YMX,YMN,N,XAX,YAX*
      DIMENSION X)100*,Y)100*
      INTEGER GRID)60,100*
      INTEGER BLANK,ASTRSK,DASH,MOD,PLUS
      DATA MOD/'I'/
      BLANK=1077952576
      ASTRSK=1547714624
      DASH=1614823488
      PLUS=1312833600
      WRITE )6,100* )X)J*,Y)J*,J=1,N*
  0   FORMAT )' ',2F15.4*
      YMIN=Y)1*
      YMAX=YMIN
      DO 40 J=1,N
      IF )Y)J*-YMIN* 28,26,26
  6   IF )Y)J*-YMAX* 40,40,30
  8   YMIN=Y)J*
      GO TO 40
  0   YMAX=Y)J*
  0   CONTINUE
      IF)YMX* 41,42,41
  2   IF)YMN* 41,4,41
  1   CONTINUE
      YMAX=YMX
      YMIN=YMN
  4   YSCAL=)YMAX-YMIN*/99.0
      WRITE )6,90* YMAX,YMIN,YSCAL
  0   FORMAT )' YAXIS 9 MAX = ',F11.4,', MIN = ',F11.4,', SCALE = ',F11.
     14*
      XMIN=X)1*
      XMAX=XMIN
      DO 13 J=1,N
      IF )X)J*-XMIN* 11,10,10
  0   IF )X)J*-XMAX* 13,13,12
  1   XMIN=X)J*
      GO TO 13
  2   XMAX=X)J*
  3   CONTINUE
      IF)XMX* 43,44,43
  4   IF)XMN* 43,8,43
  3   CONTINUE
      XMAX=XMX
      XMIN=XMN
  8   XSCAL=)XMAX-XMIN*/59.0
      WRITE )6,95* XMAX,XMIN,XSCAL
 95   FORMAT )' XAXIS 9 MAX = ',F11.4,', MIN = ',F11.4,', SCALE = ',F11.
     14*
      DO 55 JP=1,100
      DO 55 IP=1,60
 55   GRID )IP,JP*=BLANK
      DO 80 JP=1,100
      GRID)1,JP*=DASH
 80   GRID)60,JP*=DASH
      DO 85 IP=1,60
      GRID)IP,1*=MOD
 85   GRID)IP,100*=MOD
      GRID)1,1*=PLUS
      GRID)1,100*=PLUS
      GRID)60,1*=PLUS
      GRID)60,100*=PLUS
```

NOTE: *=(
)=(
for this printout

```
  IF)YAX-YMIN* 115,45,46
6 IF)YAX-YMAX* 45,45,115
5 CONTINUE
  JP=))YAX-YMIN*/YSCAL*.1.0
  DO 110 J=2,59
0 GRID)J,JP*=MOD
5 IF)XAX-XMIN* 125,124,123
3 IF)XAX-XMAX* 124,124,125
4 CONTINUE
  IP=))XAX-XMIN*/XSCAL*.1.0
  DO 120 J=2,99
0 GRID)IP,J*=DASH
5 DO 60 J=1,N
  IF)X)J*-XMIN* 60,61,62
2 IF)X)J*-XMAX* 61,61,60
1 CONTINUE
  IF)Y)J*-YMIN* 60,63,64
4 IF)Y)J*-YMAX* 63,63,60
3 CONTINUE
  IP=))X)J*-XMIN*/XSCAL*.1.0
  JP=))Y)J*-YMIN*/YSCAL*.1.0
  GRID)IP,JP*=ASTRSK
0 CONTINUE
  WRITE )6,70*
0 FORMAT )'1'*
  WRITE )6,75* ))GRID)IP,JP*,JP=1,100*,IP=1,60*
5 FORMAT )' ',100A1*
  RETURN
  END
```