UNIVERSITY OF MINNESOTA
ST. ANTHONY FALLS HYDRAULIC LABORATORY

Technical Paper No. 53, Series B

Abrupt Transition from a Circular Pipe to a Rectangular Open Channel

by

Fred W. Blaisdell, Charles A. Donnelly and Kesavarao Yalamanchili
Hydraulic Engineers, USDA, ARS

July 1969

Study conducted by

UNITED STATES DEPARTMENT OF AGRICULTURE
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SOIL AND WATER CONSERVATION RESEARCH DIVISION

in cooperation with the

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A B S T R A C T

The development of criteria and a generalized procedure for the design of an abrupt transition from a circular pipe to a rectangular open channel are presented.

The rectangular channel must be 1.0 pipe diameters wide. Wider channels cause high waves which reflect from the channel sidewalls, may overtop the sidewalls, and produce severe disturbances in the channel. To permit the pipe to expand, the channel may be widened for a distance not exceeding 0.5 pipe diameters downstream from the pipe exit, and the floor of the channel may be lowered.

The equations developed describe the locations of the water surface elements to within an average of 0.11 pipe diameters of their correct locations. The maximum anticipated location error is ±1.4 pipe diameters. The equations for the envelope curves covering the crests of the sidewall waves, which determine the channel sidewall height, provide an average freeboard of 0.08 pipe diameters and a maximum freeboard of 0.31 pipe diameters. When the envelope equations are used only 2 percent of the wall waves will overtop the sidewalls, the maximum overtopping being 0.04 pipe diameters. The average depth of flow—the depth at the wave nodes—is predicted by the equations to within a maximum deviation of +0.13 and - 0.06 pipe diameters of the observed depths. The average depth at the nodes is predicted by the equations within 0.01 pipe diameters of the observed average depth.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

A	coefficient in Eq. 6, dimensionless
d	depth of flow, in feet
d	differential
d_{aN}	average depth of flow as computed by Eqs. 11 and 15, in feet
d_N	depth of water surface elements in the transition channel, in feet
d_{wN}	wave height above the computed average depth of flow d_{aN}, in feet
D	pipe diameter, in feet (unless otherwise defined)
f	Darcy-Weisbach friction factor, dimensionless
f_e	psuedo Darcy-Weisbach energy loss factor, dimensionless
g	acceleration due to gravity = 32.2 feet per second per second
h_e	energy head, in feet of water, $= d_N + \left(\frac{Q}{d_N D}\right)^2 \frac{1}{2g}$
h_ℓ	energy loss, in feet of water
L_p	length of parallel-walled section, in feet, in the transition developed by C. D. Smith
N	number of the water surface element. Used as a number or a subscript. N = 1, 5, 9, 13, . . . designate sidewall waves N = 3, 7, 11, 15, . . . designate centerline waves Even values of N designate nodes where the transverse water surface is level
Q	discharge, in cubic feet per second
R	hydraulic radius, in feet
$\mathbb{R}$	Reynolds number, dimensionless, $= \frac{4VR}{\nu}$
S	pipe slope, sine
t	time, in seconds
t_p	pipe wall thickness, in feet
V_p	velocity in the pipe, in feet per second
x	horizontal distance from the pipe exit, in feet
x_N	horizontal distance from the pipe exit to surface element N, in feet
x_Δ	distance between x_2 and x_N, in feet

y — vertical distance from pipe invert at its exit (unless otherwise defined), in feet

α — slope angle of pipe, in degrees = $\tan(\sin^{-1} S)$

Δ — increment of . . .

λ — wave length, in feet

ν — kinematic viscosity, in feet^2 per second

π — 3.14159

$\langle\ \rangle$ — indicates that the quantity within the pointed brackets is zero for negative values

ABRUPT TRANSITION FROM A CIRCULAR PIPE TO A RECTANGULAR OPEN CHANNEL[±]

INTRODUCTION

An outlet for closed conduit spillways consisting of a horizontal cantilevered channel of rectangular cross section having a flip bucket or flip sill at the downstream end was proposed by the Engineering Division, Soil Conservation Service (SCS), U.S. Department of Agriculture. It was reasoned that the flip sill would throw the water upward and away from the exit end of the cantilevered channel and spread it out. The excavated or self-formed plunge pool would thus be further from the cantilevered channel exit and the toe of the dam. Also, the falling jet would impinge on the tailwater surface at a steeper angle to facilitate the vertical dissipation of energy, and the lesser horizontal component of the velocity would reduce the strength of the horizontal eddies that widen the plunge pool and eat into the dam toe.

Closed conduit spillways frequently are made of circular pipe, whereas the proposed cantilever is rectangular in cross section. Therefore, a transition between the circular barrel and the rectangular cantilever is required. Because the transition and the flip sill can be studied separately, the test program was divided into two parts: (1) the development of a transition between a circular spillway conduit and a rectangular open channel, and (2) a study of the flip sill.

The test results and generalized rules for the design of an abrupt transition between a circular pipe and a rectangular open channel are reported here.

REQUIREMENTS

The SCS imposed several practical limits on the transition design:

1. It was suggested that the transition be abrupt.

2. To facilitate installation, the outside of the pipe should be no closer than 3 in. to the inside walls and floor of the transition. In other words, the inside width of the transition should not be less than the pipe diameter D, plus two times the pipe wall thickness t_p, plus two times 3 in. or $(D + 2t_p + 6'')$, and the floor of the transition must be a minimum of $(t_p + 3'')$ below the pipe invert. The specific dimensions were generalized in terms of the pipe diameter D, with consideration given to the pipe sizes and wall thicknesses used by SCS. The minimum transition width was set at 1.5 D and the minimum distance of the transition floor below the pipe invert was set at 0.25 D. These generalized dimensions simulate a 24-in. diameter pipe having a 3-in. wall and are greater than the minimums required for larger pipes.

[±]Agricultural Research Service Report No. 41-304-141.

3. To allow for settlement of the dam fill, the pipe must be free to move longitudinally a maximum of 6 in. This is equivalent to 0.25 D for a 24-in. diameter pipe.

4. The flow in the transition must have a relatively level transverse surface at the location of the flip sill.

PREVIOUS WORK

The only available report presenting the results of research on an abrupt transition from a circular pipe to a rectangular open channel was published by the Canada Department of Agriculture in 1954*. One object of this research was to develop a flaring transition between a circular pipe and a stilling basin. C. D. Smith reports:

> After the first series of tests had been run, it was evident that it was undesirable to have the straight wall flare begin immediately at the end of the circular pipe. Invariably flow separation occurred at the walls at the start of the transition. This resulted in the formation of a high local shock wave on the wall further along in the transition. It was found that this could be eliminated by the use of a short parallel section between the pipe and the start of the transition. In this parallel section the cavities which normally exist under the jet (when in its circular form) are allowed to fill, and at the start of the transition the jet is essentially rectangular and two dimensional.

The required length of the parallel-walled section L_p is given as:

$$\frac{L_p}{D} = 0.1 \frac{Q}{D^{5/2}}$$

where Q is the discharge in cubic feet per second. The width of the parallel-walled section is equal to the pipe diameter D. The transition begins its flare at the end of the parallel-walled section.

Two conclusions can be drawn from the research conducted by Smith: (1) a parallel-walled section equal in width to the pipe diameter is required to prevent high local shock waves, and (2) although the length of the parallel-walled section gave good performance when used in conjunction with flaring transition sidewalls, this length may not be correct for other transition geometries.

At the request of Edwin Freyburger, then in charge of the Design and Construction Section, Engineering and Watershed Planning Unit, Soil Conservation Service, Milwaukee, Wisconsin, a short series of tests was run in November, 1957, on an abrupt transition from a circular pipe to a rectangular chute. F. W. Blaisdell reported in a letter to Mr. Freyburger dated November 19, 1957, that:

1. The chute width should be equal to the pipe diameter.

2. A parallel sidewall section having a floor slope identical to the pipe slope should be used. The sidewalls should be spaced one pipe diameter apart. The length of this section apparently should be, after the Canadian experiments, $0.1\,Q/D^{5/2}$.

3. The use of fillets is beneficial but they do not seem necessary if the parallel sidewall section is used.

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*Smith, C. D., "Hydraulic Design of Outlet Transition and Stilling Basin for Single Barreled Conduits," Design Bulletin No. 2, Canada Department of Agriculture, Regina, Saskatchewan, Canada, May, 15, 1954, 15 pp.

The floor of the chute for these tests was tangent to the invert of the pipe. The floor had a slope equal to the pipe slope in the parallel-walled section, and a parabolic curve to fit the jet trajectory between the parallel-walled section and the steeply sloping chute.

The results of the tests conducted by the Prairie Farm Rehabilitation Administration and the Agricultural Research Service were incorporated into Soil Conservation Service Standard Drawing No. 3-E-45341, part of which is reproduced as Fig. 1. Fig. 1 shows that:

1. The chute width is equal to the pipe diameter.

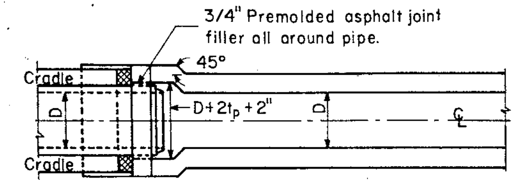
2. An expansion section is provided between the pipe and the chute.

3. The pipe is set above the chute floor to provide for pipe expansion.

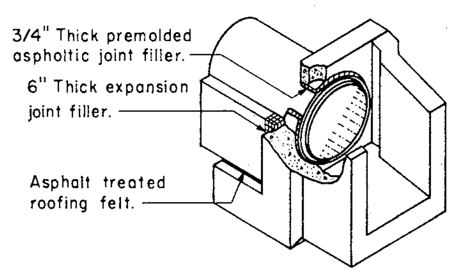
4. A length of chute having the same slope as the slope of the pipe is provided between the pipe exit and the point where the jet strikes the chute floor.

5. A parallel-walled section is provided which has a floor slope equal to the pipe slope and a length recommended as a result of the reported tests.

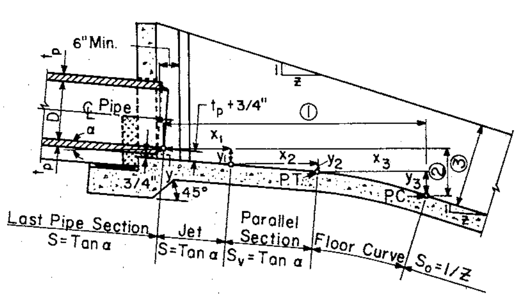
6. A floor curve is provided between the parallel section and the steeply sloping chute.



PLAN



ISOMETRIC VIEW



SECTION ON CENTERLINE

① Horizontal distance from invert at outlet end of pipe to P.C.
② Difference in elevation between these 2 points.
③ Normal height of chute sidewalls at P.C.

NOTE: THIS PROCEDURE APPLIES FOR VALUES OF $\frac{Q}{D^{5/2}} \leq 20$

GENERAL FORMULAS	REF.
JET $y=(t_p+\frac{3"}{4})\sec\alpha$, slope length $= x_1 \sec\alpha$, $y_1 = y + x_1 \tan\alpha$ $x_1=\sqrt{\frac{2v_p^2\cos^2\alpha y}{g}}$	1
PARALLEL SECTION slope length $=0.1\frac{Q}{D^{3/2}}$ $y_2=(\text{slope length})\sin\alpha$ $x_2=(\text{slope length})\cos\alpha$	2
FLOOR CURVE $x_3=50(\frac{1}{z}-\tan\alpha)$ $y_3=25(\frac{1}{z^2}-\tan^2\alpha)$ Note: Coordinates of any point between P.T. and P.C. are given by equation: $y=0.01x^2+S_vx$	3
WIDTH OF CHUTE SIDEWALLS (inside) = D	2
MINIMUM HEIGHT OF CHUTE SIDEWALLS height = D + 0.5'	
REFERENCES (1) National Handbook Section 5-Hydraulics page 5.6-2 (2) See footnote *, page 1 (3) National Handbook Section 14 - Chute Spillways page 2.120, 2.141, 2.142, 2.143 and 2.144	

Fig. 1 - Soil Conservation Service Transition Layout

These results of previous research, although limited, provide an indication of the problems to be anticipated in developing general criteria for the design of an abrupt transition from circular to a rectangular open channel.

TEST APPARATUS

Figure 2 shows the test apparatus. The water for the experiments is obtained from the laboratory main supply channel. The offtake from the main supply channel is a 6-in. steel pipe. A 4-in. steel pipe, 10 in. long, was welded into the 6-in. supply line, forming a reducing tee.

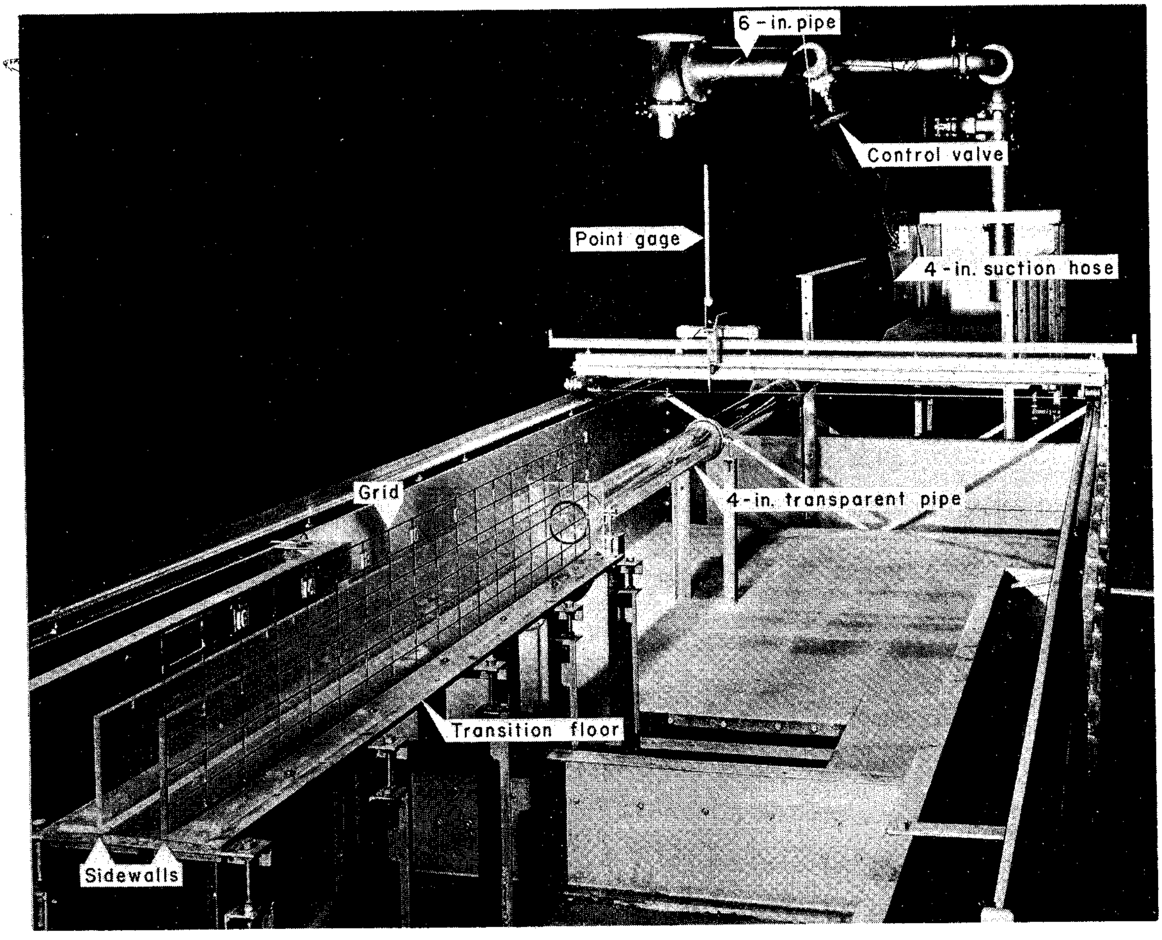


Fig. 2 - Test Apparatus

The rate of flow is indicated by a water manometer connected to piezometer taps located in zones of high and low pressures on opposite sides of the 4-in. pipe close to its junction with the 6-in. pipe. The calibrated relationship between the pressure difference and the discharge is used to determine the rate of flow through the transition. The 4-in. steel pipe terminates in a 4-in. flow control valve.

A 4-in. rubber suction hose, 16.5 ft. long, connects the 4-in. valve with the 4-in. diameter by 10-ft. (30 D) long pipe located upstream of the transition. This pipe is made of transparent plastic so that the flow approaching the transition can be observed.

The transition floor is an aluminum plate, ground to a plane surface. The aluminum plate is 1/2 in. thick, 12 in. (3 D) wide, and 72 in. (18 D) long. The transition floor is supported on threaded rods so it can be leveled and its height adjusted.

The transition sidewalls are clear plastic, 7 in. (1.75 D) high. They can be moved transversely and longitudinally to obtain various combinations of transition width and expansion section length.

A grid, made of 1/8-in. brass rods spaced 4 in. (1 D) longitudinally and 2 in. (0.5 D) vertically, is placed along one sidewall so that a photographic record can be made of the wave lengths and heights. Zero for the longitudinal dimension is the pipe exit; zero for the vertical dimension is the transition floor. Distances are numbered in pipe diameters.

A point gage that traverses longitudinally and transversely was used to determine levels anywhere in the transition. A rake consisting of five teeth 1/4 in. wide and spaced 5/8 in. apart was substituted for the point for the tests of the 1.0 D-wide transition to make it easier to determine the locations and depths of the water surface configuration components and to improve the precision of the measurements.

DESCRIPTION OF FLOW

A knowledge of how the water discharges from the pipe and impinges and spreads on the transition floor is necessary in order to understand the performance of the transition.

The water leaves the pipe as a circular jet, as can be seen in Fig. 3. Beyond the pipe exit, the jet is acted on by gravity and, if falling freely, assumes a parabolic trajectory. The trajectory of the bottom of the jet has the equation

$$y = x \tan \alpha + \frac{g}{2} \frac{x^2}{V_p^2 \cos^2 \alpha} \quad (1)$$

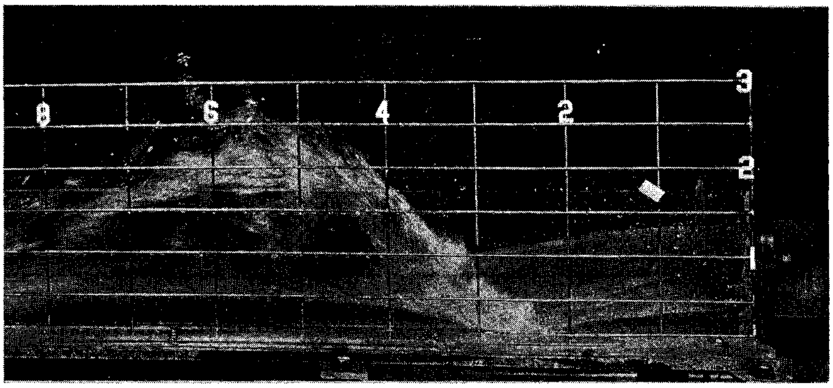


Fig. 3 - Jet Leaving Pipe has a Parabolic Trajectory
Width = 1.5 D; y/D = 0.25; $Q/D^{5/2}$ = 15.13.

where y is the vertical distance below the pipe invert, x is the horizontal distance from the pipe exit, V_p is the velocity at the pipe exit, and α is the slope angle of the pipe, in degrees.

In terms of the pipe diameter D and the generalized discharge $Q/D^{5/2}$

$$\frac{y}{D} = \frac{x}{D}\tan\alpha + \frac{g\pi^2}{32\left(Q/D^{5/2}\right)^2\cos^2\alpha}\left(\frac{x}{D}\right)^2 \qquad (2)$$

If the pipe is horizontal, as it was during the experiments reported here, $\alpha = 0$ and

$$y = \frac{g}{2}\frac{x^2}{V_p^2} \qquad (3)$$

$$\frac{y}{D} = \frac{g\pi^2}{32\left(Q/D^{5/2}\right)^2}\left(\frac{x}{D}\right)^2 \qquad (4)$$

and

$$\frac{x}{D} = \frac{4}{\pi}\sqrt{\frac{2}{g}}\,\frac{Q}{D^{5/2}}\sqrt{\frac{y}{D}} \qquad (5)$$

There is no pressure within the freely falling jet so, unless there are other influences, the jet will maintain its circular form until it strikes the transition floor. In other words, the jet will not begin to change shape or begin to spread until it impinges on the floor of the transition. This is shown in Fig.4, where $Q/D^{5/2} = 11.76$ and the value of y/D for the bottom of the jet is 0.25. The Eq. 5 value of x/D, 1.87, agrees well with the point of impingement of the bottom of the jet on the transition floor. For the top of the jet, $(y+D)/D = 1.25$ and the Eq. 5 value of x/D is 4.17. This distance is close to the projection of the top surface of the jet to the transition floor. On the basis of these comparisons, it is apparent that Eqs. 1 to 5 predict the trajectory of the freely falling jet.

The initial contact of the jet with the transition floor (at about x/D = 1.87 in Fig. 4) causes the jet to begin to spread laterally. This lateral spreading continues until the flow strikes the transition channel sidewalls. The transverse component of the velocity then causes the flow to climb the sidewalls. This action is shown in Fig. 4.

The water that has climbed the sidewalls (N = 1 in Fig. 5)* then falls toward the transition floor. This creates a cross wave which, when combined with the downstream flow, forms the diagonal wave shown in Fig. 5. The diagonal wave height is augmented where the waves originating at opposite walls cross at the transition centerline (N = 3 in Fig. 5). The diagonal waves then continue across the channel and are reflected from the walls opposite those at which they originated (N = 5 in Fig. 5). The reflections (N = 1, 5 and 9 in Fig. 5) and crossings (N = 3, 7 and 11 in Fig. 5) are repeated over and over so that the resulting water surface displays a diamond-shaped pattern. This pattern can be seen in Fig. 5. The waves decrease in height with distance downstream, but their effect continues for a considerable distance.

*N is the number of the water surface configuration component—the number of quarter wave lengths from the pipe exit. The first sidewall wave crest is assigned N = 1 and for succeeding sidewall wave crests N = 5, 9, 13, ... The centerline crossing waves are assigned N = 3, 7, 11, ... The points at which the transverse water surface is essentially horizontal, which are here called "nodes," are even numbers—N = 2, 4, 6, 8, 10, ...

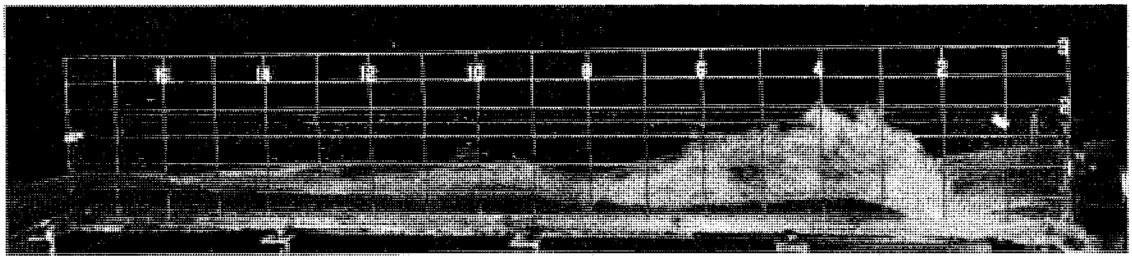


Fig. 4 - Jet Impinges on Floor
Width = 1.5 D; y/D = 0.25; $Q/D^{5/2}$ = 11.76.

The water surface is almost horizontal at the nodes, which are located approximately midway between the peaks of the sidewall and the center crossing waves, (N = 2, 4, 6, 8 and 10 in Fig. 5). Therefore, since a node meets the criterion of item 4 of the section on REQUIREMENTS that the water surface be relatively level transversely at the location of the flip sill, a node may be the point at which to locate a flip sill or other appurtenance.

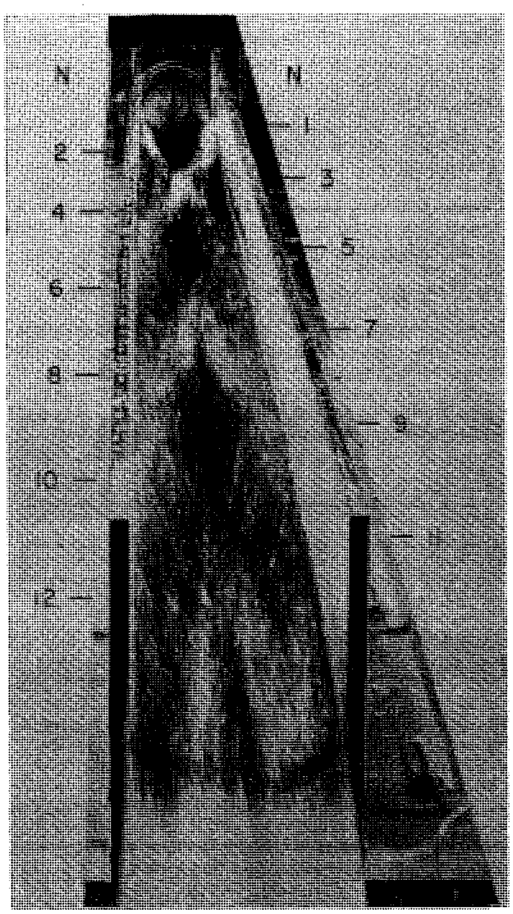


Fig. 5 - Diagonal Wave Pattern in Downstream Channel
Width = 1.0 D; y/D = 0.25; $Q/D^{5/2}$ = 10.5.

This description of the flow in abrupt transitions from circular to rectangular cross sections illustrates the problems and limitations that must be overcome in this type of transition to insure its satisfactory performance.

TEST PROGRAM

Four independent variables required tests to determine their effect on the transition performance and to develop design criteria. These variables are: (1) the width of the transition channel relative to the pipe diameter, (2) the transition channel floor elevation relative to the pipe invert, (3) the expansion of the barrel, and (4) the discharge. Two dependent variables are: (1) the required transition channel sidewall height to contain the flow, and (2) the length of transition channel required to insure satisfactory flow conditions for satisfactory performance of the flip sill or other appurtenance. The length of the transition channel will be determined during the tests of the flip sill; here, the locations and heights of the water surface components will be determined.

As noted in the section on REQUIREMENTS, the minimum width of the transition was established as 1.5 pipe diameters (1.5 D) for practical reasons. This width was tested. However, the experiences cited previously suggested that a transition this wide would produce poor flow conditions. For this reason, additional tests were scheduled using transition widths of 1.25 D and 1.0 D.

The floor of the transition must be set lower than the pipe invert to permit the pipe to clear the

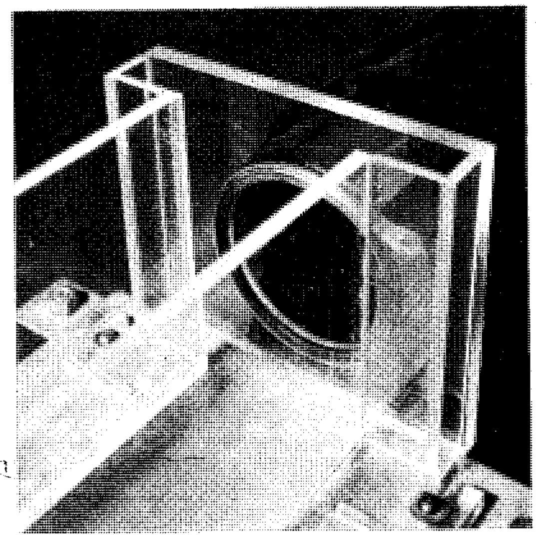


Fig. 6 - Widened Channel Section to Permit Pipe to Expand

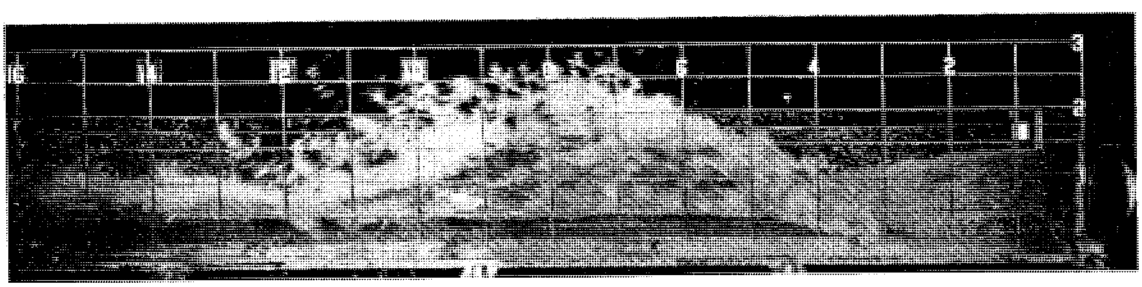
Channel width = 1.0 D; y/D = 0.25.

floor when it moves into the expansion section of the transition. A study of the wall thicknesses of commercial concrete pipe and the required clearance between the pipe and the transition floor showed that the greatest depression of the floor required is 0.25 D below the pipe invert and the minimum depression is 0.10 D. The tests were performed with the floor level with the pipe invert and 0.05 D, 0.10 D, 0.15 D, 0.20 D, 0.25 D, and 0.30 D below the pipe invert.

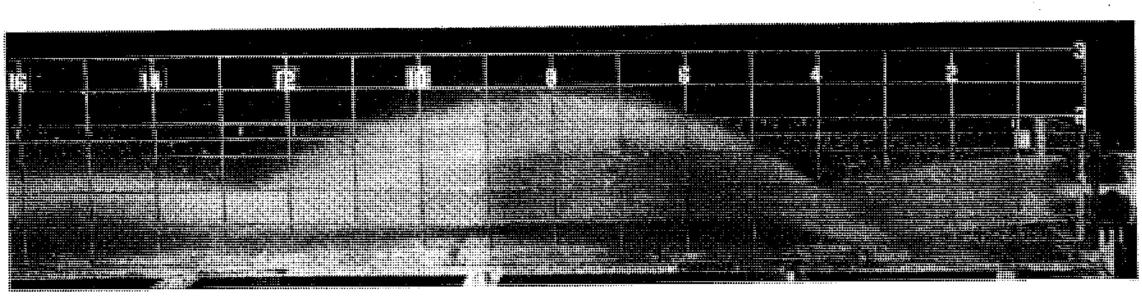
The pipe and the transition floor were horizontal for all tests reported here.

A section is required at the transition entrance to permit the pipe to expand when the transition width is less than 1.5 D. Practical considerations dictated a minimum expansion length of 0.25 D. Additional tests were made to determine the maximum length of the expansion section that could be used without adversely affecting the transition performance. The expansion sections tested were 0.25 D, 0.375 D, 0.5 D, and 0.625 D long. Their width was 1.8 D. A typical expansion section is shown in Fig. 6.

The transition must function satisfactorily at all discharges. To make the discharge Q a generalized dimension, it was divided by $D^{5/2}$ because for a given value of this ratio all pipe diameters give similar flow patterns. The range of $Q/D^{5/2}$ tested was from 1.5 to 20.



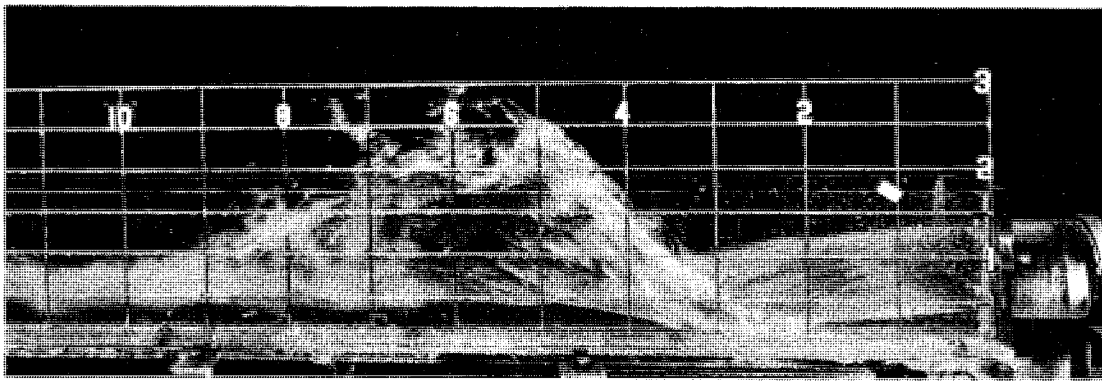
(a) Exposure is 1/250 second.



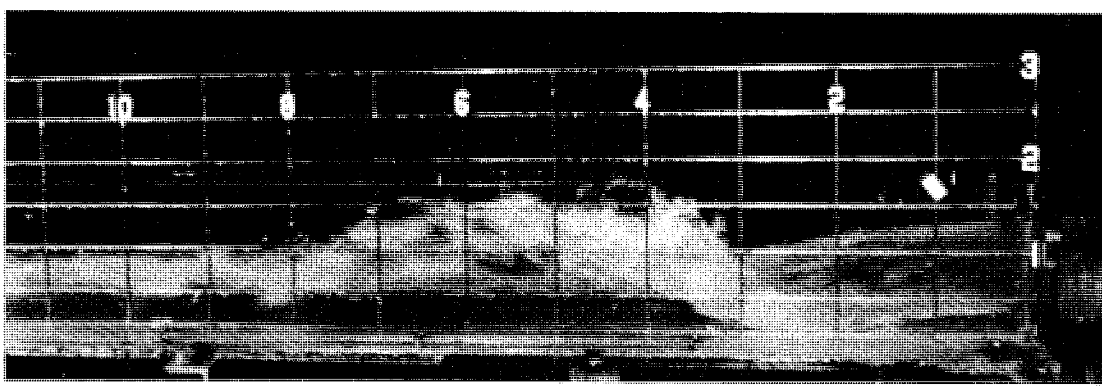
(b) Exposure is 1/2 second.

Fig. 7 - Splash in the Transition Channel
Width = 1.5 D; y/D = 0.25; $Q/D^{5/2}$ = 14.0.

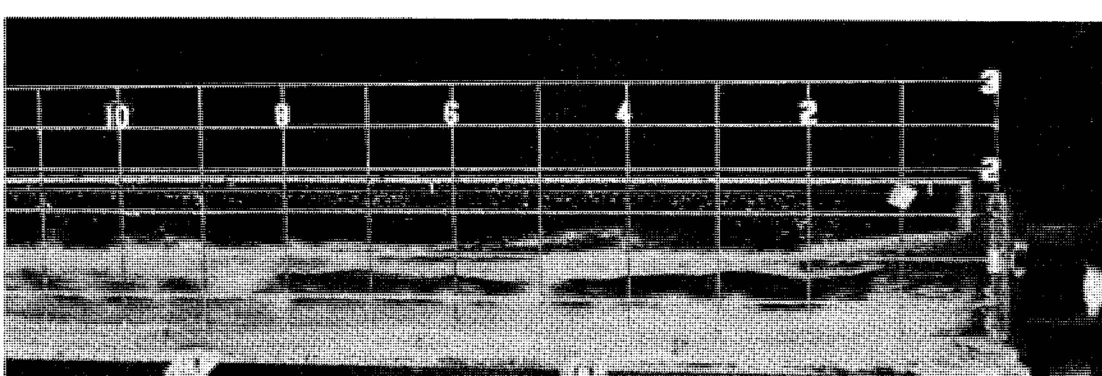
Measurements of the water surface elevations in the transition were taken. However, photographic recording of the flow in the transition proved adequate to evaluate the transition performance when the water surface was rough. Short-exposure photographs were taken to show the nature of the splash (see Fig. 7a). Long-exposure photographs were taken to indicate the average maximum height of the splash and the sidewall height required to contain the splash (see Fig. 7b).



(a) Width is 1.5 D.



(b) Width is 1.25 D.



(c) Width is 1.0 D.

Fig. 8 - Effect of Transition Channel Width on the Performance
$y/D = 0.25$; $Q/D^{5/2} = 14.87$.

After the tests had been completed and the results had been analyzed, advantage was taken of an opportunity to study the effect of scale on the findings. These tests were made using a 36-in. pipe in a 9-ft. (3 D) wide concrete channel. This pipe is 9 times the size of the 4-in. pipe previously used. Since the widest channel previously tested was 1.5 D wide, tests were made on the 4-in. pipe duplicating the large-scale tests. The transition floor for the comparison tests was 0.21 D below the pipe invert. The flow, $Q/D^{5/2}$, was 9.04 and 12.6 for both pipe sizes.

RESULTS OF TESTS

The experiments determined, for a wide range of discharges, the effect on the performance of the abrupt circular-to-rectangular transition of (1) the distance between the sidewalls relative to the pipe diameter, (2) the elevation of the transition floor with respect to the pipe invert, and (3) the length of the pipe expansion section. Design criteria are presented for these three dimensions and the sidewall height. Equations are developed to define the longitudinal positions of the wave elements, the depth of flow at the nodes and the average depth of flow, and the heights of the sidewall waves. The data used to develop the design criteria and the equations are listed in Table 2, appendix.

Distance Between the Sidewalls

The section on DESCRIPTION OF FLOW describes the spreading of the jet to the sidewalls and the waves that form when the flow is reflected from the sidewalls.

The width of the transition channel greatly affects the wave heights and the splash. This is shown in Fig. 8 where the height at the sidewall of the initial wave is 3.0 D for the 1.5 D-wide transition, 2.0 D for the 1.25 D-wide transition, and 1.3 D for the 1.0 D-wide transition. No numerical data are necessary to show the effect of the transition channel width on the wave height, nor were any used. The superior performance of the 1.0 D-wide transition is obvious from casual observation and from photographs similar to those shown in Fig. 8.

The wave height is lower in the narrower transitions because the falling jet suppresses the rising wave at the wall. In the 1.5 D-wide and 1.25 D-wide transitions, there is sufficient space between the 1.0 D-wide falling jet and the wall for the wave to move upward past the jet. In the 1.0 D-wide transition, the jet occupies the full width of the transition so that the rising wall wave cannot bypass the falling jet. The result is a much smoother water surface in the transition. This superior performance of the 1.0 D-wide transition occurs at all discharges.

It is recommended that the transition channel width be 1.0 D.

Expansion Section

A special expansion section is required to permit the pipe to expand when the transition channel width is equal to the pipe diameter. This expansion section is located at the pipe exit and precedes the the transition proper.

The transition channel floor was 0.25 D below the pipe invert during the tests to determine the effect of the expansion section on the performance.

If the expansion section is short enough, the jet leaving the pipe will shoot through the expansion section and into the transition channel without causing flow disturbances. This is because the jet leaving the pipe is free-falling and therefore does not expand immediately. The appearance of the jet as it passes through the expansion section is illustrated in Fig. 9. There it can be seen that the jet does not im-

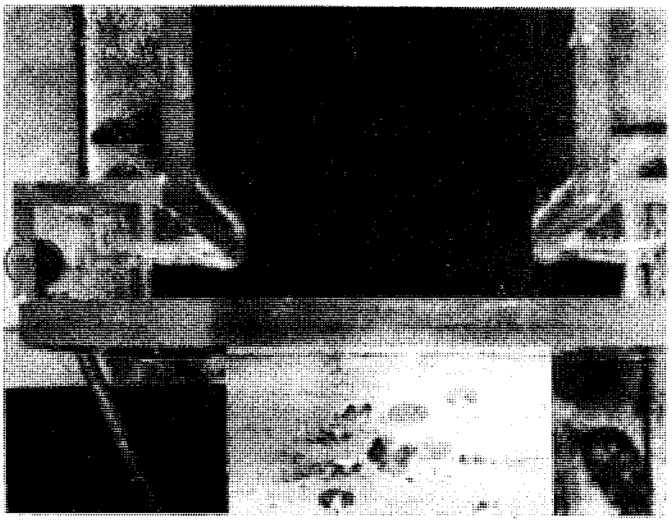


Fig. 9 - Appearance of the Jet as it Leaves the Pipe, Passes Through the Expansion section, and Enters the 1.0 D Wide Transition Channel

At a high discharge ($Q/D^{5/2}$ = 10.5) the jet passes through the expansion section and into the transition channel without spreading. Expansion section is 0.25 D long by 1.8 D wide.

pinge on the downstream walls of the expansion section and that the expansion section does not cause additional disturbance to the flow in the transition channel. The tests showed that satisfactory flow conditions were obtained for expansion section lengths of 0.25 D, 0.375 D, and 0.50 D. However, when the expansion section was lengthened to 0.625 D, the jet spread out, struck the downstream face of the expansion section, and caused high waves and excessive disturbance in the transition channel.

The performance of the expansion section is best at high discharges but is satisfactory at low discharges. At high discharges, the jet from the pipe exit shoots through the expansion section and into the transition channel without causing disturbances in the expansion section or in the transition channel. This is illustrated in Fig. 9. At low discharges, the jet spreads transversely and the edges of the jet strike the downstream walls of the expansion section as shown in Fig. 10. However, because the velocity is low at these low discharges, the disturbances in the expansion section and the waves that form within the transition channel are small, and they are tolerable.

The width of the expansion section tested was 1.8 D. Based on SCS criteria and a 24-in.-diameter pipe, the minimum width would be about 1.5 D. However, the width tested is not important because the width of the expansion section has no effect on the flow conditions in the transition channel. The range of discharge tested was from $Q/D^{5/2}$ = 1.5 to 20. At high discharges there was little or no water in the expansion section. At low discharges only a small part of the flow entered the expansion section and this did not cause any problems. Therefore, the expansion width is not controlled by hydraulic considerations. Practical considerations indicate that the expansion section width must be greater than the outside diameter of the pipe ($> (D + 2t_p)$) in order to permit the pipe to expand.

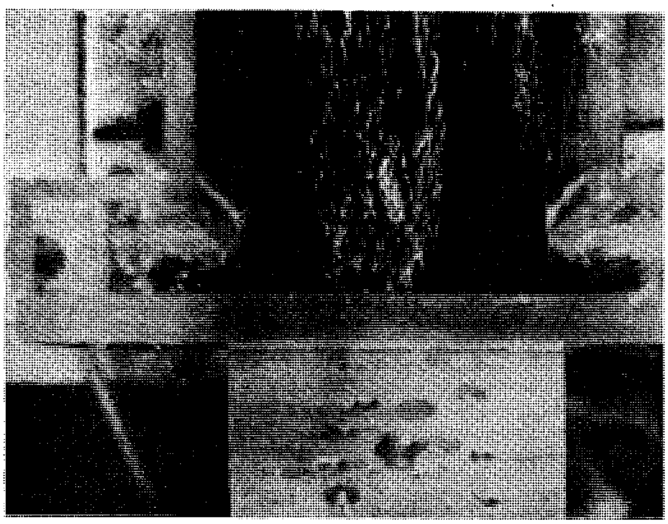


Fig. 10 - Appearance of the Jet as it Leaves the Pipe, Passes Through the Expansion Section, and Enters the 1.0 D Wide Transition Channel

At a low discharge ($Q/D^{5/2}$ = 5.4) the jet edges spread into the expansion section but do not cause intolerable flow conditions. Expansion section is 0.25 D long by 1.8 D wide.

The tests show that: (1) the minimum length of the expansion section is determined by the anticipated pipe expansion; (2) the maximum length of the expansion section should not exceed 0.5 D in order to avoid excessive disturbances in the expansion section and in the transition channel; and (3) the expansion section width is not controlled by hydraulic considerations, but should be greater than the outside diameter of the pipe so there will be no constraint on the longitudinal movement of the pipe.

Water Surface Configuration

The water surface configuration has been described qualitatively in the section entitled DESCRIPTION OF FLOW and is illustrated in Fig. 5. Elements comprising the water surface configuration—the sidewall wave, the centerline crossing waves and the nodes (the cross sections where the water surface is horizontal)—will now be described quantitatively. This quantitative description is limited to the recommended 1.0 D-wide transition having an expansion section 0.25 D long and a horizontal transition floor located from 0.00 D to 0.30 D below the pipe invert.

The precision of this quantitative description is variable. For low discharges, the wave peaks and water surface are relatively well defined and there is a minimum of splash. For high discharges, splash makes it difficult to determine the wave height and the long wave crests make it difficult to determine the exact position of the wave crest. These comments should be kept in mind when evaluating the agreement of the experimental data with the equations developed from the data and the agreement of the plotted data with the curves which represent the equations.

Distance from Pipe Exit to Surface Elements

Distances from the pipe exit to the crests of the wall waves (N odd: 1, 5, 9, . . .), to the crests of the diagonal waves where they cross at the centerline (N odd: 3, 7, 11, . . .), and to the nodes where the water surface is approximately horizontal (N even: 2, 4, 6, . . .) are plotted against $Q/D^{5/2}$ for each y/D tested in Figs. 11, 12, 13, 14, 15, 16 and 17. The plotted data pertain to full pipe. Full pipe flow was obtained in the model when $Q/D^{5/2}$ exceeded 4.5 to 5.2 on increasing discharges and was maintained down to $Q/D^{5/2} = 3.8$ for decreasing discharges.

Families of straight lines have been adjusted to the data plotted in Figs. 11 to 17 to give the best fit for all the data. Exact agreement of the curves with the experimental data cannot be expected because judgment is required in making the measurements, especially at the higher discharges where the water surface is poorly defined and there is considerable splash. However, the experimental data generally agree well with the curves shown. Some check tests were made for those tests where the original data deviated appreciably from the curves and were suspect. The check test data fall close to the curves as drawn.

The curves as drawn have the equation,

$$\frac{x_N}{D} = A\left(\frac{Q}{D^{5/2}} + 10\sqrt{\frac{y}{D}}\right) - 4.5\sqrt[4]{\frac{y}{D}} \qquad (6)$$

where x_N is the horizontal distance from the pipe exit to the surface configuration element, and y is the vertical distance from the floor of the transition to the pipe invert and is positive. Eq. 6 is valid only when the velocity in the transition is supercritical.

(Continued on page 20)

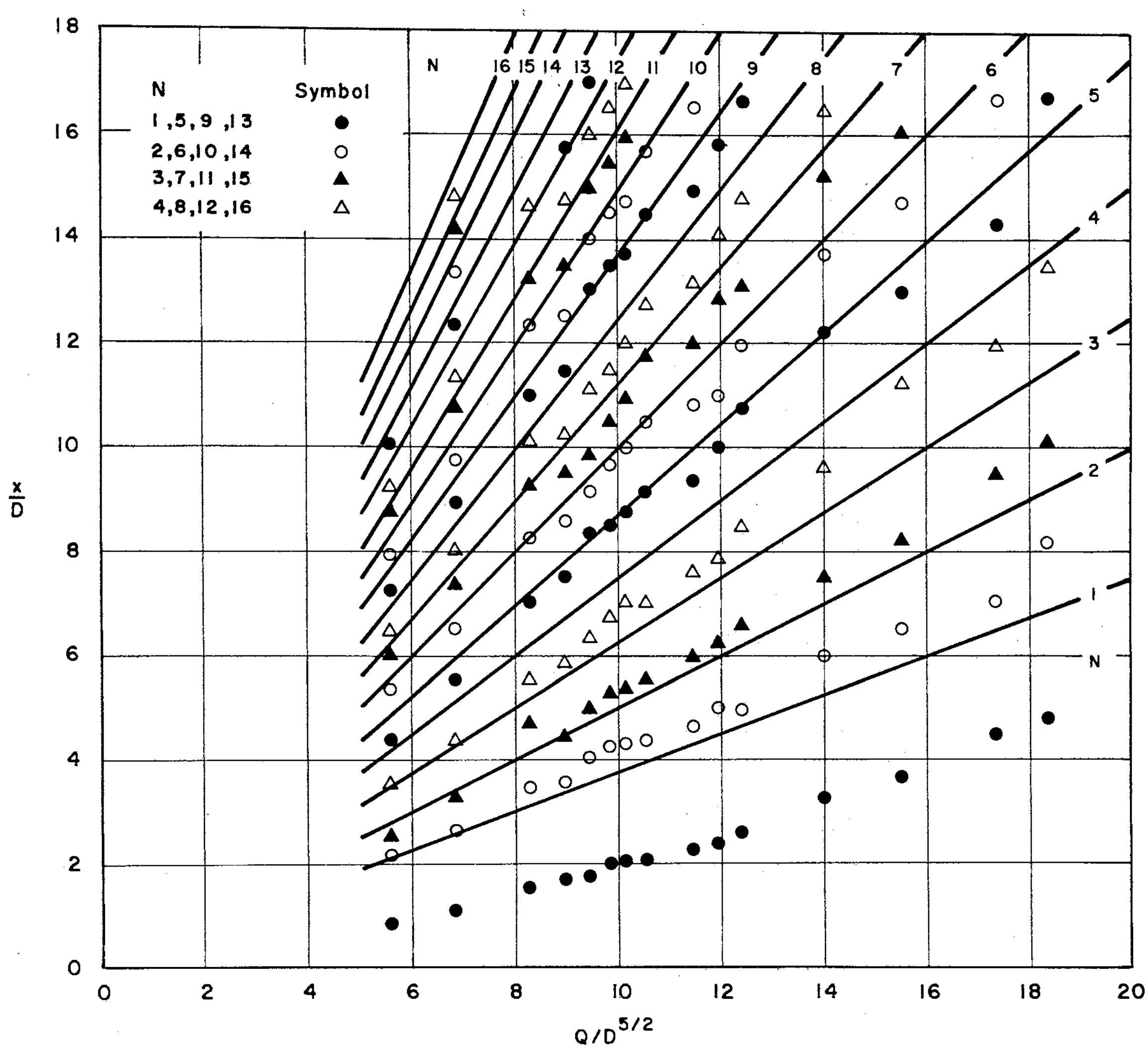


Fig. 11 - Distance from Pipe Exit to Water Surface Components
Pipe is full. Transition is 1.0 D wide. Expansion Section is 0.25 D long. $y/D = 0.00$.

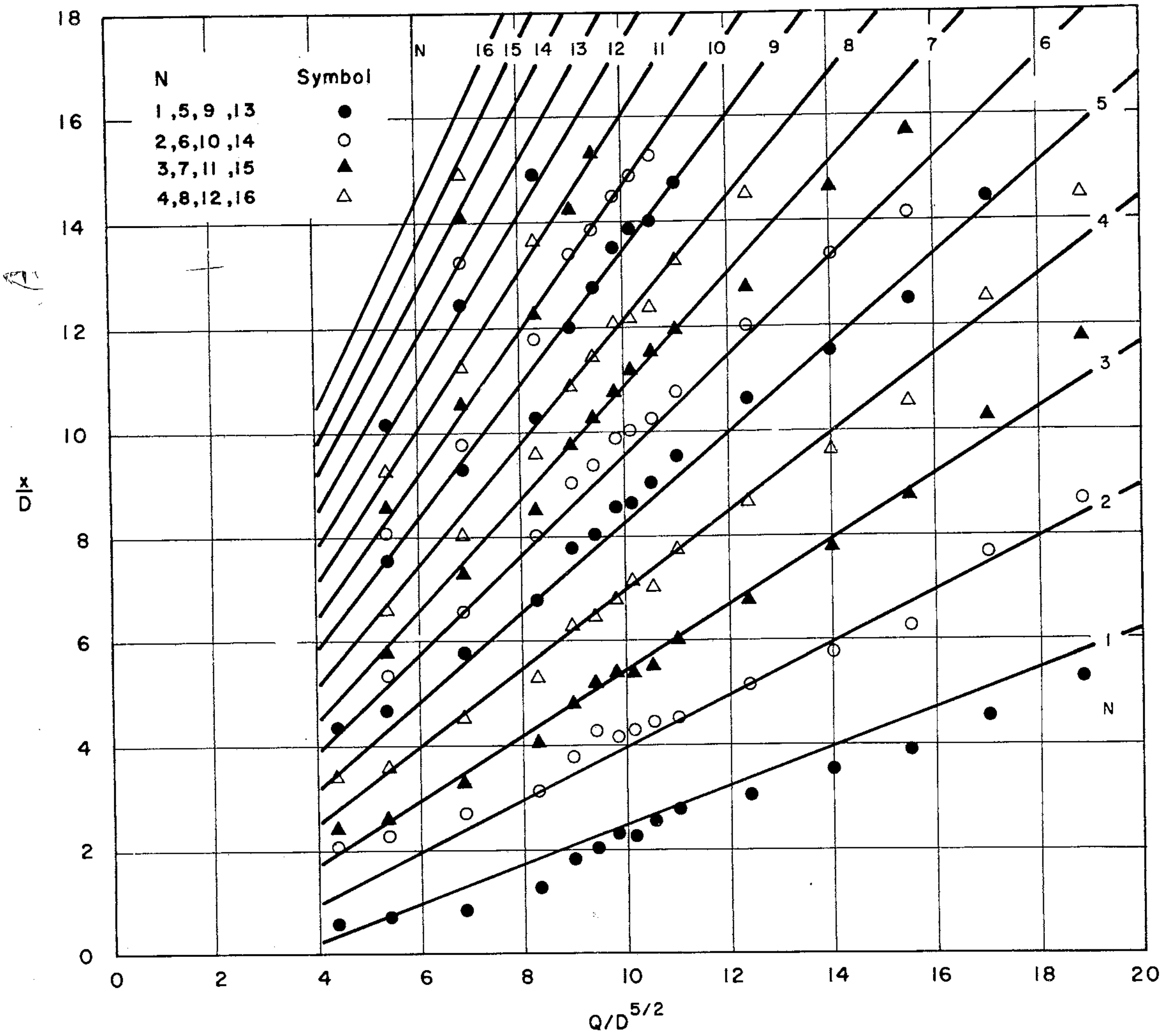


Fig. 12 - Distance from Pipe Exit to Water Surface Components
Pipe is full. Transition is 1.0 D wide. Expansion section is 0.25 D long. y/D = 0.05.

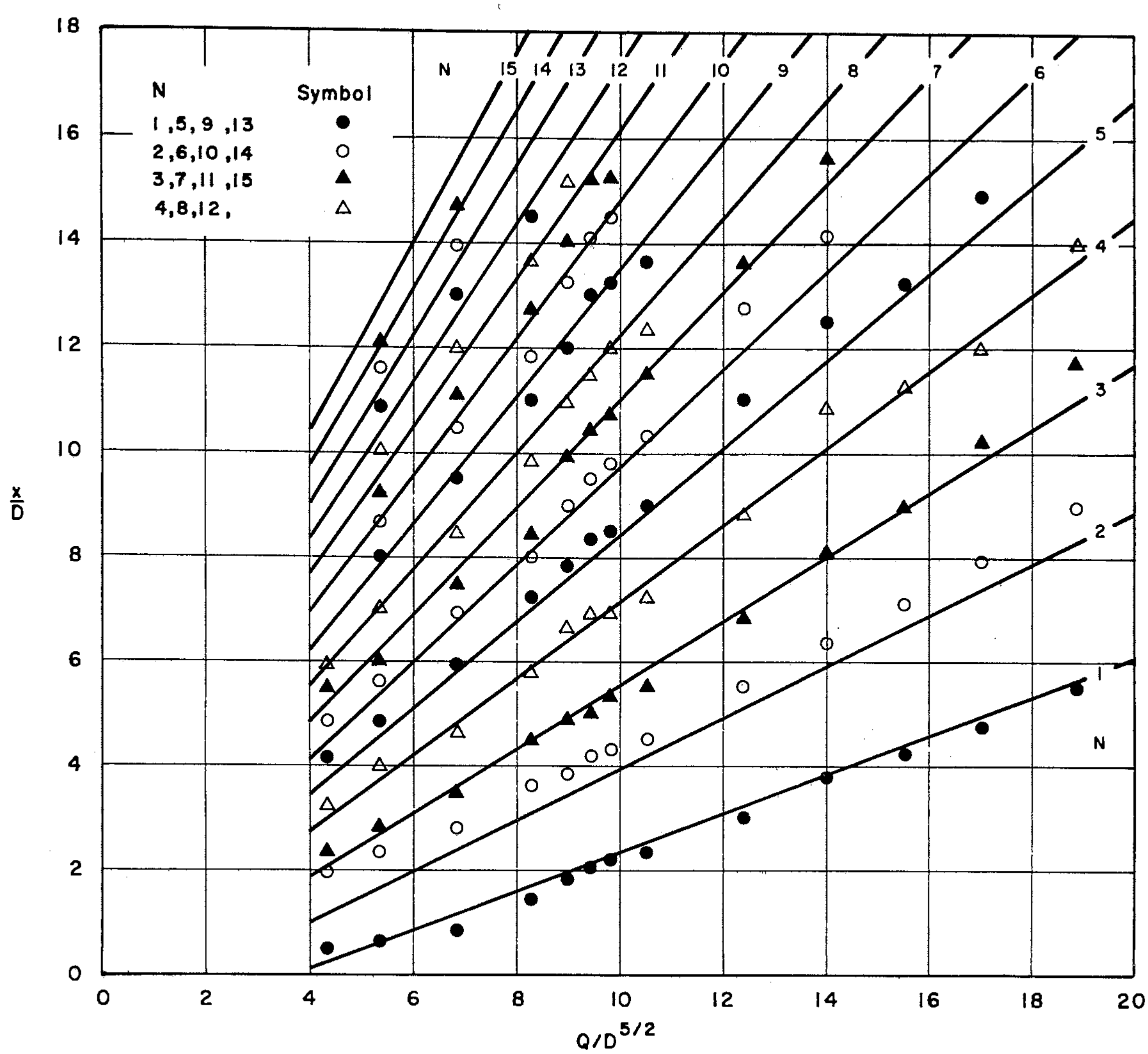


Fig. 13 - Distance from Pipe Exit to Water Surface Components
Pipe is full. Transition is 1.0 D wide. Expansion section is 0.25 D long. $y/D = 0.10$.

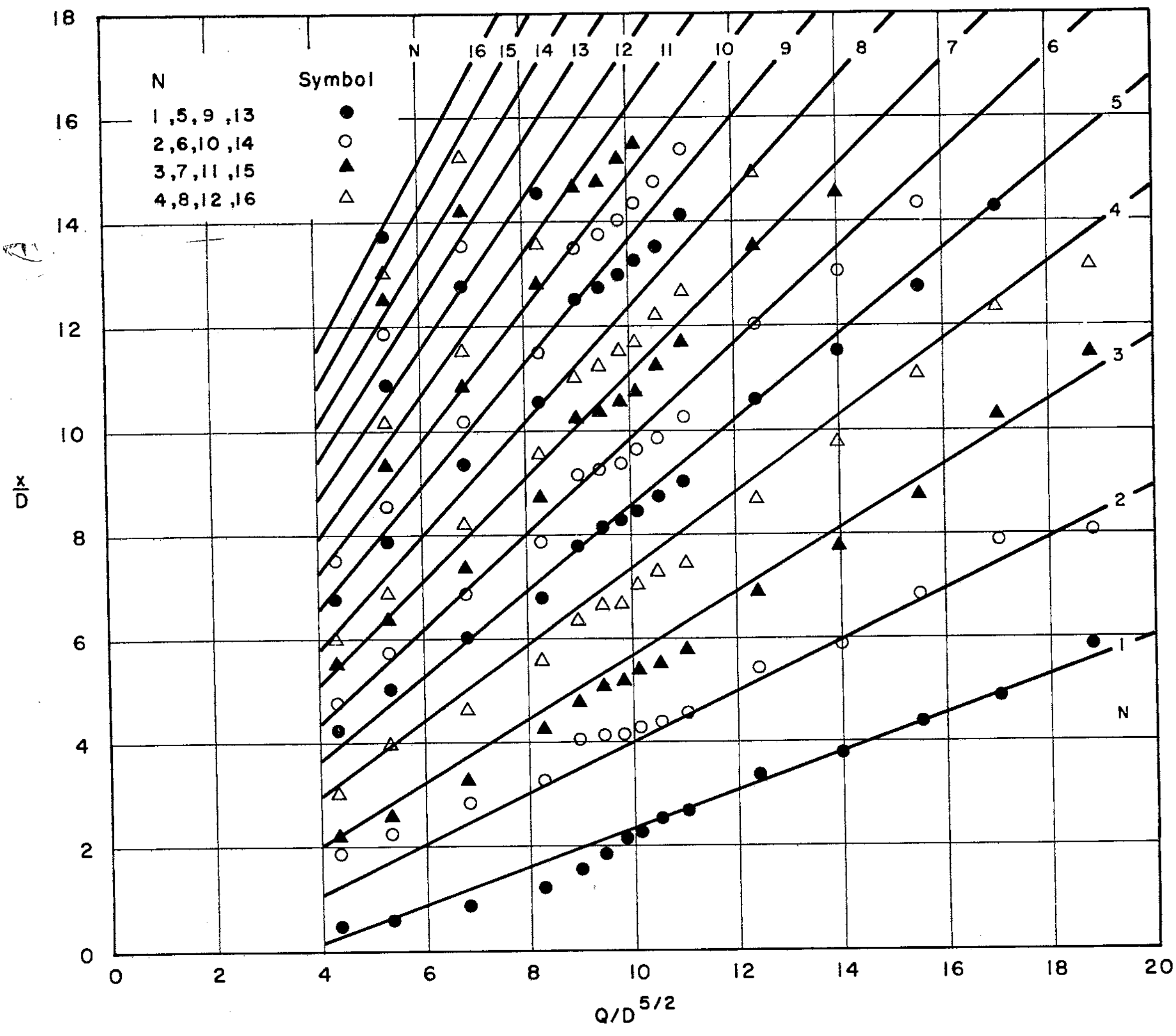


Fig. 14 - Distance from Pipe Exit to Water Surface Components
Pipe is full. Transition is 1.0 D wide. Expansion section is 0.25 D long. y/D = 0.15.

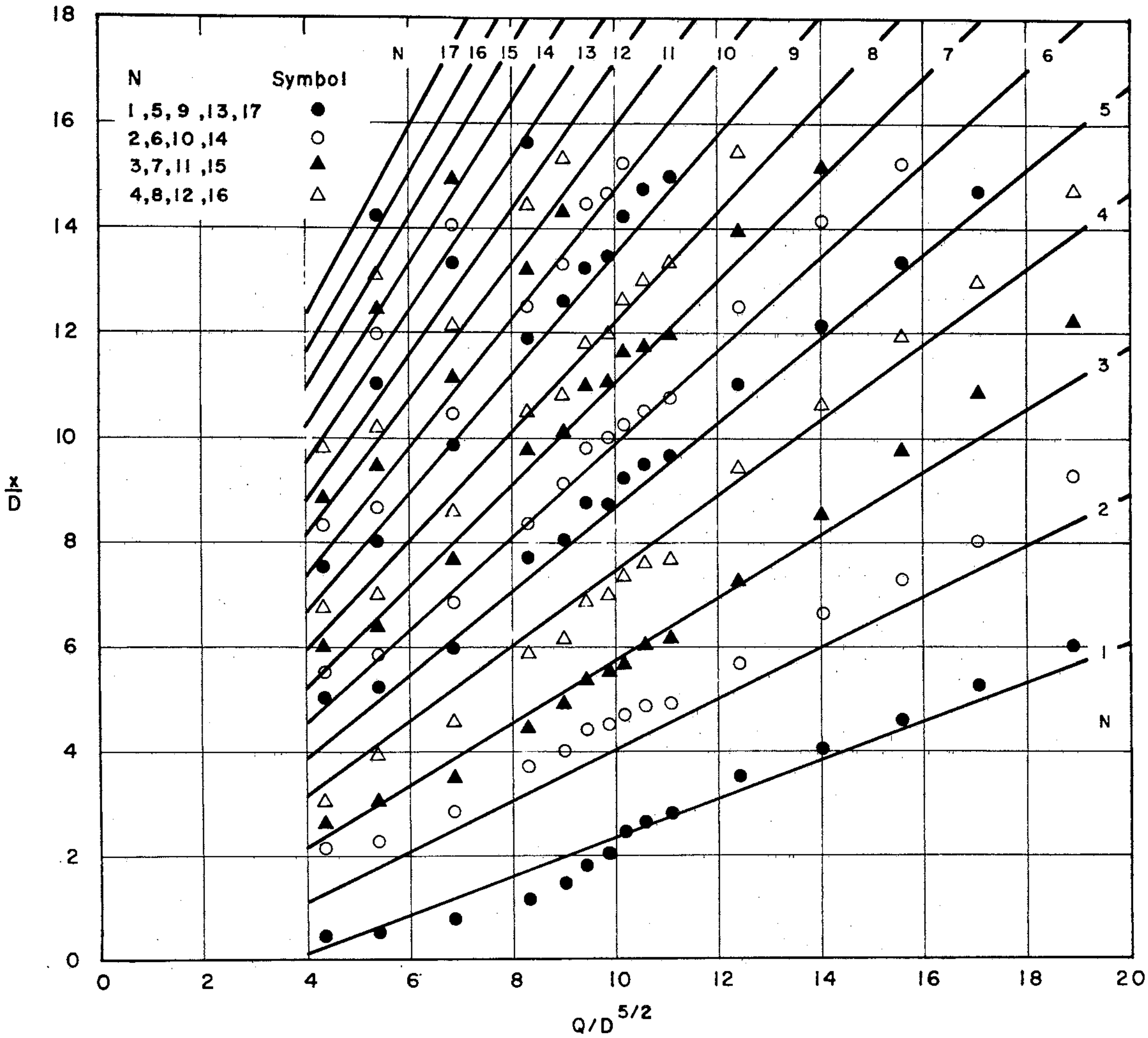


Fig. 15 - Distance from Pipe Exit to Water Surface Components
Pipe is full. Transition is 1.0 D wide. Expansion section is 0.25 D long. y/D = 0.20.

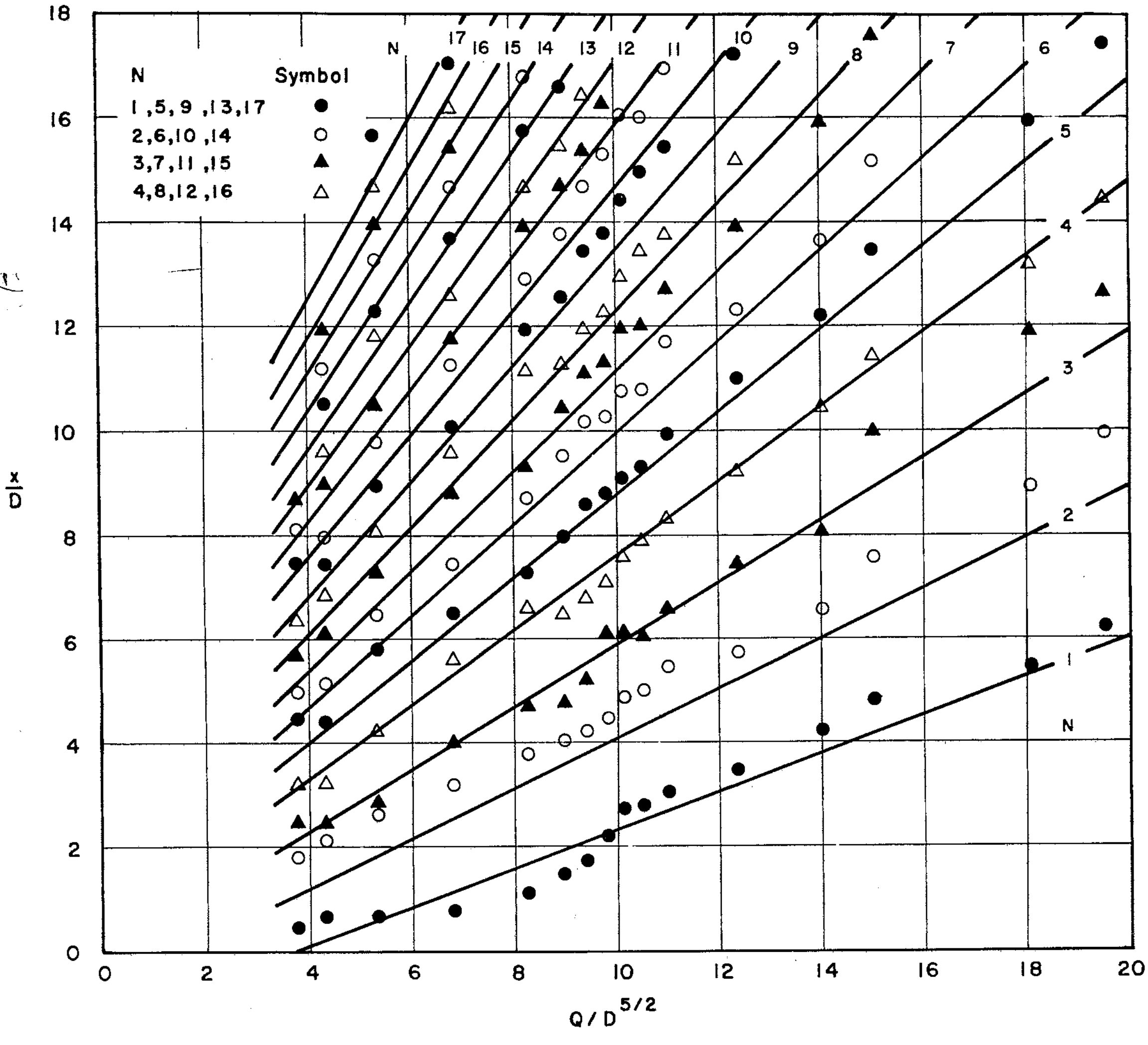


Fig. 16 - Distance from Pipe Exit to Water Surface Components
Pipe is full. Transition is 1.0 D wide. Expansion section is 0.25 D long. y/D = 0.25.

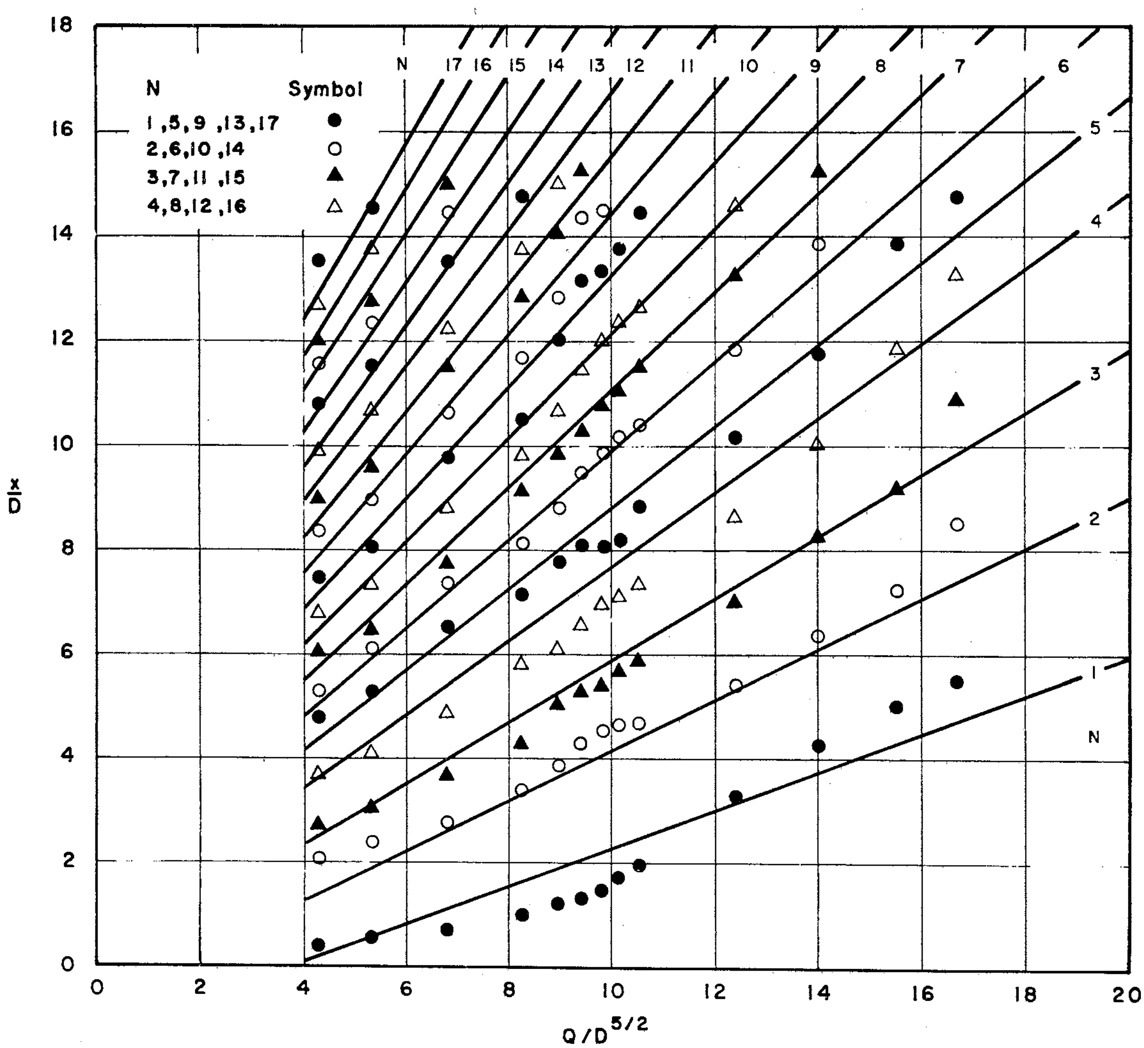


Fig. 17 - Distance from Pipe Exit to Water Surface Components
Pipe is full. Transition is 1.0 D wide. Expansion section is 0.25 D long. $y/D = 0.30$

(Continued from page 12)

To obtain A, the slopes of the curves fitted to the data in Figs. 11 to 17 have been plotted against N in Fig. 18. Lines have been drawn in Fig. 18 to represent the slopes for each value of y/D. These lines have the equation

$$A = \frac{1}{32}\left[8 + \left(4 - \frac{y}{D}\right) N - 2.5 \langle N - 4 \rangle \sqrt{\frac{y}{D}}\right] \tag{7}$$

The quantity between the pointed brackets is zero for negative values.

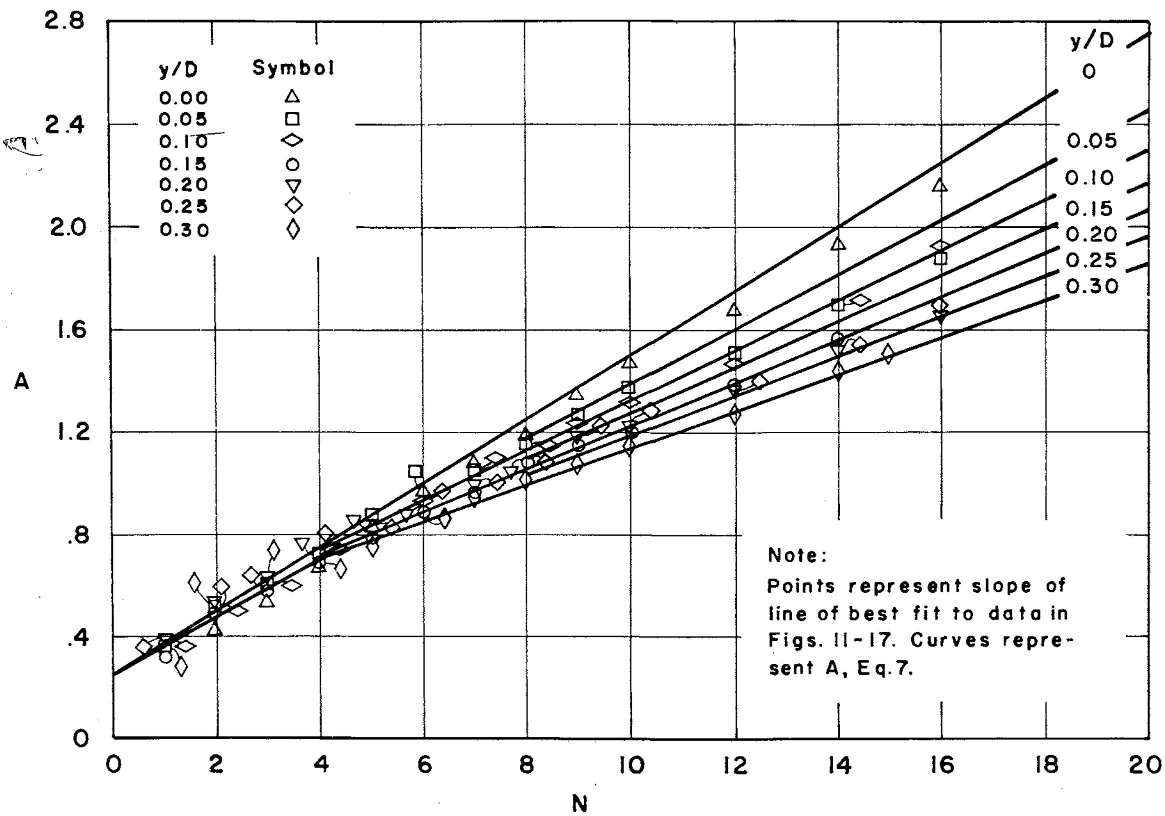


Fig. 18 - Values of A

It is anticipated that Eqs. 6 and 7 or Figs. 11, 12, 13, 14, 15, 16 and 17 will be used to determine the effect of the water surface elements and the transition channel length on the performance of a flip sill or other appurtenance. Eqs. 6 and 7 and Figs. 11 to 17 can also be used to determine the locations of the wave crests, the heights of which govern the sidewall height, or the locations of the other elements comprising the configuration of the water surface in the transition channel.

Wave Length

The wave length λ is taken as the distance between the crests of the same wave where it is reflected from the same side of the transition. This is illustrated in Fig. 19.

In terms of N and x relative to D,

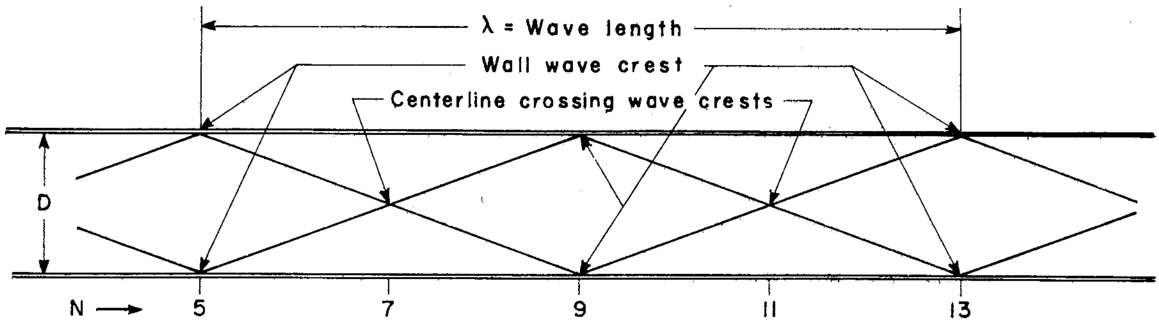


Fig. 19 - Wave Pattern in the Transition

$$\frac{\lambda}{D} = 8\,\frac{\Delta x/\Delta N}{D} \tag{8}$$

Eq. 8 can be evaluated by differentiating Eq. 6, which gives

$$\frac{\lambda}{D} = 8\,\frac{dx/dN}{D} = \frac{1}{4}\left(4 - \frac{y}{D} - 2.5\langle N - 4\rangle^{0}\sqrt{\frac{y}{D}}\right)\left(10\sqrt{\frac{y}{D}} + \frac{Q}{D^{5/2}}\right) \tag{9}$$

When $N>4$, $\langle N - 4\rangle^{0} = 1$ and Eq. 9 becomes

$$\frac{\lambda}{D} = \frac{1}{4}\left(4 - \frac{y}{D} - 2.5\sqrt{\frac{y}{D}}\right)\left(10\sqrt{\frac{y}{D}} + \frac{Q}{D^{5/2}}\right) \tag{10}$$

For the special case of $y/D = 0$, Eqs. 9 and 10 reduce to

$$\frac{\lambda}{D} = \frac{Q}{D^{5/2}} \tag{10a}$$

All attempts to evaluate the wave lengths from the experimental data when $N \leq 5$ were unsuccessful. However, inspection of the data indicated that the observed wave lengths could be averaged for each $Q/D^{5/2}$ and y/D when $N > 5$. These averages are plotted in Fig. 20.

The curves for Eq. 10 drawn in Fig. 20 show that the agreement of Eq. 10 with the data is only fair and that the agreement decreases with increasing $Q/D^{5/2}$. A possible explanation for the poorer agreement at the higher value of $Q/D^{5/2}$ is that there are fewer wave crests in the test channel length so the averages are based on fewer measurements, the wave crests are long and flat making difficult the exact determination of the wave crest location, and the large amount of splash makes exact measurement impossible.

In spite of its lack of precision, Eq. 10 is presented because it probably represents a reasonable estimate of the wave length and the average distance between the water surface components when $N > 5$.

Depth of Flow at Nodes

The depth of flow measured at the nodes, where the transverse water surface is approximately horizontal, that is, at N = 2, 4, 6, 8, . . ., is taken to be the average depth of flow from which the initial depth of flow and the energy losses in the transition can be determined. This information is needed to compute the average water surface profile in the transition.

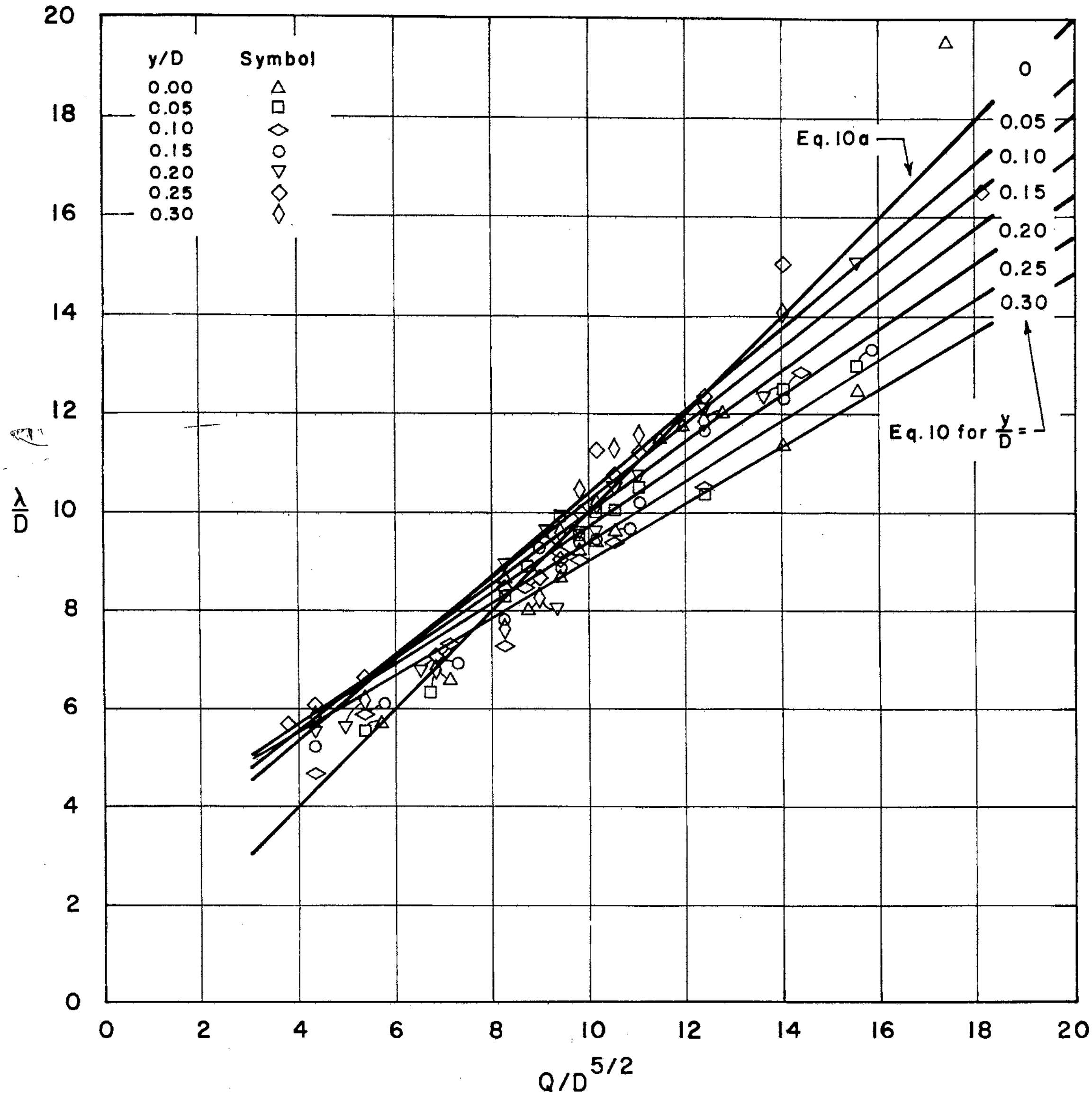


Fig. 20 - Wave Lengths for N > 5

Initial Depth of Flow.—The initial depth of flow is taken as the depth of flow d_2/D at N = 2. The experimental data are plotted in Fig. 21. The depths d_4/D at N = 4 are also plotted in Fig. 21 to provide additional data because of the difficulty of determining the elevation of the rough water surface. Because of the short distance and small losses between N = 2 and N = 4, d_4/D should approximate d_2/D. Examination of the data in Fig. 21 shows that sometimes d_2/D exceeded d_4/D, sometimes d_2/D was less than d_4/D, sometimes d_2/D was identical to d_4/D, and that no regular pattern is evident.

Equations have been derived that represent the data to within ±0.04D average and ±0.06D maximum deviation. These equations are:

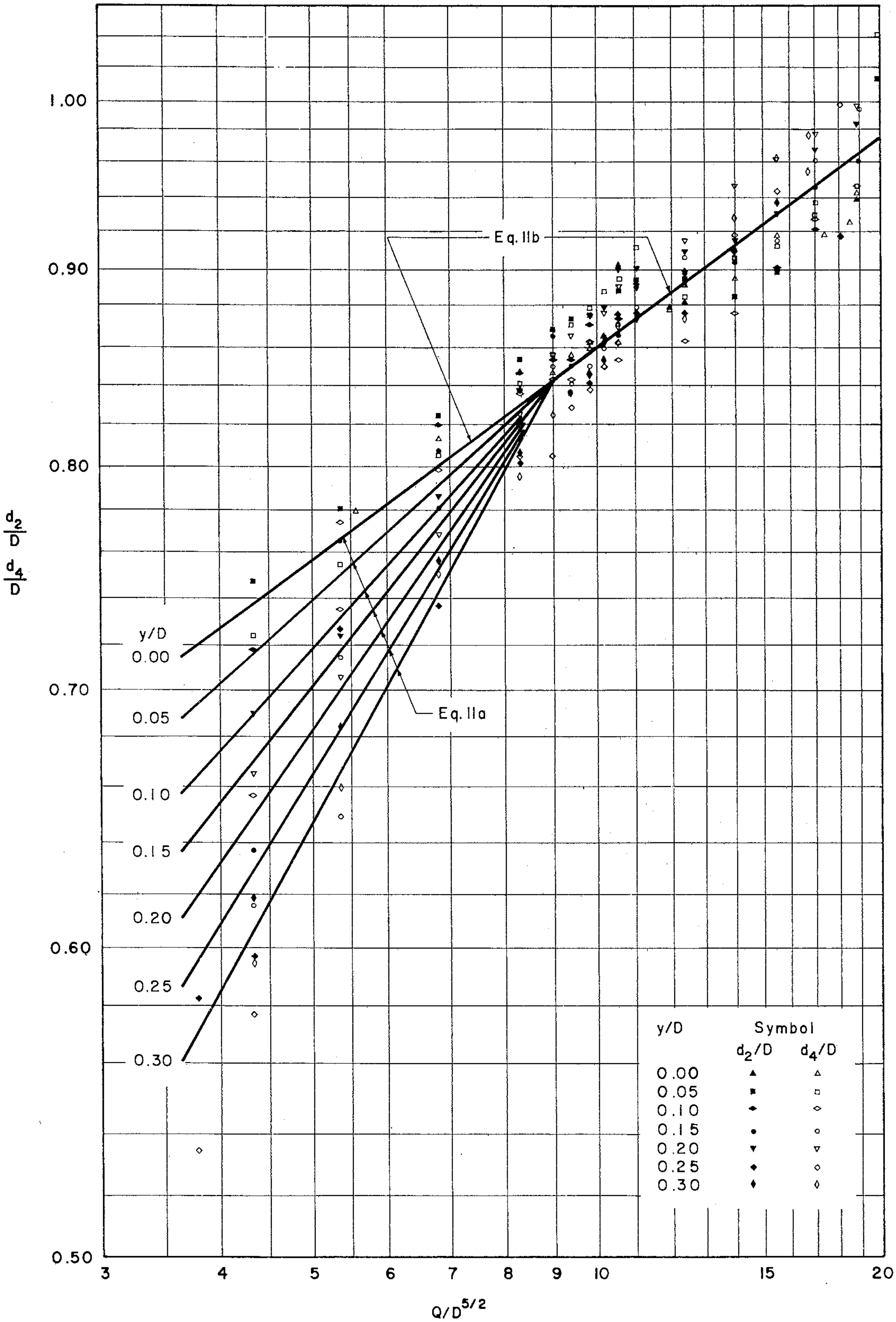


Fig. 21 - Initial Depth of Flow

for $\frac{Q}{D^{5/2}} \leq 9$,

$$\frac{d_2}{D} = \log^{-1}\left(\bar{1}.7542 - 0.840\frac{y}{D}\right)\left(\frac{Q}{D^{5/2}}\right)^{\left(0.180 + 0.88\frac{y}{D}\right)} \tag{11a}$$

and for $\frac{Q}{D^{5/2}} \geq 9$,

$$\frac{d_2}{D} = 0.5675\left(\frac{Q}{D^{5/2}}\right)^{0.180} \tag{11b}$$

Rate of Energy Loss.—The rate of energy loss along the transition channel was determined by computing the relative energy head at each node h_e/D and plotting this value against the relative distance along the transition x/D. A typical plot is shown in Fig. 22. The slope of the line fitted to the data represents the rate of energy loss h_ℓ/x. The rate of energy loss was determined for each experimental value of y/D and $Q/D^{5/2}$.

The data shown in Fig. 22 represent the approximate extremes of the discharges used during the tests. At low discharges there were 10 to 11 nodes—data points—to define the curve, and the surface was relatively smooth and therefore easy to measure accurately. As a result, the rate-of-energy-loss curve is well defined for low discharges. The definition of the curve decreases with increasing discharge. At high discharges there were only 2 or 3 nodes to define the curve, and the surface had so much splash that accurate measurement was impossible. For the higher discharges the rate of energy loss curve is poorly defined and its slope as determined is of low precision.

It was reasoned that the rate of total energy loss in the transition, like the rate of friction energy loss, would be a function of the velocity head. To verify this reasoning, the rate of energy loss h_ℓ/x was plotted against Q^2/D^5, a measure of the velocity head. The data are shown in Fig. 23. The resulting straight line is not well defined, especially at the high values of Q^2/D^5 where it was difficult to accurately evaluate h_ℓ/x. The curve drawn in Fig. 23 has the equation

$$\frac{h_\ell}{x} = 0.010 + 7 \times 10^{-5}\left(\frac{Q}{D^{5/2}}\right)^2 \tag{12}$$

or, in terms of the pipe diameter,

$$\frac{h_\ell}{D} = \left[0.010 + 7 \times 10^{-5}\left(\frac{Q}{D^{5/2}}\right)^2\right]\frac{x}{D} \tag{13}$$

Originally it had been reasoned that the rate of total energy loss in the transition channel could be divided into the rate of friction energy loss and a rate of turbulent energy loss, the turbulent energy loss being caused by the rough water surface and standing waves in the transition. However, when the friction

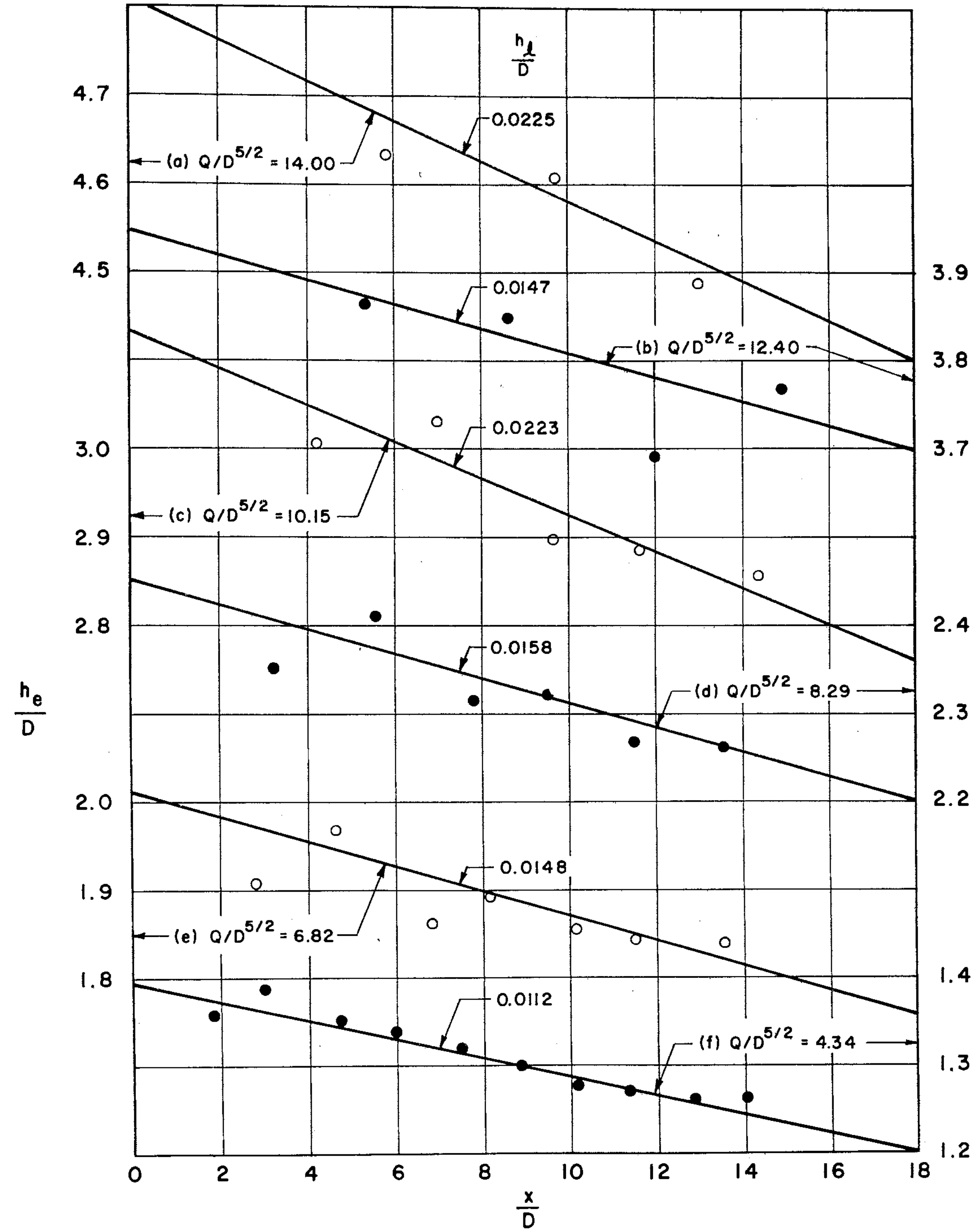


Fig. 22 - Typical Plot of Relative Energy versus Relative Distance Along the Transition

loss using an assumed Darcy-Weisbach friction factor f of 0.010 was subtracted from the total energy loss, the residual energy loss was negative for the higher discharges. This is, of course, impossible.

This anomaly was investigated by computing a psuedo Darcy-Weisbach friction factor f_e which represents the total energy loss in the transition. The value of f_e was computed at a point near the

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

	x/D			d/D			
N	TEST	EQ.	DIFF.	TEST	EQ.	DIFF.	DIFF.
		y/D = .00		$Q/D^{5/2}$ = 8.99			
10	12,560	13.485	.925	,891	,893		,002
11	13,500	14.609	1.109	,930			
12	14,750	15.732	.982	,900	,907		,007
13	15,750	16.856	1.106	,960	1,003	,043	
		y/D = .00		$Q/D^{5/2}$ = 9.41			
1	1,750	3.529	1.779	1,044	1,176	,132	
2	4,060	4.705	.645	,855	,850		-,005
3	4,940	5.881	.941	,921			
4	6,310	7.057	.747	,855	,860		,005
5	8,370	8.234	-.136	,924	1,012	,088	
6	9,190	9.410	.220	,870	,875		,005
7	9,870	10.586	.716	,912			
8	11,120	11.762	.642	,879	,885		,006
9	13,060	12.939	-.121	,948	,990	,042	
10	14,070	14.115	.045	,894	,902		,008
11	15,000	15.291	.291	,921			
12	16,060	16.467	.407	,897	,914		,017
13	17,060	17.644	.584	,960	1,014	,054	
		y/D = .00		$Q/D^{5/2}$ = 9.82			
1	2,000	3.682	1.682	1,044	1,193	,149	
2	4,250	4.910	.660	,858	,856		-,002
3	5,250	6.137	.887	,951			
4	6,750	7.365	.615	,861	,868		,007
5	8,500	8.592	.093	94,500	1,023	-93,477	
6	9,690	9.820	.130	,876	,882		,006
7	10,500	11.047	.547	,924			
8	11,500	12.275	.775	,888	,891		,003
9	13,500	13.502	.002	,951	1,000	,049	
10	14,500	14.730	.230	,897	,907		,010
11	15,500	15.957	.458	,930			
12	16,560	17.185	.625	,903	,919		,016
		y/D = .00		$Q/D^{5/2}$ = 10.15			
1	2,000	3.806	1.806	1,098	1,206	,108	
2	,100	5.075	4.975	,864	,861		-,003
3	5,370	6.344	.974	,957			
4	0	7.612	7.612	,864	,861		-,003
5	8,750	8.881	.131	,957	1,054	,097	
6	10,000	10.150	.150	,885	,908		,023
7	10,940	11.419	.479	,930			
8	12,000	12.687	.688	,894	,919		,025
9	13,750	13.956	.206	,963	1,030	,067	
10	14,750	15.225	.475	,900	,935		,035
11	16,000	16.494	.494	,933			
12	17,000	17.762	.762	,903	,948		,045
		y/D = .00		$Q/D^{5/2}$ = 10.53			
1	2,060	3.949	1.889	1,110	1,221	,111	
2	4,310	5.265	.955	,861	,867		,006
3	5,500	6.581	1.081	,939			
4	7,000	7.897	.897	,861	,878		,017
5	9,120	9.214	.094	,954	1,046	,092	
6	10,500	10.530	.030	,900	,894		-,006
7	11,750	11.846	.096	,924			
8	12,750	13.162	.413	,900	,905		,005

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		y/D = .00		$Q/D^{5/2}$ = 10.53			
9	14,500	14.479	-.021	,954	1,019	,065	
10	15,750	15.795	.045	,900	,920		.020
		y/D = .00		$Q/D^{5/2}$ = 11.80			
1	2,250	4.425	2.175	1,155	1,272	,117	
2	4,620	5.900	1.280	,876	,885		.009
3	6,000	7.375	1.375	,978			
4	7,620	8.850	1.230	,876	,896		.020
5	9,380	10.325	.945	,963	1,081	,118	
6	10,870	11.800	.930	,894	,910		.016
7	12,000	13.275	1.275	,945			
8	13,190	14.750	1.560	,903	,920		.017
9	14,940	16.225	1.285	,954	1,045	,091	
10	16,560	17.700	1.140	,909	,935		.026
		y/D = .00		$Q/D^{5/2}$ = 11.95			
1	2,370	4.481	2.111	1,140	1,278	,138	
2	5,000	5.975	.975	,879	,887		.008
3	6,250	7.469	1.219	,993			
4	7,870	8.962	1.092	,872	,898		.026
5	10,000	10.456	.456	,969	1,086	,117	
6	11,000	11.950	.950	,903	,910		.007
7	12,870	13.444	.574	,933			
8	14,120	14.937	.817	,906	,924		.018
9	15,870	16.431	.561	,963	1,051	,088	
		y/D = .00		$Q/D^{5/2}$ = 12.40			
1	2,620	4.650	2.030	1,143	1,296	,153	
2	4,940	6.200	1.260	,882	,893		.011
3	6,560	7.750	1.190	1,029			
4	8,690	9.300	.610	,891	,907		.016
5	10,750	10.850	.100	,972	1,101	,129	
6	12,000	12.400	.400	,894	,920		.026
7	13,120	13.950	.830	,963			
8	14,810	15.500	.690	,891	,932		.041
9	16,690	17.050	.360	,963	1,064	,101	
		y/D = .00		$Q/D^{5/2}$ = 14.00			
1	3,250	5.250	2.000	1,206	1,360	,154	
2	6,000	7.000	1.000	,894	,913		.019
3	7,500	8.750	1.250	1,050			
4	9,620	10.500	.880	,894	,925		.031
5	12,250	12.250	0	,999	1,145	,146	
6	13,750	14.000	.250	,900	,940		.040
7	15,250	15.750	.500	,954			
8	16,500	17.500	1.000	,900	,951		.051
		y/D = .00		$Q/D^{5/2}$ = 15.52			
1	3,620	5.820	2.200	1,269	1,421	,152	
2	6,500	7.760	1.260	,900	,930		.030
3	8,250	9.700	1.450	1,080			
4	11,250	11.640	.390	,918	,945		.027
5	13,000	13.580	.580	,984	1,184	,200	
6	14,750	15.520	.770	,918	,958		.040
7	16,120	17.460	1.340	,960			

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		y/D = .00		$Q/D^{5/2}$ = 17.38			
1	4,500	6.518	2.018	1,302	1,495	,193	
2	8,060	8.690	.630	,918	,949		,031
3	9,500	10.862	1.362	1,083			
4	12,000	13.035	1.035	,918	,961		,043
5	14,310	15.207	.897	,993	1,230	,237	
6	16,750	17.380	.630	,918	,977		,059
		y/D = .00		$Q/D^{5/2}$ = 18.34			
1	4,810	6.877	2.067	1,326	1,534	,208	
2	8,190	9.170	.980	,927	,958		,031
3	10,120	11.462	1.342	1,104			
4	13,500	13.755	.255	,927	,975		,048
5	16,750	16.047	-.703	1,008	1,261	,253	
		y/D = .00		$Q/D^{5/2}$ = 18.90			
1	5,120	7.087	1.967	1,356	1,556	,200	
2	8,430	9.450	1.020	,933	,963		,030
3	10,500	11.812	1.312	1,149			
4	13,750	14.175	.425	,936	,980		,044
5	17,000	16.538	-.462	1,020	1,274	,254	
		y/D = .05		$Q/D^{5/2}$ = 4.34			
1	,562	.328	-.234	1,029	1,050	,021	
2	2,000	1.140	-.860	,747	,716		-,031
3	2,310	1.951	-.359	,789			
4	3,380	2.763	-.617	,723	,748		,025
5	4,430	3.460	-.970	,804	,854	,050	
		y/D = .05		$Q/D^{5/2}$ = 5.36			
1	,687	.709	.022	1,053	1,050	-,003	
2	2,250	1.646	-.604	,780	,751		-,029
3	2,560	2.584	.024	,813			
4	3,560	3.522	-.038	,753	,766		,013
5	4,690	4.327	-.363	,837	,861	,024	
6	5,310	5.132	-.178	,792	,789		-,003
7	5,750	5.936	.186	,828			
8	6,560	6.741	.181	,804	,809		,005
9	7,500	7.546	.046	,870	,881	,011	
10	8,060	8.351	.291	,831	,840		,009
11	8,560	9.156	.596	,867			
12	9,250	9.961	.711	,840	,874		,034
13	10,190	10.766	.576	,924	,975	,051	
		y/D = .05		$Q/D^{5/2}$ = 6.82			
1	,880	1.254	.374	1,065	1,073	,008	
2	2,690	2.372	-.318	,825	,792		-,033
3	3,250	3.490	.240	,867			
4	4,500	4.608	.108	,810	,806		-,004
5	5,750	5.567	-.183	,900	,918	,018	
6	6,560	6.527	-.033	,843	,822		-,021
7	7,250	7.486	.236	,882			
8	8,000	8.446	.446	,843	,834		-,009
9	9,250	9.406	.156	,915	,914	-,001	
10	9,750	10.365	.615	,864	,850		-,014

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

	x/D			d/D			
N	TEST	EQ.	DIFF.	TEST	EQ.	DIFF.	DIFF.
		y/D = .05		$Q/D^{5/2}$ = 6.82			
11	10,500	11.325	.825	,906			
12	11,250	12.285	1.035	,888	,866		-,022
13	12,440	13.244	.804	,945	,948	,003	
14	13,250	14.204	.954	,894	,889		-,005
15	14,120	15.164	1.044	,930			
16	14,940	16.123	1.183	,885	,912		,027
		y/D = .05		$Q/D^{5/2}$ = 8.29			
1	1,250	1.803	.553	1,062	1,132	,070	
2	3,310	3.102	-.208	,852	,828		-,024
3	4,000	4.402	.402	,915			
4	5,250	5.701	.451	,840	,839		-,001
5	6,750	6.816	.066	,942	,972	,030	
6	8,000	7.932	-.068	,876	,855		-,021
7	8,500	9.047	.547	,921			
8	9,560	10.163	.603	,885	,865		-,020
9	10,250	11.278	1.028	,942	,952	,010	
10	11,750	12.393	.643	,900	,879		-,021
11	12,250	13.509	1.259	,945			
12	13,620	14.624	1.004	,900	,892		-,008
13	14,940	15.740	.800	,969	,985	,016	
		y/D = .05		$Q/D^{5/2}$ = 8.99			
1	1,750	2.064	.314	1,065	1,160	,095	
2	3,750	3.450	-.300	,867	,843		-,024
3	4,750	4.836	.086	,948			
4	6,250	6.221	-.029	,855	,856		,001
5	7,750	7.411	-.339	,945	,998	,053	
6	9,000	8.601	-.399	,888	,870		-,018
7	9,750	9.790	.040	,942			
8	10,880	10.980	.100	,894	,881		-,013
9	12,000	12.170	.170	,957	,978	,021	
10	13,380	13.359	-.021	,915	,896		-,019
11	14,250	14.549	.299	,951			
		y/D = .05		$Q/D^{5/2}$ = 9.41			
1	2,000	2.221	.221	1,104	1,176	,072	
2	4,250	3.659	-.591	,873	,850		-,023
3	5,120	5.096	-.024	,975			
4	6,440	6.534	.094	,870	,860		-,010
5	8,000	7.768	-.232	,987	1,009	,022	
6	9,370	9.002	-.368	,900	,875		-,025
7	10,250	10.236	-.014	,945			
8	11,440	11.470	.030	,900	,886		-,014
9	12,750	12.704	-.046	,972	,987	,015	
10	13,880	13.939	.059	,909	,900		-,009
11	15,370	15.173	-.197	,919			
		y/D = .05		$Q/D^{5/2}$ = 9.82			
1	2,250	2.374	.124	1,140	1,193	,053	
2	4,180	3.862	-.318	,875	,856		-,019
3	5,370	5.351	-.019	1,020			
4	6,750	6.839	.089	,879	,868		-,011
5	8,560	8.116	-.444	1,005	1,024	,019	
6	9,880	9.394	-.486	,909	,883		-,026
7	10,750	10.671	-.079	,951			

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		$y/D = .05$		$Q/D^{5/2} = 9.82$			
8	12.060	11.949	-.111	.912	.894		-.018
9	13.500	13.227	-.273	.990	1.000	.010	
10	14.500	14.504	.004	.915	.907		-.008
		$y/D = .05$		$Q/D^{5/2} = 10.15$			
1	2.250	2.498	.248	1.173	1.206	.033	
2	4.250	4.026	-.224	.888	.861		-.027
3	5.370	5.555	.185	1.029			
4	7.120	7.084	-.036	.888	.874		-.014
5	8.620	8.397	-.223	1.008	1.033	.025	
6	10.000	9.709	-.291	.915	.887		-.028
7	11.180	11.022	-.158	.966			
8	12.180	12.334	.154	.915	.898		-.017
9	13.880	13.647	-.233	1.005	1.008	.003	
10	14.880	14.959	.079	.905	.912		.007
		$y/D = .05$		$Q/D^{5/2} = 10.53$			
1	2.500	2.639	.139	1.194	1.221	.027	
2	4.430	4.215	-.215	.888	.867		-.021
3	5.500	5.791	.291	1.035			
4	7.000	7.367	.367	.894	.878		-.016
5	9.000	8.720	-.280	.972	1.045	.073	
6	10.250	10.072	-.178	.936	.892		-.044
7	11.500	11.425	-.075	.966			
8	12.370	12.778	.408	.921	.902		-.019
9	14.000	14.131	.131	.984	1.016	.032	
10	15.250	15.484	.234	.930	.917		-.013
		$y/D = .05$		$Q/D^{5/2} = 11.03$			
1	2.750	2.826	.076	1.200	1.241	.041	
2	4.500	4.464	-.036	.894	.874		-.020
3	6.000	6.101	.101	1.050			
4	7.750	7.739	-.011	.906	.888		-.018
5	9.500	9.145	-.355	.981	1.060	.079	
6	10.750	10.550	-.200	.942	.900		-.042
7	11.940	11.956	.016	.969			
8	13.250	13.362	.112	.921	.912		-.009
9	14.750	14.768	.018	.990	1.029	.039	
		$y/D = .05$		$Q/D^{5/2} = 12.40$			
1	3.000	3.338	.338	1.242	1.296	.054	
2	5.120	5.144	.024	.894	.893		-.001
3	6.750	6.951	.201	1.083			
4	8.620	8.758	.138	.885	.906		.021
5	10.620	10.309	-.311	.990	1.100	.110	
6	12.000	11.860	-.140	.936	.919		-.017
7	12.750	13.411	.661	.969			
8	14.500	14.961	.461	.915	.929		.014
		$y/D = .05$		$Q/D^{5/2} = 14.00$			
1	3.500	3.935	.435	1.272	1.360	.088	
2	5.750	5.939	.189	.885	.913		.028
3	7.750	7.944	.194	1.098			
4	9.620	9.948	.328	.897	.926		.029
5	11.500	11.668	.168	1.005	1.143	.138	

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		y/D = .05		$Q/D^{5/2}$ = 14.00			
6	13,370	13,389	.019	,942	,940		-,002
7	14,620	15.109	.489	,969			
		y/D = .05		$Q/D^{5/2}$ = 15.52			
1	3,870	4.503	.633	1,314	1,421	,107	
2	6,250	6.695	.445	,897	,930		,033
3	8,750	8.886	.136	1,140			
4	10,500	11,078	.578	,912	,944		,032
5	12,500	12,960	.460	1,020	1,183	,163	
6	14,190	14,841	.651	,930	,957		,027
7	15,750	16.723	.973	,975			
		y/D = .05		$Q/D^{5/2}$ = 17.02			
1	4,500	5,063	.563	1,350	1,481	,131	
2	7,620	7,440	-.180	,930	,945		,015
3	10,250	9.817	-.433	1,209			
4	12,500	12.194	-.306	,936	,961		,025
5	14,430	14.234	-.196	1,041	1,223	,182	
		y/D = .05		$Q/D^{5/2}$ = 18.87			
1	5,250	5.754	.504	1,425	1,555	,130	
2	8,680	8.359	-.321	,945	,963		,018
3	11,750	10,964	-.786	1,260			
4	14,500	13.570	-.930	,945	,981		,036
		y/D = .10		$Q/D^{5/2}$ = 4.34			
1	,500	,259	-.241	1,044	1,100	,056	
2	1,940	1.174	-.766	,717	,694		-,023
3	2,370	2.088	-.282	,705			
4	3,250	3.002	-.248	,657	,716		,059
5	4,190	3.731	-.459	,720	,801	,081	
6	4,870	4.460	-.410	,684	,754		,070
7	5,500	5.189	-.311	,726			
8	5,940	5.918	-.022	,705	,805		,100
		y/D = .10		$Q/D^{5/2}$ = 5.36			
1	,625	,639	.014	1,086	1,100	,014	
2	2,370	1.677	-.693	,765	,734		-,031
3	2,810	2.716	-,094	,789			
4	4,000	3.755	-.245	,735	,750		,015
5	4,870	4,583	-.287	,807	,841	,034	
6	5,620	5,411	-.209	,765	,769		,004
7	6,000	6.239	.239	,801			
8	7,000	7.067	.067	,780	,788		,008
9	8,000	7.895	-.105	,843	,857	,014	
10	8,690	8,723	.033	,798	,816		,018
11	9,250	9.551	.301	,834			
12	10,060	10,380	.320	,816	,845		,029
13	10,870	11.208	.338	,876	,922	,046	
14	11,620	12.036	.416	,840	,898		,058
15	12,190	12,864	.674	,876			

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

	x/D			d/D			
N	TEST	EQ.	DIFF.	TEST	EQ.	DIFF.	DIFF.
		y/D = .10		$Q/D^{5/2}$ = 6.82			
1	.870	1.182	.312	1.080	1.100	.020	
2	2.810	2.398	-.412	.819	.783		-.036
3	3.500	3.615	.115	.849			
4	4.620	4.831	.211	.798	.795		-.003
5	5.940	5.801	-.139	.873	.907	.034	
6	6.940	6.771	-.169	.831	.812		-.019
7	7.500	7.741	.241	.870			
8	8.440	8.711	.271	.840	.825		-.015
9	9.500	9.681	.181	.900	.902	.002	
10	10.500	10.651	.151	.861	.843		-.018
11	11.120	11.621	.501	.900			
12	12.000	12.591	.591	.870	.858		-.012
13	13.000	13.561	.561	.936	.936	.000	
14	13.940	14.531	.591	.876	.879		.003
15	14.750	15.501	.751	.900			
		y/D = .10		$Q/D^{5/2}$ = 8.29			
1	1.440	1.728	.288	1.035	1.132	.097	
2	3.620	3.124	-.496	.846	.825		-.021
3	4.500	4.520	.020	.888			
4	5.750	5.916	.166	.834	.836		.002
5	7.250	7.028	-.222	.936	.969	.033	
6	8.000	8.141	.141	.855	.849		-.006
7	8.440	9.254	.814	.900			
8	9.810	10.367	.557	.864	.861		-.003
9	11.000	11.480	.480	.933	.951	.018	
10	11.870	12.592	.722	.888	.874		-.014
11	12.750	13.705	.955	.921			
12	13.620	14.818	1.198	.888	.886		-.002
13	14.500	15.931	1.431	.954	.975	.021	
		y/D = .10		$Q/D^{5/2}$ = 8.99			
1	1.810	1.989	.179	1.023	1.160	.137	
2	3.870	3.470	-.400	.852	.843		-.009
3	4.870	4.951	.081	.933			
4	6.620	6.432	-.188	.846	.857		.011
5	7.810	7.613	-.197	.954	.998	.044	
6	9.000	8.793	-.207	.876	.870		-.006
7	9.940	9.974	.034	.915			
8	10.940	11.155	.215	.876	.881		.005
9	12.000	12.336	.336	.957	.977	.020	
10	13.250	13.517	.267	.900	.895		-.005
11	14.000	14.698	.698	.942			
12	15.250	15.878	.628	.900	.908		.008
		y/D = .10		$Q/D^{5/2}$ = 9.41			
1	2.060	2.145	.085	1.032	1.176	.144	
2	4.190	3.677	-.513	.852	.850		-.002
3	5.000	5.209	.209	.954			
4	6.940	6.742	-.198	.842	.863		.021
5	8.370	7.963	-.407	.966	1.011	.045	
6	9.500	9.185	-.315	.876	.876		-.000
7	10.440	10.406	-.034	.936			
8	11.500	11.628	.128	.885	.887		.002

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

	x/D			d/D			
N	TEST	EQ.	DIFF.	TEST	EQ.	DIFF.	DIFF.
		y/D = .10		$Q/D^{5/2}$ = 9.41			
9	13,000	12.850	-.150	,960	,989	,029	
10	14,120	14.071	-.049	,903	,901		-,002
11	15,250	15.293	.043	,939			
		y/D = .10		$Q/D^{5/2}$ = 9.82			
1	2,190	2.297	.107	1,041	1,193	,152	
2	4,310	3.879	-.431	,870	,856		-,014
3	5,310	5.462	.152	,963			
4	6,940	7.044	.104	,861	,868		,007
5	8,500	8.305	-.195	,966	1,023	,057	
6	9,810	9.567	-.243	,894	,882		-,012
7	10,750	10.828	.078	,951			
8	12,000	12.090	.090	,888	,893		,005
9	13,250	13.351	.101	,963	,998	,035	
10	14,500	14.613	.113	,903	,907		,004
11	15,250	15.874	.624	,936			
		y/D = .10		$Q/D^{5/2}$ = 10.53			
1	2,310	2.561	.251	1,095	1,221	,126	
2	4,500	4.230	-.270	,873	,867		-,006
3	5,560	5.899	.339	,972			
4	7,250	7.568	.318	,858	,879		,021
5	9,000	8.898	-.102	,981	1,044	,063	
6	10,310	10.228	-.082	,903	,892		-,011
7	11,500	11.559	,059	,930			
8	12,370	12.889	.519	,894	,902		,008
9	13,690	14.220	.530	,960	1,014	,054	
		y/D = .10		$Q/D^{5/2}$ = 12.40			
1	3,000	3.257	.257	1,164	1,296	,132	
2	5,500	5.153	-.347	,861	,893		,032
3	6,870	7.050	.180	1,044			
4	8,810	8.947	.137	,861	,905		,044
5	11,000	10.459	-.541	,990	1,100	,110	
6	12,750	11.971	-.779	,915	,921		,006
7	13,620	13.483	-.137	,927			
		y/D = .10		$Q/D^{5/2}$ = 14.00			
1	3,750	3.852	.102	1,272	1,360	,088	
2	6,370	5.943	-.427	,876	,913		,037
3	8,120	8.035	-.085	1,110			
4	10,440	10.127	-.313	,876	,927		,051
5	12,500	11.794	-.706	1,008	1,144	,136	
6	14,190	13.462	-.728	,912	,940		,028
7	15,620	15.130	-.490	,948			
		y/D = .10		$Q/D^{5/2}$ = 15.52			
1	4,250	4.417	.167	1,350	1,421	,071	
2	7,120	6.694	-.426	,900	,930		,030
3	9,000	8.971	-.029	1,170			
4	11,250	11.248	-.002	,900	,943		,043
5	13,250	13.063	-.187	1,032	1,183	,151	

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		y/D = .10		$Q/D^{5/2}$ = 17.02			
1	4,750	4.975	.225	1,410	1,481	,071	
2	7,940	7.434	-.506	,921	,945		,024
3	10,250	9.894	-.356	1,200			
4	12,000	12.354	.354	,927	,958		,031
5	14,940	14.315	-.625	1,044	1,223	,179	
		y/D = .10		$Q/D^{5/2}$ = 18.87			
1	5,500	5,663	.163	1,410	1,555	,145	
2	9,000	8,348	-.652	,945	,963		,018
3	11,750	11.033	-.717	1,260			
4	14,000	13.718	-.282	,945	,979		,034
		y/D = .15		$Q/D^{5/2}$ = 4.34			
1	,440	.241	-.199	1,092	1,150	,058	
2	1,870	1.229	-.641	,636	,672		,036
3	2,190	2.217	.027	,681			
4	3,000	3.205	.205	,615	,686		,071
5	4,250	3.945	-.305	,675	,771	,096	
6	4,750	4.684	-.066	,642	,714		,072
7	5,500	5.424	-.076	,675			
8	6,000	6.164	.164	,654	,742		,088
9	6,750	6.903	.153	,705	,808	,103	
10	7,500	7.643	.143	,672	,805		,133
		y/D = .15		$Q/D^{5/2}$ = 5.36			
1	,560	,619	,059	1,146	1,150	,004	
2	2,250	1,729	-.521	,765	,717		-,048
3	2,560	2,840	.280	,786			
4	3,940	3,951	.011	,714	,732		,018
5	5,000	4.783	-.217	,795	,823	,028	
6	5,750	5.614	-.136	,765	,751		-,014
7	6,370	6.446	.076	,786			
8	6,810	7.277	.467	,774	,763		-,011
9	7,870	8,108	.238	,822	,830	,008	
10	8,560	8,940	.380	,777	,785		,008
11	9,310	9.771	.461	,825			
12	10,120	10.603	.483	,810	,810		,000
13	10,870	11.434	.564	,876	,878	,002	
14	11,870	12.266	.396	,831	,847		,016
15	12,500	13.097	.597	,849			
16	13,000	13,929	.929	,834	,883		,049
17	13,750	14.760	1.010	,885	,980	,095	
		y/D = .15		$Q/D^{5/2}$ = 6.82			
1	,810	1.159	.349	1,149	1,150	,001	
2	2,810	2.446	-.364	,807	,773		-,034
3	3,250	3.732	.482	,837			
4	4,620	5.019	.399	,780	,785		,005
5	6,000	5.982	-.018	,870	,897	,027	
6	6,810	6.945	.135	,838	,800		-,038
7	7,310	7.908	.598	,849			
8	8,190	8.871	.681	,822	,811		-,011
9	9,370	9.834	.464	,885	,888	,003	
10	10,190	10.796	.606	,846	,827		-,019
11	10,870	11.759	.889	,879			
12	11,500	12.722	1.222	,855	,838		-,017
13	12,750	13.685	.935	,924	,918	-,006	

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		$y/D = .15$		$Q/D^{5/2} = 6.82$			
14	13,560	14.648	1.088	,858	,858		.000
15	14,250	15.611	1.361	,885			
16	15,250	16.574	1.324	,858	,877		.019
		$y/D = .15$		$Q/D^{5/2} = 8.29$			
1	1,190	1,704	.514	1,098	1,150	,052	
2	3,250	3.167	-.083	,840	,822		-.018
3	4,250	4.630	.380	,891			
4	5,560	6,094	.534	,819	,834		.015
5	6,750	7.189	.439	,921	,965	,044	
6	7,870	8,284	.414	,855	,847		-.008
7	8,750	9.380	.630	,885			
8	9,560	10.475	.915	,852	,858		.006
9	10,500	11.570	1.070	,924	,947	.023	
10	11,500	12.666	1.166	,876	,870		-.006
11	12,810	13.761	.951	,906			
12	13,560	14.856	1.296	,876	,884		.008
13	14,500	15.952	1.452	,936	,974	,038	
		$y/D = .15$		$Q/D^{5/2} = 8.99$			
1	1,560	1,963	.403	1,050	1,160	,110	
2	4,060	3.510	-.550	,864	,843		-.021
3	4,750	5,058	.308	,945			
4	6,310	6,606	.296	,849	,854		.005
5	7,750	7.764	.014	,975	,997	,022	
6	9,120	8,922	-.198	,885	,869		-.016
7	10,250	10.081	-.169	,930			
8	11,000	11,239	.239	,885	,880		-.005
9	12,500	12.397	-.103	,963	,979	,016	
10	13,500	13.556	.056	,903	,895		-.008
11	14,690	14.714	.024	,942			
		$y/D = .15$		$Q/D^{5/2} = 9.41$			
1	1,810	2.118	.308	1,038	1,176	,138	
2	4,120	3.716	-.404	,849	,850		.001
3	5,060	5.315	.255	,939			
4	6,620	6.913	.293	,840	,862		.022
5	8,120	8.109	-.011	,984	1,010	,026	
6	9,250	9.305	.055	,891	,875		-.016
7	10,370	10,501	.131	,930			
8	11,250	11.697	.447	,885	,886		.001
9	12,750	12.894	.144	,984	,988	,004	
10	13,750	14,090	.340	,909	,900		-.009
11	14,750	15,286	.536	,933			
		$y/D = .15$		$Q/D^{5/2} = 9.82$			
1	2,120	2.270	.150	1,020	1,193	,173	
2	4,120	3,918	-.202	,849	,856		.007
3	5,190	5.565	.375	,939			
4	6,620	7.212	.592	,849	,868		.019
5	8,250	8.446	.196	,975	1,023	,048	
6	9,370	9.679	.309	,876	,881		.005
7	10,500	10,912	.412	,939			
8	11,500	12,145	.645	,894	,892		-.002
9	12,940	13.378	.438	,966	,997	,031	
10	14,000	14,611	.611	,888	,905		.017
11	15,250	15,844	.594	,930			

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
	y/D = .15			$Q/D^{5/2}$ = 10.15			
1	2,250	2,392	.142	1,047	1,206	,159	
2	4,250	4,080	-.170	,864	,861		-,003
3	5,370	5,767	.397	,984			
4	7,000	7,454	.454	,858	,873		,015
5	8,430	8,717	.287	,990	1,032	,042	
6	9,620	9,979	.359	,894	,886		-,008
7	10,750	11,242	.492	,945			
8	11,680	12,505	.825	,897	,896		-,001
9	13,250	13,768	.518	,972	1,005	,033	
10	14,370	15,031	.661	,906	,909		,003
11	15,500	16,294	.794	,936			
	y/D = .15			$Q/D^{5/2}$ = 10.53			
1	2,500	2,533	.033	1,056	1,221	,165	
2	4,370	4,266	-.104	,864	,867		,003
3	5,500	5,999	.499	,981			
4	7,250	7,732	.482	,870	,879		,009
5	8,750	9,029	.279	,996	1,044	,048	
6	9,870	10,326	.456	,906	,891		-,015
7	11,250	11,623	.373	,960			
8	12,190	12,920	.730	,900	,902		,002
9	13,500	14,217	.717	,987	1,014	,027	
10	14,750	15,514	.764	,915	,914		-,001
	y/D = .15			$Q/D^{5/2}$ = 11.03			
1	2,690	2,718	.028	1,065	1,241	,176	
2	4,560	4,511	-.049	,879	,874		-,005
3	5,750	6,304	.554	,993			
4	7,440	8,097	.657	,879	,886		,007
5	9,000	9,439	.439	1,005	1,058	,053	
6	10,250	10,781	.531	,912	,898		-,014
7	11,690	12,124	.434	,954			
8	12,690	13,466	.776	,909	,909		-,000
9	14,120	14,808	.688	,996	1,026	,030	
10	15,370	16,150	.780	,912	,922		,010
	y/D = .15			$Q/D^{5/2}$ = 12.40			
1	3,370	3,226	-.144	1,200	1,296	,096	
2	5,370	5,183	-.187	,897	,893		-,004
3	6,870	7,141	.271	1,110			
4	8,690	9,099	.409	,900	,905		,005
5	10,560	10,565	.005	1,011	1,098	,087	
6	12,000	12,030	.030	,930	,918		-,012
7	13,500	13,496	-.004	,975			
8	14,940	14,961	.021	,915	,930		,015
	y/D = .15			$Q/D^{5/2}$ = 14.00			
1	3,750	3,818	.068	1,230	1,360	,130	
2	5,870	5,968	.098	,903	,913		,010
3	7,750	8,119	.369	1,125			
4	9,750	10,269	.519	,906	,926		,020
5	11,500	11,879	.379	1,020	1,142	,122	
6	13,000	13,488	.488	,924	,938		,014
7	14,560	15,098	.538	,981			

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D			d/D			
	TEST	EQ.	DIFF.	TEST	EQ.	DIFF.	DIFF.
		y/D = .15		$Q/D^{5/2}$ = 15.52			
1	4,370	4.381	.011	1,320	1,421	,101	
2	6,810	6.714	-.096	,915	,930		,015
3	8,750	9.047	.297	1,161			
4	11,060	11.381	.321	,915	,944		,029
5	12,750	13.127	.377	1,080	1,182	,102	
6	14,370	14.873	.503	,927	,955		,028
		y/D = .15		$Q/D^{5/2}$ = 17.02			
1	4,870	4.936	.066	1,434	1,481	,047	
2	7,870	7.450	-.420	,945	,945		,000
3	10,250	9.964	-.286	1,284			
4	12,370	12.477	.107	,960	,960		-,000
5	14,250	14.359	.109	1,095	1,221	,126	
		y/D = .15		$Q/D^{5/2}$ = 18.87			
1	5,870	5.622	-.248	1,487	1,555	,068	
2	9,060	8.358	-.702	,960	,963		,003
3	11,500	11.094	-.406	1,350			
4	15,120	13.830	-1.290	,990	,982		-,008
		y/D = .20		$Q/D^{5/2}$ = 4.34			
1	,440	,240	-.200	1,131	1,200	,069	
2	2,120	1.287	-.833	,690	,650		-,040
3	2,620	2.333	-.287	,726			
4	3,000	3.379	.379	,666	,660		-,006
5	5,000	4.118	-.882	,735	,749	,014	
6	5,500	4.857	-.643	,705	,691		-,014
7	6,000	5.595	-.405	,729			
8	6,750	6.334	-.416	,702	,711		,009
9	7,500	7.072	-.428	,756	,769	,013	
10	8,310	7.811	-.499	,720	,745		,025
11	8,870	8.549	-.321	,762			
12	9,810	9.288	-.522	,741	,823		,082
		y/D = .20		$Q/D^{5/2}$ = 5.36			
1	,500	,616	.116	1,140	1,200	,060	
2	2,250	1.784	-.466	,723	,701		-,022
3	3,000	2.951	-.049	,750			
4	3,940	4.119	.179	,705	,714		,009
5	5,250	4.943	-.307	,762	,806	,044	
6	5,810	5.767	-.043	,741	,731		-,010
7	6,370	6.591	.221	,762			
8	7,000	7.415	.415	,744	,743		-,001
9	8,000	8.239	.239	,801	,807	,006	
10	8,690	9.063	.373	,756	,761		,005
11	9,440	9.887	.447	,789			
12	10,180	10.711	.531	,777	,780		,003
13	11,000	11.535	.535	,831	,845	,014	
14	11,940	12.359	.419	,804	,807		,003
15	12,440	13.183	.743	,825			
16	13,120	14.008	.888	,804	,829		,025
17	14,250	14.832	.582	,861	,910	,049	
		y/D = .20		$Q/D^{5/2}$ = 6.82			
1	,750	1.155	.405	1,191	1,200	,009	
2	2,810	2.496	-.314	,786	,764		-,022

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		y/D = .20		$Q/D^{5/2}$ = 6.82			
3	3,500	3.837	.337	,831			
4	4,560	5.177	.617	,768	,775		,007
5	6,000	6.124	.124	,855	,886	,031	
6	6,870	7.070	.200	,807	,790		-,017
7	7,620	8.017	.397	,840			
8	8,620	8.963	.343	,804	,802		-,002
9	9,810	9.910	.100	,879	,879	,000	
10	10,440	10.856	.416	,831	,816		-,015
11	11,120	11.802	.682	,876			
12	12,120	12.749	.629	,843	,830		-,013
13	13,310	13.695	.385	,924	,909	-,015	
14	14,000	14.642	.642	,855	,847		-,008
15	14,940	15.588	.648	,879			
		y/D = .20		$Q/D^{5/2}$ = 8.29			
1	1,120	1.697	.577	1,101	1,200	,099	
2	3,690	3.212	-.478	,840	,819		-,021
3	4,440	4.728	.288	,903			
4	5,810	6.243	.433	,825	,830		,005
5	7,750	7.313	-.437	,927	,965	,038	
6	8,370	8.382	.012	,855	,844		-,011
7	9,750	9.452	-.298	,888			
8	10,500	10.522	.022	,867	,857		-,010
9	11,870	11.591	-.279	,992	,949	-,043	
10	12,500	12.661	.161	,873	,870		-,003
11	13,250	13.731	.481	,915			
12	14,440	14.800	.360	,882	,883		,001
13	15,620	15.870	.250	,951	,975	,024	
		y/D = .20		$Q/D^{5/2}$ = 8.99			
1	1,440	1.955	.515	1,074	1,200	,126	
2	4,000	3.553	-.447	,852	,843		-,009
3	4,870	5.152	.282	,930			
4	6,120	6.751	.631	,855	,853		-,002
5	8,060	7.879	-.181	,954	,999	,045	
6	9,120	9.007	-.113	,870	,870		-,000
7	10,120	10.136	.016	,915			
8	10,810	11.264	.454	,879	,879		,000
9	12,620	12.392	-.228	,954	,980	,026	
10	13,310	13.520	.210	,894	,894		,000
11	14,310	14.649	.339	,924			
12	15,310	15.777	.467	,894	,907		,013
		y/D = .20		$Q/D^{5/2}$ = 9.41			
1	1,750	2.110	.360	1,044	1,200	,156	
2	4,440	3.758	-.682	,864	,850		-,014
3	5,370	5.407	.037	,969			
4	6,810	7.055	.245	,864	,861		-,003
5	8,750	8.219	-.531	,972	1,012	,040	
6	9,810	9.382	-.428	,894	,876		-.018
7	11,000	10.546	-.454	,939			
8	11,810	11.709	-.101	,897	,887		-.010
9	13,250	12.873	-.377	,954	,989	,035	
10	14,500	14.036	-.464	,906	,902		-,004

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D			d/D			
	TEST	EQ.	DIFF.	TEST	EQ.	DIFF.	DIFF.
		$y/D = .20$		$Q/D^{5/2} = 9.82$			
1	2,000	2.261	.261	1,026	1,200	,174	
2	4,500	3.958	-.542	,875	,856		-,019
3	5,500	5.655	.155	,960			
4	6,940	7.352	.412	,845	,867		,022
5	8,750	8.550	-.200	,990	1,023	,033	
6	10,000	9.748	-.252	,900	,882		-,018
7	11,120	10.946	-.174	,942			
8	12,000	12.144	.144	,900	,892		-,008
9	13,500	13.342	-.158	,966	,998	,032	
10	14,690	14.540	-.150	,906	,907		,001
		$y/D = .20$		$Q/D^{5/2} = 10.15$			
1	2,440	2.383	-.057	1,053	1,206	,153	
2	4,690	4.119	-.571	,876	,861		-,015
3	5,690	5.855	.165	,984			
4	7,310	7.592	.282	,879	,873		-,006
5	9,250	8.817	-.433	1,005	1,034	,029	
6	10,250	10.043	-.207	,915	,886		-,029
7	11,620	11.268	-.352	,957			
8	12,690	12.494	-.196	,915	,898		-,017
9	14,250	13.719	-.531	,981	1,008	,027	
10	15,250	14.945	-.305	,921	,912		-,009
		$y/D = .20$		$Q/D^{5/2} = 10.53$			
1	2,620	2.523	-.097	1,071	1,221	,150	
2	4,810	4.304	-.506	,894	,867		-,027
3	6,000	6.086	.086	1,026			
4	7,620	7.867	.247	,885	,879		-,006
5	9,500	9.125	-.375	1,011	1,045	,034	
6	10,500	10.382	-.118	,921	,892		-,029
7	11,750	11.639	-.111	,978			
8	13,000	12.897	-.103	,921	,904		-,017
9	14,750	14.154	-.596	,990	1,018	,028	
		$y/D = .20$		$Q/D^{5/2} = 11.03$			
1	2,750	2.707	-.043	1,077	1,241	,164	
2	4,870	4.548	-.322	,900	,874		-,026
3	6,190	6.389	.199	1,032			
4	7,690	8.230	.540	,891	,886		-,005
5	9,620	9.529	-.091	1,026	1,059	,033	
6	10,750	10.828	.078	,930	,899		-,031
7	12,000	12.127	.127	,984			
8	13,310	13.427	.117	,915	,910		-,005
9	15,000	14.726	-.274	1,014	1,029	,015	
		$y/D = .20$		$Q/D^{5/2} = 12.40$			
1	3,500	3.212	-.288	1,206	1,296	,090	
2	5,690	5.216	-.474	,909	,893		-,016
3	7,250	7.219	-.031	1,080			
4	9,440	9.223	-.217	,915	,907		-,008
5	11,000	10.637	-.363	1,065	1,099	,034	
6	12,500	12.051	-.449	,945	,919		-,026
7	14,000	13.465	-.535	,996			
8	15,500	14.879	-.621	,921	,931		,010

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

	x/D			d/D			
N	TEST	EQ.	DIFF.	TEST	EQ.	DIFF.	DIFF.
		y/D = .20		$Q/D^{5/2}$ = 14.00			
1	4.000	3.802	-.198	1.305	1.360	.055	
2	6.620	5.996	-.624	.915	.913		-.002
3	8.500	8.189	-.311	1.209			
4	10.620	10.383	-.237	.954	.926		-.028
5	12.120	11.931	-.189	1.080	1.142	.062	
6	14.190	13.479	-.711	.960	.940		-.020
7	15.250	15.027	-.223	.999			
		y/D = .20		$Q/D^{5/2}$ = 15.52			
1	4.560	4.363	-.197	1.380	1.421	.041	
2	7.250	6.737	-.513	.930	.930		-.000
3	9.750	9.111	-.639	1.287			
4	11.940	11.485	-.455	.960	.945		-.015
5	13.370	13.161	-.209	1.104	1.183	.079	
6	15.250	14.836	-.414	.969	.957		-.012
		y/D = .20		$Q/D^{5/2}$ = 17.02			
1	5.250	4.916	-.334	1.470	1.481	.011	
2	8.000	7.468	-.532	.966	.945		-.021
3	10.870	10.020	-.850	1.350			
4	13.000	12.572	-.428	.975	.961		-.014
5	14.750	14.374	-.376	1.110	1.223	.113	
		y/D = .20		$Q/D^{5/2}$ = 18.87			
1	6.000	5.598	-.402	1.500	1.555	.055	
2	9.250	8.370	-.880	.981	.963		-.018
3	12.250	11.142	-1.108	1.355			
4	14.750	13.914	-.836	.990	.980		-.010
		y/D = .25		$Q/D^{5/2}$ = 3.79			
1	.440	.046	-.394	1.068	1.250	.182	
2	1.810	1.076	-.734	.582	.597		.015
3	2.500	2.106	-.394	.597			
4	3.250	3.136	-.114	.534	.612		.078
5	4.500	3.823	-.677	.600	.685	.085	
6	5.000	4.509	-.491	.573	.635		.062
7	5.750	5.196	-.554	.597			
8	6.370	5.883	-.487	.573	.658		.085
9	7.500	6.569	-.931	.597	.722	.125	
10	8.120	7.256	-.864	.594	.705		.111
11	8.750	7.943	-.807	.630			
		y/D = .25		$Q/D^{5/2}$ = 4.34			
1	.620	.248	-.372	1.089	1.250	.161	
2	2.120	1.342	-.778	.597	.630		.033
3	2.440	2.437	-.003	.633			
4	3.250	3.531	.281	.576	.640		.064
5	4.440	4.261	-.179	.657	.716	.059	
6	5.190	4.991	-.199	.633	.659		.026
7	6.120	5.720	-.400	.627			
8	6.870	6.450	-.420	.609	.679		.070
9	7.500	7.180	-.320	.642	.731	.089	
10	8.000	7.909	-.091	.633	.695		.062
11	9.000	8.639	-.361	.684			
12	9.690	9.369	-.321	.657	.725		.068

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		y/D = .25		$Q/D^{5/2}$ = 4.34			
13	10.560	10.098	-.462	.714	.789	.075	
14	11.250	10.828	-.422	.678	.768		.090
15	12.000	11.558	-.442	.708			
		y/D = .25		$Q/D^{5/2}$ = 5.36			
1	.690	.622	-.068	1.119	1.250	.131	
2	2.690	1.836	-.854	.726	.685		-.041
3	2.870	3.050	.180	.759			
4	4.250	4.264	.014	.645	.696		.051
5	5.870	5.074	-.796	.762	.789	.027	
6	6.500	5.883	-.617	.747	.714		-.033
7	7.370	6.692	-.678	.780			
8	8.120	7.502	-.618	.753	.728		-.025
9	9.000	8.311	-.689	.777	.790	.013	
10	9.870	9.121	-.749	.774	.745		-.029
11	10.560	9.930	-.630	.801			
12	11.870	10.739	-1.131	.789	.767		-.022
13	12.370	11.549	-.821	.834	.827	-.007	
14	13.310	12.358	-.952	.792	.786		-.006
15	14.000	13.167	-.833	.807			
16	14.750	13.977	-.773	.795	.809		.014
17	15.750	14.786	-.964	.837	.882	.045	
		y/D = .25		$Q/D^{5/2}$ = 6.82			
1	.880	1.158	.278	1.140	1.250	.110	
2	3.250	2.543	-.707	.735	.755		.020
3	4.000	3.928	-.072	.807			
4	5.620	5.314	-.306	.768	.768		.000
5	6.560	6.237	-.323	.822	.877	.055	
6	7.500	7.161	-.339	.798	.780		-.018
7	8.810	8.084	-.726	.822			
8	9.620	9.007	-.613	.813	.795		-.018
9	10.120	9.931	-.189	.828	.866	.038	
10	11.310	10.854	-.456	.816	.807		-.009
11	11.870	11.778	-.092	.849			
12	12.690	12.701	.011	.828	.818		-.010
13	13.750	13.625	-.125	.873	.895	.022	
14	14.750	14.548	-.202	.828	.835		.007
15	15.500	15.471	-.029	.852			
16	16.250	16.395	.145	.834	.849		.015
17	17.120	17.318	.198	.867	.926	.059	
		y/D = .25		$Q/D^{5/2}$ = 8.29			
1	1.120	1.698	.578	1.056	1.250	.194	
2	3.810	3.255	-.555	.801	.816		.015
3	4.750	4.813	.063	.852			
4	6.620	6.370	-.250	.804	.831		.027
5	7.310	7.408	.098	.858	.959	.101	
6	8.750	8.447	-.303	.828	.843		.015
7	9.370	9.485	.115	.861			
8	11.200	10.523	-.677	.828	.857		.029
9	12.000	11.562	-.438	.852	.945	.093	
10	13.000	12.600	-.400	.849	.869		.020
11	14.000	13.638	-.362	.867			
12	14.750	14.676	-.074	.858	.880		.022
13	15.810	15.715	-.095	.888	.971	.083	
14	16.810	16.753	-.057	.852	.895		.043

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

	x/D			d/D			
N	TEST	EQ.	DIFF.	TEST	EQ.	DIFF.	DIFF.
		y/D = .25		$Q/D^{5/2}$ = 8.99			
1	1,500	1.955	.455	1,011	1,250	,239	
2	4,060	3.594	-.466	,804	,843		,039
3	4,810	5.234	.424	,882			
4	6,500	6.873	.373	,804	,855		,051
5	8,000	7.966	-.034	,906	,998	,092	
6	9,560	9,059	-.501	,855	,872		,017
7	10,500	10.152	-.348	,888			
8	11,370	11.245	-.125	,864	,882		,018
9	12,620	12,338	-.282	,906	,979	,073	
10	13,810	13.431	-.379	,867	,897		,030
11	14,750	14.524	-.226	,912			
12	15,500	15.617	.117	,873	,908		,035
13	16,620	16.710	.090	,924	1,005	,081	
		y/D = .25		$Q/D^{5/2}$ = 9.41			
1	1,750	2.109	.359	,944	1,250	,306	
2	4,250	3.798	-.452	,834	,850		,016
3	5,250	5.487	.237	1,041			
4	6,810	7.175	.365	,828	,862		,034
5	8,620	8.301	-.319	,897	1,012	,115	
6	10,250	9.427	-.823	,849	,879		,030
7	11,120	10.553	-.567	,900			
8	12,000	11.678	-.322	,849	,889		,040
9	13,500	12.804	-.696	,888	,992	,104	
10	14,750	13.930	-.820	,864	,905		,041
11	15,500	15,056	-.444	,885			
12	16,500	16.181	-.319	,864	,915		,051
		y/D = .25		$Q/D^{5/2}$ = 9.82			
1	2,250	2.260	.010	,978	1,250	,272	
2	4,500	3.996	-.504	,840	,856		,016
3	6,120	5.733	-.387	1,047			
4	7,120	7.470	.350	,837	,868		,031
5	8,880	8.628	-.252	,939	1,024	,085	
6	10,380	9.786	-.594	,852	,884		,032
7	11,380	10,943	-.437	,885			
8	12,380	12.101	-.279	,861	,894		,033
9	13,870	13.259	-.611	,918	1,000	,082	
10	15,380	14.417	-.963	,879	,910		,031
11	16,310	15.575	-.735	,897			
		y/D = .25		$Q/D^{5/2}$ = 10.15			
1	2,750	2.381	-.369	,987	1,250	,263	
2	4,940	4.156	-.784	,849	,861		,012
3	6,120	5,932	-.188	,933			
4	7,620	7.707	.087	,849	,873		,024
5	9,120	8.891	-.229	,966	1,032	,066	
6	10,810	10.074	-.736	,858	,888		,030
7	12,000	11.258	-.742	,900			
8	13,000	12.441	-.559	,858	,899		,041
9	14,500	13.625	-.875	,936	1,008	,072	
10	16,120	14.809	-1.311	,873	,915		,042
		y/D = .25		$Q/D^{5/2}$ = 10.53			
1	2,810	2.520	-.290	,969	1,250	,281	
2	5,060	4.340	-.720	,870	,867		-,003
3	6,080	6.160	.080	,963			

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		$y/D = .25$		$Q/D^{5/2} = 10.53$			
4	7,940	7.980	.040	,861	,879		,018
5	9,370	9.193	-.177	,927	1,044	,117	
6	10,810	10.407	-.403	,882	,892		,010
7	12,060	11.620	-.440	,927			
8	13,500	12.833	-.667	,888	,905		,017
9	15,000	14.047	-.953	,924	1,018	,094	
10	16,060	15.260	-.800	,864	,918		,054
		$y/D = .25$		$Q/D^{5/2} = 11.03$			
1	3,060	2.704	-.356	1,066	1,250	,184	
2	5,500	4.583	-.917	,876	,874		-,002
3	6,620	6.461	-.159	,975			
4	8,370	8.340	-.030	,879	,886		,007
5	10,000	9.592	-.408	,972	1,058	,086	
6	11,750	10.844	-.906	,894	,900		,006
7	12,750	12.097	-.653	,924			
8	13,810	13.349	-.461	,891	,910		,019
9	15,500	14.601	-.899	,963	1,028	,065	
10	17,000	15.854	-1.146	,894	,925		,031
		$y/D = .25$		$Q/D^{5/2} = 12.40$			
1	3,500	3.207	-.293	1,113	1,296	,183	
2	5,810	5.246	-.564	,876	,893		,017
3	7,500	7.285	-.215	1,047			
4	9,250	9.324	.074	,897	,906		,009
5	11,060	10.684	-.376	,969	1,099	,130	
6	12,310	12.043	-.267	,900	,918		,018
7	13,940	13.402	-.538	,933			
8	15,250	14.762	-.488	,894	,930		,036
9	17,250	16.121	-1.129	,954	1,062	,108	
		$y/D = .25$		$Q/D^{5/2} = 14.00$			
1	4,250	3.795	-.455	1,155	1,360	,205	
2	6,620	6.021	-.599	,909	,913		,004
3	8,120	8.248	.128	1,098			
4	10,500	10.474	-.026	,918	,926		,008
5	12,250	11.959	-.291	,996	1,142	,146	
6	13,750	13.443	-.307	,915	,938		,023
7	16,000	14.927	-1.073	,966			
		$y/D = .25$		$Q/D^{5/2} = 15.52$			
1	4,870	4.353	-.517	1,182	1,421	,239	
2	7,620	6.757	-.863	,936	,930		-,006
3	10,060	9.162	-.898	1,173			
4	11,500	11.567	.067	,942	,942		,000
5	13,500	13.170	-.330	,993	1,182	,189	
6	15,250	14.773	-.477	,933	,955		,022
7	17,620	16.376	-1.244	,963			
		$y/D = .25$		$Q/D^{5/2} = 18.10$			
1	5,500	5.300	-.200	1,287	1,524	,237	
2	9,000	8.007	-.993	,939	,956		,017
3	12,000	10.714	-1.286	1,233			
4	13,250	13.421	.171	,993	,969		-,024
5	16,000	15.226	-.774	1,017	1,250	,233	

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

	x/D			d/D			
N	TEST	EQ.	DIFF.	TEST	EQ.	DIFF.	DIFF.
		y/D = .25		$Q/D^{5/2}$ = 19.54			
1	6,250	5,829	-.421	1,293	1,582	,289	
2	10,000	8,705	-1.295	1,014	,969		-,045
3	12,750	11,580	-1.170	1,197			
4	14,500	14.456	-.044	1,041	,983		-,058
5	17,500	16.373	-1.127	1,038	1,286	,248	
		y/D = .30		$Q/D^{5/2}$ = 4.34			
1	,370	,259	-.111	1,191	1,300	,109	
2	2,060	1,394	-.666	,618	,610		-,008
3	2,690	2,529	-.161	,651			
4	3,690	3,664	-.026	,594	,622		,028
5	4,750	4,379	-.371	,669	,696	,027	
6	5,250	5,094	-.156	,612	,635		,023
7	6,000	5,809	-.191	,642			
8	6,750	6,525	-.225	,624	,649		,025
9	7,440	7,240	-.200	,690	,700	,010	
10	8,370	7,955	-.415	,636	,667		,031
11	8,940	8,670	-.270	,669			
12	9,870	9,385	-.485	,654	,686		,032
13	10,750	10,100	-.650	,702	,742	,040	
14	11,560	10,815	-.745	,681	,712		,031
15	12,000	11,530	-.470	,696			
16	12,690	12,245	-.445	,681	,736		,055
17	13,500	12,960	-.540	,720	,802	,082	
		y/D = .30		$Q/D^{5/2}$ = 5.36			
1	,500	,632	.132	1,206	1,300	,094	
2	2,370	1.885	-.485	,684	,670		-,014
3	3,000	3.138	.138	,714			
4	4,060	4.391	.331	,660	,680		,020
5	5,250	5.180	-.070	,738	,769	,031	
6	6,060	5.970	-.090	,690	,694		,004
7	6,440	6.759	.319	,708			
8	7,310	7.548	.238	,690	,704		,014
9	8,000	8.338	.338	,762	,763	,001	
10	8,940	9.127	.187	,705	,717		,012
11	9,560	9.916	.356	,738			
12	10,690	10.706	.016	,720	,732		,012
13	11,500	11.495	-.005	,765	,794	,029	
14	12,370	12.284	-.086	,735	,749		,014
15	12,750	13.074	.324	,771			
16	13,750	13.863	.113	,744	,765		,021
17	14,500	14.652	.152	,792	,828	,036	
		y/D = .30		$Q/D^{5/2}$ = 6.82			
1	,690	1.166	.476	1,239	1,300	,061	
2	2,750	2.588	-.162	,756	,745		-,011
3	3,620	4.010	.390	,804			
4	4,870	5.431	.561	,750	,757		,007
5	6,500	6.327	-.173	,840	,869	,029	
6	7,310	7.223	-.087	,783	,772		-,011
7	7,750	8.118	.368	,810			
8	8,750	9.014	.264	,786	,781		-,005
9	9,750	9.910	.160	,843	,856	,013	
10	10,620	10.805	.185	,804	,793		-,011
11	11,500	11.701	.201	,852			
12	12,250	12.597	.347	,810	,805		-,005

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		y/D = .30		$Q/D^{5/2}$ = 6.82			
13	13,500	13.492	-.008	,870	,883	,013	
14	14,440	14.388	-.052	,816	,822		,006
15	15,000	15.284	.284	,873			
		y/D = .30		$Q/D^{5/2}$ = 8.29			
1	1,000	1.703	.703	1,188	1,300	,112	
2	3,370	3.295	-.075	,807	,813		,006
3	4,250	4.887	.637	,855			
4	5,750	6.479	.729	,795	,825		,030
5	7,120	7.482	.362	,900	,957	,057	
6	8,120	8.484	.364	,822	,838		,016
7	9,120	9.487	.367	,846			
8	9,750	10.490	.740	,825	,847		,022
9	10,500	11.492	.992	,882	,935	,053	
10	11,690	12.495	.805	,825	,859		,034
11	12,870	13.498	.628	,864			
12	13,750	14.501	.751	,849	,873		,024
13	14,750	15.503	.753	,906	,962	,056	
		y/D = .30		$Q/D^{5/2}$ = 8.99			
1	1,190	1.959	.769	1,155	1,300	,145	
2	3,810	3.632	-.178	,825	,843		,018
3	5,000	5.305	.305	,885			
4	6,060	6.978	.918	,825	,854		,029
5	7,750	8.031	.281	,954	,998	,044	
6	8,810	9.085	.275	,855	,869		,014
7	9,870	10.139	.269	,864			
8	10,690	11.192	.502	,855	,879		,024
9	12,000	12.246	.246	,912	,977	,065	
10	12,810	13.300	.490	,855	,892		,037
11	14,060	14.353	.293	,885			
12	15,000	15.407	.407	,900	,906		,006
		y/D = .30		$Q/D^{5/2}$ = 9.41			
1	1,310	2.113	.803	1,128	1,300	,172	
2	4,250	3.834	-.416	,834	,850		,016
3	5,250	5.555	.305	,912			
4	6,560	7.277	.717	,834	,861		,027
5	8,060	8.361	.301	,987	1,009	,022	
6	9,440	9.445	.005	,861	,875		,014
7	10,250	10.530	.280	,909			
8	11,440	11.614	.174	,861	,886		,025
9	13,120	12.698	-.422	,918	,989	,071	
10	14,370	13.783	-.587	,858	,903		,045
11	15,250	14.867	-.383	,894			
		y/D = .30		$Q/D^{5/2}$ = 9.82			
1	1,440	2.263	.823	1,113	1,300	,187	
2	4,500	4.031	-.469	,849	,856		,007
3	5,370	5.800	.430	,927			
4	6,940	7.569	.629	,849	,867		,018
5	8,000	8.683	.683	,990	1,020	,030	
6	9,870	9.797	-.073	,885	,881		-,004
7	10,750	10.911	.161	,912			
8	12,000	12.026	.026	,882	,892		,010
9	13,310	13.140	-.170	,924	,997	,073	
10	14,500	14.254	-.246	,897	,906		,009

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		y/D = .30		$Q/D^{5/2}$ = 10.15			
1	1,690	2.383	.693	1,095	1,300	,205	
2	4,620	4,190	-.430	,852	,861		,009
3	5,690	5.997	.307	,939			
4	7,060	7.804	.744	,861	,872		,011
5	8,690	8,942	.252	1,005	1,032	,027	
6	10,190	10,080	-.110	,888	,887		-,001
7	11,000	11.219	.219	,930			
8	12,370	12,357	-.013	,900	,897		-,003
9	13,750	13,495	-.255	,930	1,006	,076	
		y/D = .30		$Q/D^{5/2}$ = 10.53			
1	1,940	2.522	.582	1,074	1,300	,226	
2	4,690	4.373	-.317	,900	,867		-,033
3	5,870	6.224	.354	,945			
4	7,310	8.075	.765	,870	,878		,008
5	8,810	9.241	.431	1,020	1,043	,023	
6	10,370	10.407	.037	,888	,892		,004
7	11,500	11.572	.072	,924			
8	12,620	12.738	.118	,888	,902		,014
9	14,440	13.904	-.536	,945	1,017	,072	
		y/D = .30		$Q/D^{5/2}$ = 11.03			
1	2,370	2.705	.335	1,065	1,300	,235	
2	4,870	4.614	-.256	,885	,874		-,011
3	6,250	6.522	.272	,954			
4	7,690	8.431	.741	,873	,886		,013
5	9,000	9.633	.633	1,026	1,057	,031	
6	10,500	10.836	.336	,894	,898		,004
7	11,810	12.038	.228	,945			
8	12,940	13.240	.300	,894	,909		,015
9	14,750	14.442	-.308	,960	1,027	,067	
		y/D = .30		$Q/D^{5/2}$ = 12.40			
1	3,250	3.206	-.044	1,122	1,300	,178	
2	5,370	5.273	-.097	,888	,893		,005
3	7,000	7.340	.340	1,020			
4	8,620	9.407	.787	,873	,905		,032
5	10,120	10.709	.589	1,083	1,097	,014	
6	11,810	12.011	.201	,912	,917		,005
7	13,250	13.313	.063	,975			
8	14,560	14.615	.055	,912	,929		,017
		y/D = .30		$Q/D^{5/2}$ = 14.00			
1	4,250	3.791	-.459	1,218	1,360	,142	
2	6,370	6.043	-.327	,909	,913		,004
3	8,250	8.295	.045	1,080			
4	10,000	10.547	.547	,927	,925		-,002
5	11,750	11.966	.216	1,125	1,141	,016	
6	13,870	13.384	-.486	,924	,939		,015
7	15,250	14.803	-.447	,990			
		y/D = .30		$Q/D^{5/2}$ = 15.52			
1	5,000	4.347	-.653	1,335	1,421	,086	
2	7,250	6.775	-.475	,936	,930		-,006
3	9,120	9.202	.082	1,245			

TABLE 2.--SUMMARY OF DATA AND AGREEMENT WITH EQUATIONS--CONTINUED

N	x/D TEST	x/D EQ.	x/D DIFF.	d/D TEST	d/D EQ.	d/D DIFF.	d/D DIFF.
		$y/D = .30$		$Q/D^{5/2} = 15.52$			
4	11,870	11,630	-.240	,960	,945		-,015
5	13,870	13.159	-.711	1,131	1,185	,054	
		$y/D = .30$		$Q/D^{5/2} = 16.67$			
1	5,500	4,767	-,733	1,401	1,467	,066	
2	8,500	7,328	-1.172	,954	,942		-,012
3	10,870	9,889	-,981	1,260			
4	13,250	12,450	-,800	,975	,957		-,018
5	14,750	14,063	-.687	1,140	1,212	,072	