ESTIMATING SMALL STREAM WATER FLOW

A rough but very rapid method of estimating water flow in small streams is given here. In looking for water sources for drinking, irrigation or power generation, one should survey all the streams available.

If sources are needed for use over a long period, it is necessary to collect information throughout the year to determine flow changes--especially high and low flows. The number of streams that must be used and the flow variations are important factors in determining the necessary facilities for utilizing the water.

Tools and Materials

Timing device, preferably watch with second hand

Measuring tape

Float (see below)

Stick for measuring depth

The following equation will help you to measure flow quickly: $Q = K \times A \times V$, where:

Q (Quantity) = flow in liters per minute

A (Area) = cross-section of stream, perpendicular to flow, in square meters

V (Velocity) = stream velocity, meters per minute

K (Constant) = a corrected conversion factor. This is used because surface flow is normally faster than average flow. For normal stages use K = 850; for flood stages use K = 900 to 950.

FIGURE 1

To Find A (Area) of a Cross-Section

The stream will probably have different depths along its length so select a place where the depth of the stream is average.

1. Take a measuring stick and place it upright in the water about 50cm from the bank.
2. Note the depth of water.
3. Move the stick 1 meter from the bank in a line directly across the stream.
4. Note the depth.
5. Move the stick 1.5 meters from the bank, note the depth, and continue moving it at 50cm intervals until you cross the stream.

Note the depth each time you place the stick upright in the stream. Draw a grid, like the one in Figure 2, and mark the varying depths on it so that a cross-section of the stream is shown. A scale of 1cm to 10cm is often used for such grids. By counting the grid squares and fractions of squares, the area of the water can be estimated. For example, the grid shown here has a little less than 4 square meters of water.

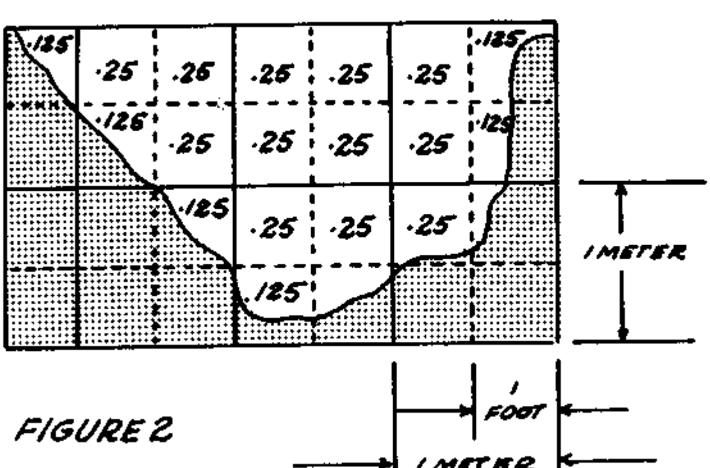


FIGURE 2

To Find V (Velocity)

Put a float in the stream and measure the distance of travel in one minute (or fraction of a minute, if necessary.) The width of the stream should be as constant as possible and free of rapids, where the velocity is being measured.

A light surface float, such as a chip, will often change course because of wind or surface currents. A weighted float which sits upright in the water will not change course so easily. A lightweight tube or tin can, partly filled with water or gravel so that it floats upright with only a small part showing above water, will not change course so easily and makes a better float for measuring.

Measuring Wide Streams

For a wide, irregular stream, it is better to divide the stream into 2 or 3 meter sections and measure the area and velocity of each. Q is then calculated for each section and the Qs added together to give a total flow.

Example (see Figure 2):

Cross section is 4 square meters

Velocity of float = 6 meters traveled in 1/2 minute

Stream flow is normal

$$Q = 850 \times 4 \times \frac{6 \text{ meters}}{.5 \text{ minute}}$$

Q = 40,800 liters per minute
or
680 liters per second

Using English Units

If English units of measurement are used, the equation for measuring stream flow is: Q = K x A x V, where:

Q = flow in U.S. gallons per minute

A = cross-section of stream, perpendicular to flow, in square feet

V = stream velocity in feet per minute

K = a corrected conversion factor: 6.4 for normal stages; 6.7 to 7.1 for flood stages

The grid to be used would be similar to the one in Figure 3; a commonly used scale is 1" to 12".

Example:

Cross-section is 15 square feet

Velocity of float = 20 feet traveled in 1/2 minute

Stream flow is normal

$$Q = 6.4 \times 15 \times \frac{20 \text{ feet}}{.5 \text{ minute}}$$

Q = 3800 gallons per minute

Source:

Design of Fishways and Other Fish Facilities by C. H. Clay, P. E. Department of Fisheries of Canada, Ottawa, 1961.

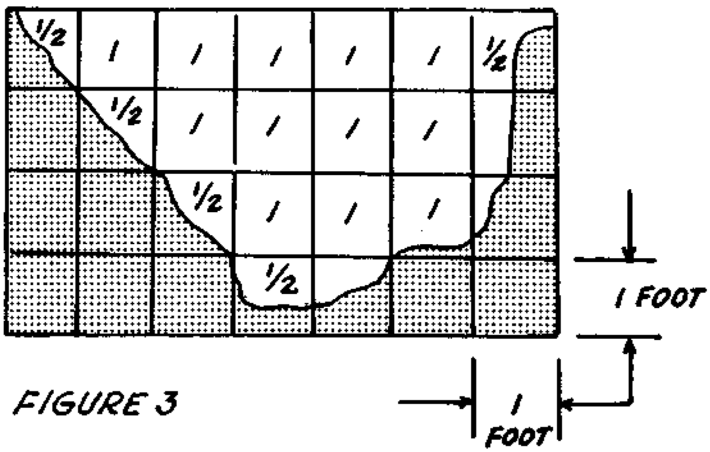


FIGURE 3

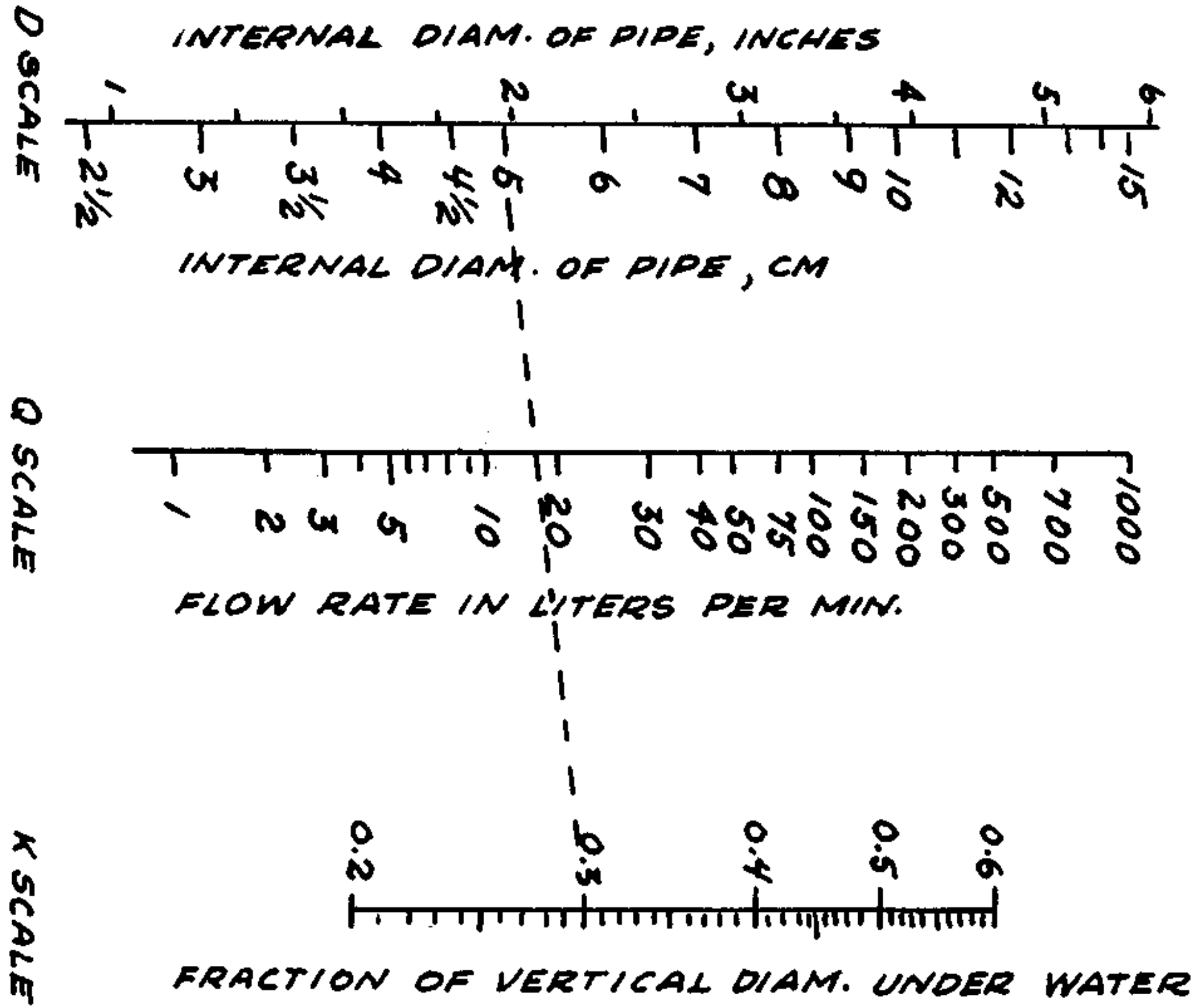

D SCALE
INTERNAL DIAM. OF PIPE, INCHES
1
2
3
4
5
6
2½
3
3½
4
4½
5
6
7
8
9
10
12
15
INTERNAL DIAM. OF PIPE, CM
Q SCALE
1
2
3
5
10
20
30
40
50
75
100
150
200
300
500
700
1000
FLOW RATE IN LITERS PER MIN.
K SCALE
0.2
0.3
0.4
0.5
0.6
FRACTION OF VERTICAL DIAM. UNDER WATER

FIGURE 2

MEASURING THE FLOW OF WATER IN PARTIALLY FILLED PIPES

The flow of water in partially-filled horizontal pipes or circular channels can be determined--if you know the inside diameter of the pipe and the depth of the water flowing--by using the alignment chart (nomograph) in Figure 2.

This method can be checked for low flow rates and small pipes by measuring the time required to fill a bucket or drum with a weighed quantity of water. A liter of water weighs 1kg (1 U.S. gallon of water weighs 8.33 pounds).

Tools and Materials

Ruler to measure water depth (if ruler units are inches, multiply by 2.54 to convert to centimeters)

Straight edge, to use with alignment chart

The alignment chart applies to pipes with 2.5cm to 15cm inside diameters, 20 to 60% full of water, and having a reasonably smooth surface (iron, steel, or concrete sewer pipe). The pipe or channel must be reasonably horizontal if the result is to be accurate. The eye, aided by a plumb bob line to give a vertical reference, is a sufficiently good judge. If the pipe is not horizontal another method will have to be used. To use the alignment chart, simply connect the proper point on the "K" scale with the proper point of the "d" scale with the straight edge. The flow rate can then be read from the "q" scale.

q = rate of flow of water, liters per minute 8.33 pounds = 1 gallon.

d = internal diameter of pipe in centimeters.

K = decimal fraction of vertical diameter under water. Calculate K by measuring the depth of water (h) in the pipe and dividing it by the pipe diameter (d), or $K = \frac{h}{d}$ (see Figure 1).

Example:

What is the rate of flow of water in a pipe with an internal diameter of 5cm running 0.3 full? A straight line connecting 5 on the d-scale with 0.3 on the K-scale intersects the q-scale at a flow of 18 liters per minute.

Source:

Greve Bulletin, Purdue University (12, No. 5, 1928, Bulletin 32).

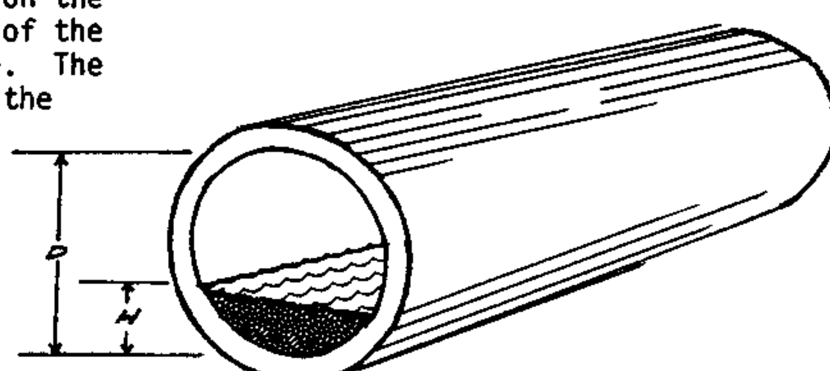
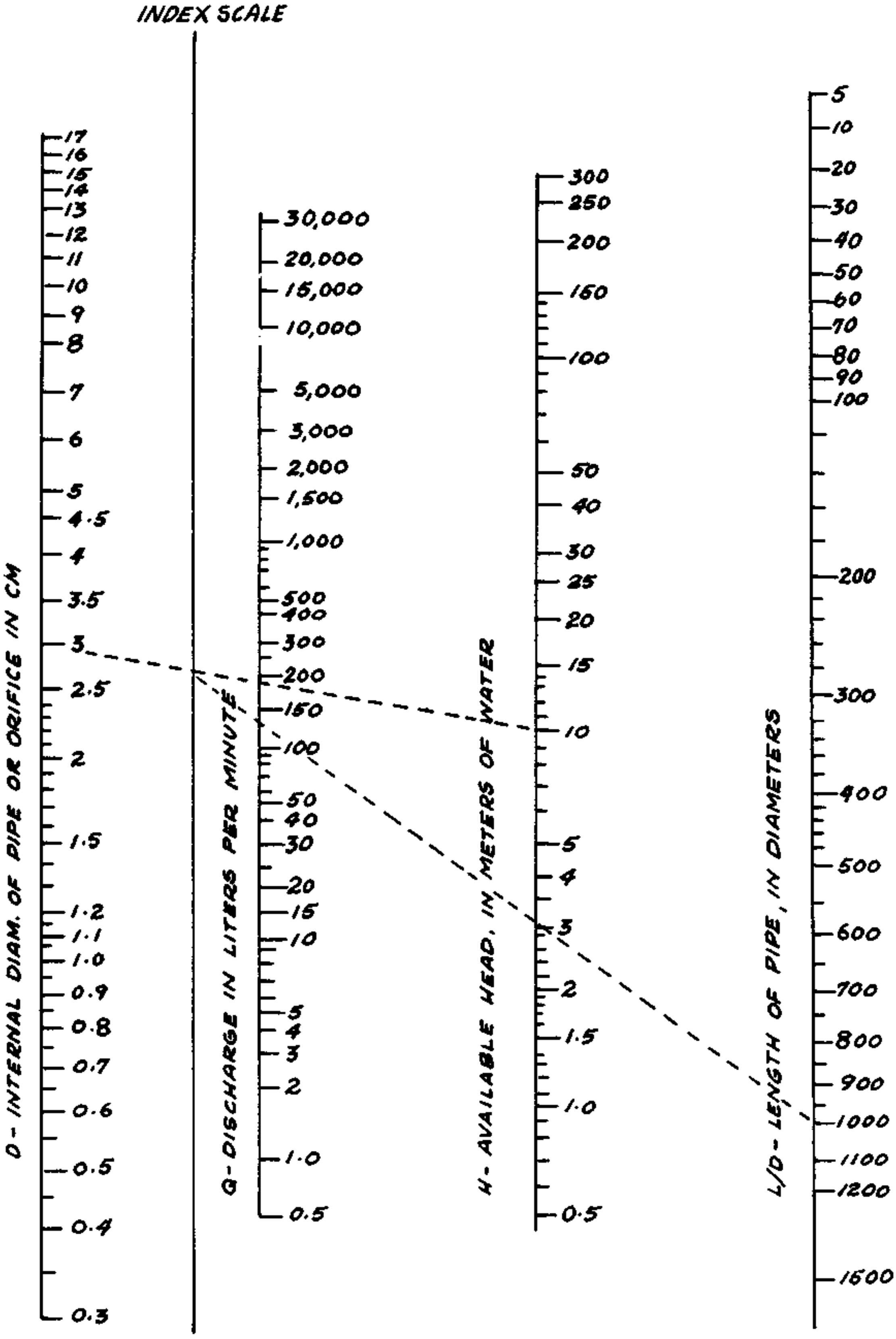


FIGURE 1

FIGURE 1



Alignment chart for determining probable water flow with known reservoir height and size and length of pipe.

DETERMINING PROBABLE WATER FLOW WITH KNOWN RESERVOIR HEIGHT AND SIZE AND LENGTH OF PIPE

The alignment chart in Figure 1 gives a reasonably accurate determination of water flow when pipe size, pipe length and height of the supply reservoir are known.

The example given here is for the analysis of an existing system. To design a new system, assume a pipe diameter and solve for flow-rate, repeating the procedure with new assumed diameters until one of them provides a suitable flow rate.

Materials

Straight edge, for use with alignment chart

Surveying instruments, if available

The alignment chart was prepared for clean, new steel pipe. Pipes with rougher surfaces or steel or cast iron pipe which has been in service for a long time may give flows as low as 50 percent of those predicted by this chart.

The available head (h) is in meters and is taken as the difference in elevation between the supply reservoir and the point of demand. This may be crudely estimated by eye, but for accurate results some sort of surveying instruments are necessary.

For best results, the length of pipe (L) used should include the equivalent lengths of fittings as described in handbook entry "Flow Resistance of Pipe Fittings," p. 80. This length (L) divided by the pipe internal diameter (D) gives the necessary "L/D" ratio. In calculating L/D, note that the units of measuring both "L" and "D" must be the same, e.g.: feet divided by feet; meters divided by meters; centimeters by centimeters.

Example:

Given Available Head (h) of 10 meters, pipe internal diameter (D) of 3cm, and equivalent pipe length (L) of 30 meters = 3000cm.

$$\text{Calculate } L/D = \frac{3000\text{cm}}{3\text{cm}} = 1000$$

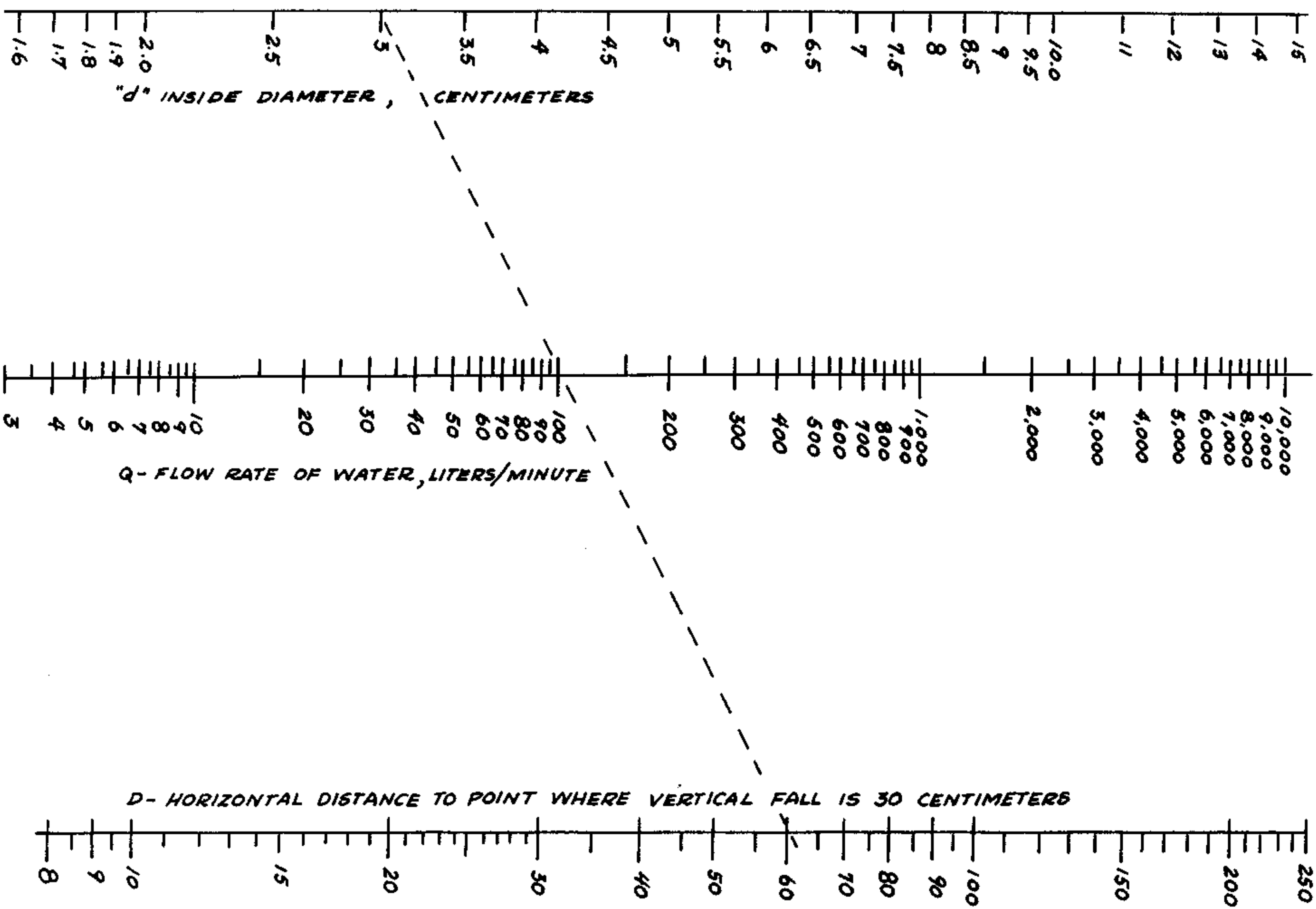
The alignment chart solution is in two steps:

1. Connect Internal Diameter 3cm to Available Head (10 meters), and make a mark on the Index Scale. (In this step, disregard "Q" scale)

2. Connect mark on Index Scale with L/D (1000), and read flow rate (Q) of approximately 140 liters per minute.

Source:

Crane Company Technical Paper #407, pages 54-55.



"d" SCALE
1.6 1.7 1.8 1.9 2.0 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10.0 11 12 13 14 15
"d" INSIDE DIAMETER, CENTIMETERS
"Q" SCALE
3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 90 100 200 300 400 500 600 700 800 900 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000 9,000 10,000
Q- FLOW RATE OF WATER, LITERS/MINUTE
"D" SCALE
D- HORIZONTAL DISTANCE TO POINT WHERE VERTICAL FALL IS 30 CENTIMETERS
8 9 10 15 20 30 40 50 60 70 80 90 100 150 200 250

FIGURE 2

ESTIMATING WATER FLOW FROM HORIZONTAL PIPES

If a horizontal pipe is discharging a full stream of water, you can estimate the rate of flow from the alignment chart in Figure 2. This is a standard engineering technique for estimating flows; its results are usually accurate to within 10 percent of the actual flow rate.

Materials

Straightedge and pencil, to use alignment chart

Tape measure

Level

Plumb bob

The water flowing from the pipe must completely fill the pipe opening (see Figure 1). The results from the chart will be most accurate when there is no constricting or enlarging fitting at the end of the pipe.

Example:

Water is flowing out of a pipe with an inside diameter (d) of 3cm (see Figure 1). The stream drops 30cm at a point 60cm from the end of the pipe.

Connect the 3cm inside diameter point on the "d" scale in Figure 2 with the 60cm point on the "D" scale. This line intersects the "q" scale at about 100 liters per minute, the rate at which water is flowing out of the pipe.

Source:

"Flow of Water from Horizontal Open-end Pipes," by Clifford L. Duckworth, Chemical Processing, June 1959, p. 73.

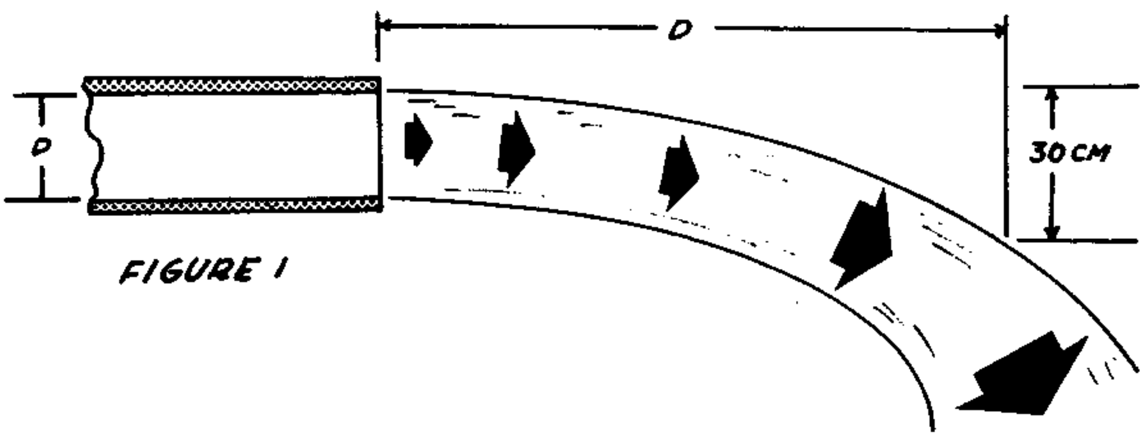


FIGURE 1

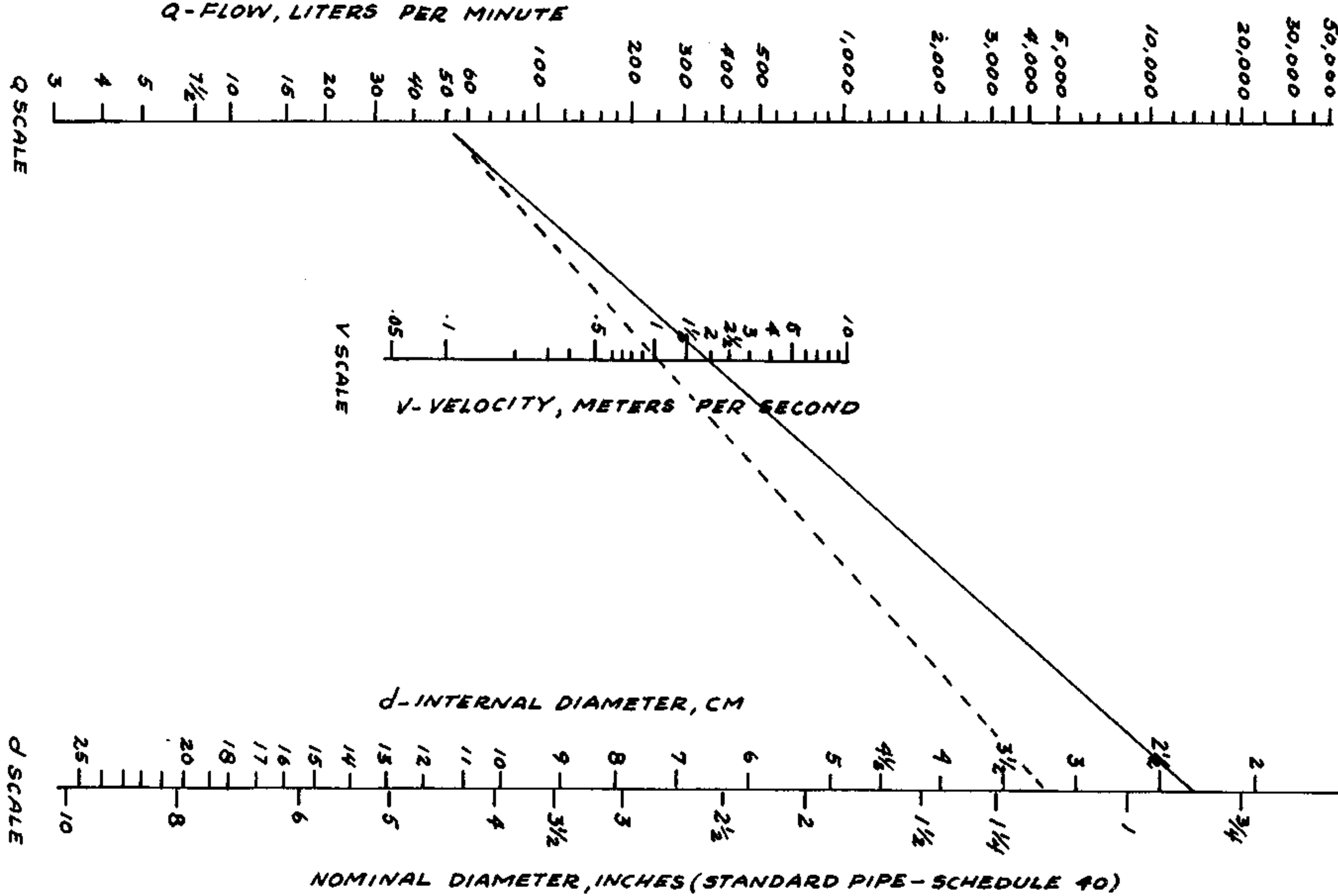

Q-FLOW, LITERS PER MINUTE
Q SCALE
3 4 5 7½ 10 15 20 30 40 50 60 100 200 300 400 500 1,000 2,000 3,000 4,000 5,000 10,000 20,000 30,000 50,000
V SCALE
.05 .1 .5 1 1½ 2 2½ 3 4 6 10
V-VELOCITY, METERS PER SECOND
d-INTERNAL DIAMETER, CM
d SCALE
25 20 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4½ 4 3½ 3 2½ 2 1½
10 8 6 5 4 3½ 3 2½ 2 1½ 1¼ 1 ¾ ½
NOMINAL DIAMETER, INCHES (STANDARD PIPE-SCHEDULE 40)

FIGURE 1

DETERMINING PIPE SIZE OR VELOCITY OF WATER IN PIPES

The choice of pipe size is one of the first steps in designing a simple water system.

The alignment chart in Figure 1 can be used to compute the pipe size needed for a water system when the water velocity is known. The chart can also be used to find out what water velocity is needed with a given pipe size to yield the required rate of flow.

Tools and Materials

Straightedge and pencil

Practical water systems use water velocities from 1.2 to 1.8 meters per second. Very fast velocity requires high pressure pumps which in turn require high pressure pumps which in turn require large motors and use excessive power. Velocities which are too low are expensive because larger pipe diameters must be used.

It may be advisable to calculate the cost of two or more systems based on different pipe size. Remember, it is usually wise to choose a little larger pipe if higher flows are expected in the next 5 or 10 years. In addition, water pipes often build up rust and scale reducing the diameter and thereby increasing the velocity and pump pressure required to maintain flow at the original rate. If extra capacity is designed into the piping system, more water can be delivered by adding to the pump capacity without changing all the piping.

To use the chart, locate the flow (liters per minute) you need on the Q-scale. Draw a line from that point, though 1.8m/sec velocity on the V-scale to the d-scale. Choose the nearest standard size pipe.

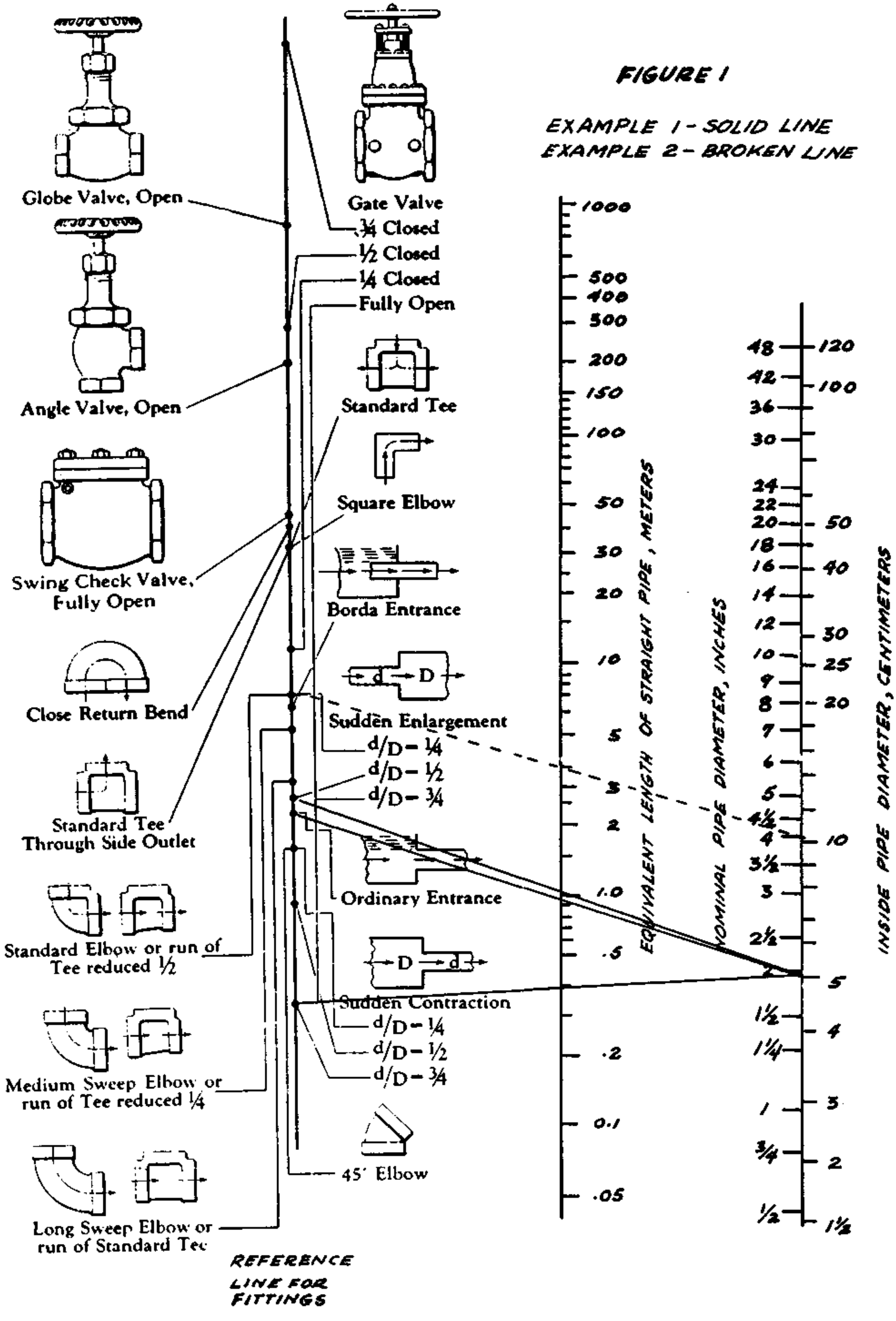
Example:

Suppose you need a flow of 50 liters per minute at the time of peak demand. Draw a line from 50 liters per minute on the Q-scale through 1.8m/sec on the V-scale. Notice that this intersects the d-scale at about 2.25. The correct pipe size to choose would be the next largest standard pipe size: e.g. 1" nominal diameter, U.S. Schedule 40. If pumping costs (electricity or fuel) are high, it would be well to limit velocity to 1.2m/sec and install a slightly larger pipe size.

Source:

Crane Company Technical Paper #409, pages 46-47.

Resistance of Valves and Fittings to Flow of Fluids



ESTIMATING FLOW RESISTANCE OF PIPE FITTINGS

One of the forces which a pump must overcome to deliver water is the friction/resistance of pipe fittings and valves to the flow of water. Any bends, valves, constrictions or enlargements (such as passing through a tank) add to friction.

The alignment chart in Figure 1 gives a simple but reliable way to estimate this resistance: it gives the equivalent length of straight pipe which would have the same resistance. The sum of these equivalent lengths is then added to the actual length of pipe: this gives the total equivalent pipe length, which is used in the following entry, "Determining Pump Capacity and Horsepower Requirement," to determine total friction loss.

Rather than calculate the pressure drop for each valve or fitting separately, this chart will give the equivalent length of straight pipe.

Valves: Note the difference in equivalent length depending on how far the valve is open.

1. Gate Valve - full opening valve; can see through it when open; used for complete shut off of flow.

2. Globe Valve - cannot see through it when open; used for regulating flow.

3. Angle Valve - like the globe, used for regulating flow.

4. Swing Check Valve - a flapper opens to allow flow in one direction but closes when water tries to flow in the opposite direction.

Fittings

Study the variety of tees and elbows: note carefully the direction of flow through the tee. To determine the equivalent length of a fitting, (a) pick proper dot on "fitting" line, (b) connect with inside diameter of pipe, using a straight edge; read equivalent length of straight pipe in meters, (c) add the fitting equivalent length to the actual length of pipe being used.

Source:

Crane Company Technical Paper #409, pages 20-21.

Example 1:

Pipe with 5cm inside diameter	Equivalent Length in Meters
a. Gate Valve (fully open)	.4
b. Flow into line - ordinary entrance	1.0
c. Sudden enlargement into 10cm pipe ($d/D = 1/2$)	1.0
d. Pipe length	10.0
Total Equivalent Pipe Length	12.4

Example 2:

Pipe with 10cm inside diameter	Equivalent Length in Meters
a. Elbow (standard)	4.0
b. Pipe length	10.0
Total Equivalent Pipe Length	14.0

With the alignment chart in Figure 2, you can determine the necessary pump size (diameter of discharge outlet) and the amount of horsepower needed to power the pump. The power can be supplied by men or by motors.

A man can generate about 0.1 horsepower (HP) for a reasonably long period and 0.4 HP for short bursts. Motors are designed for varying amounts of horsepower.

Tools

Straight edge and pencil for alignment chart

To get the approximate pump size needed for lifting liquid to a known height through simple piping, follow these steps:

1. Determine the quantity of flow desired in liters per minute.

2. Measure the height of the lift required (from the point where the water enters the pump suction piping to where it discharges).

3. Using the entry "Determining Pipe Size or Velocity of Water in Pipes," page 78, choose a pipe size which will give a water velocity of about 1.8 meters per second (6' per second). This velocity is chosen because it will generally give the most economical combination of pump and piping; Step 5 explains how to convert for higher or lower water velocities.

4. Estimate the pipe friction-loss "head" (a 3-meter "head" represents the pressure at the bottom of a 2-meter-high column of water) for the total equivalent pipe length, including suction and discharge piping and equivalent pipe lengths for valves and fittings, using the following equation:

   Friction-loss head =

   $$\frac{F \times \text{total equivalent pipe length}}{100}$$

   where F equals approximate friction head (in meters) per 100 meters of pipe. To get the value of F, see the table in Figure 1. For an explanation of total equivalent pipe length, see the preceding entry.

5. To find F (approximate friction head in meters per 100m of pipe) when water velocity is higher or lower than 1.8 meters per second, use the following equation:

   $$F = \frac{F_{\text{at } 1.8\text{m/sec}} \times V^2}{1.8\text{m/sec}^2},$$

   where V = higher or lower velocity

   Example:

   If the water velocity is 3.6m per second and $F_{\text{at } 1.8\text{m/sec}}$ is 16, then:

   $$F = \frac{16 \times 3.6^2}{1.8^2} = \frac{16 \times 13}{3.24} = 64$$

6. Obtain "Total Head" as follows: Total Head = Height of Lift + Friction-loss Head

Pipe inside diameter: cm	2.5	5.1	7.6	10.2	15.2	20.4	30.6	61.2
inches*	1"	2"	3"	4"	6"	8"	12"	24"
F (approximate friction loss in meters per 100 meters of pipe)	16	7	5	3	2	1.5	1	0.5

Figure 1. Average friction loss in meters for fresh water flowing through steel pipe when velocity is 1.8 meters (6 feet) per second.

*For the degree of accuracy of this method, either actual inside diameter in inches or nominal pipe size, U.S. Schedule 40, can be used.

7. Using a straight edge, connect the proper point on the T-scale with the proper point on the Q-scale; read motor horsepower and pump size on the other two scales.

   Example:

   Desired flow: 400 liters per minute

   Height of lift: 16 meters, No fittings

   Pipe size: 5cm

   Friction-loss head: about 1 meter

   Total head: 17 meters

   Solution:

   Pump size: 5cm

   Motor horsepower: 3HP

Note that water horsepower is less than motor horsepower (see HP-scale, Figure 2). This is because of friction losses in the pump and motor. The alignment chart should be used for rough estimate only. For an exact determination, give all information on flow and piping to a pump manufacturer or an independent expert. He has the exact data on pumps for various applications. Pump specifications can be tricky especially if suction piping is long and the suction lift is great.

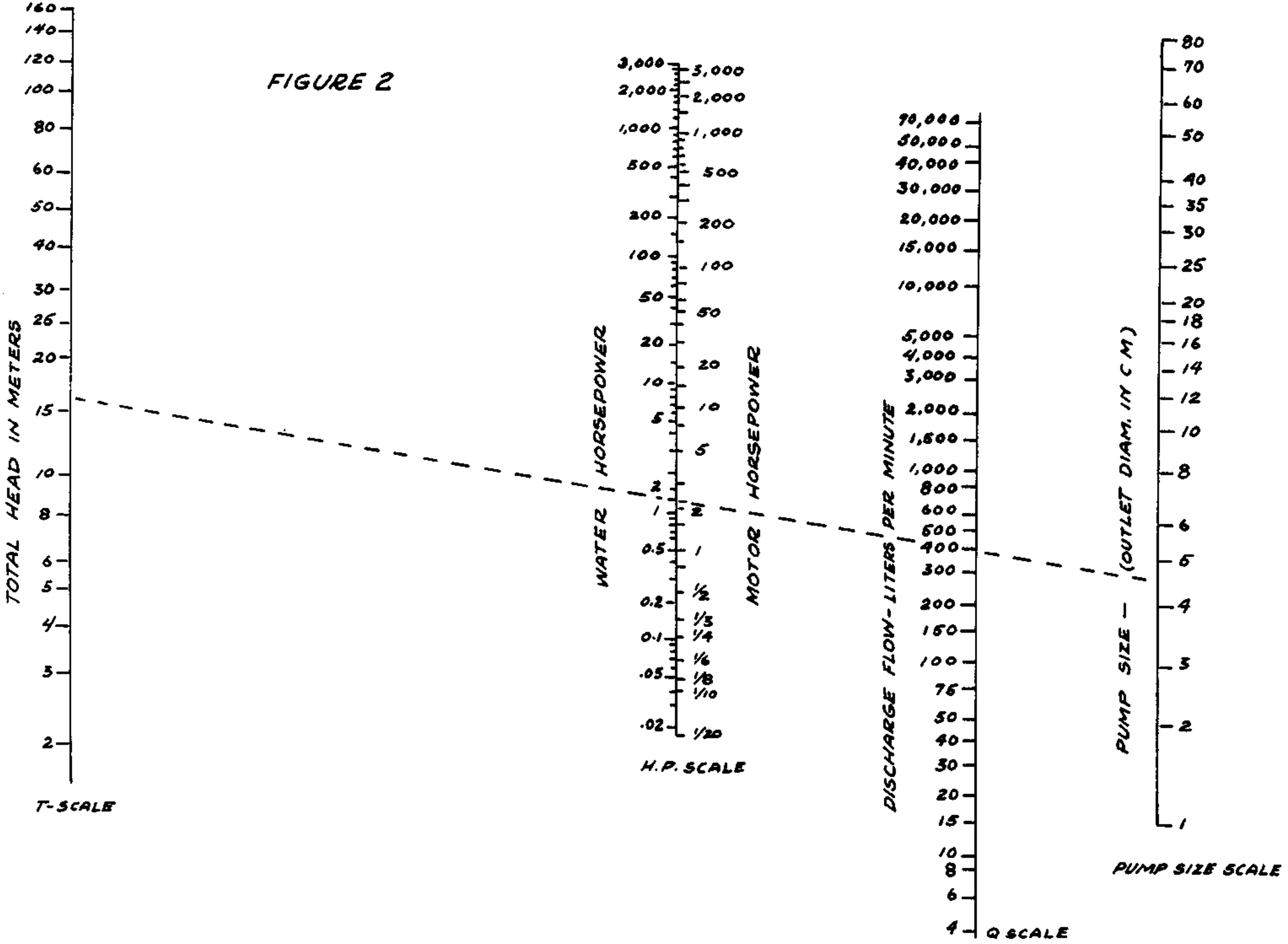
Conversion to Metric Horsepower

Given the limits of accuracy of this method, metric horsepower can be considered roughly equal to the horsepower indicated by the alignment chart. Actual metric horsepower can be obtained by multiplying horsepower by 1.014.

Source:

Nomographic Charts, by C. A. Kulman, McGraw-Hill Book Co., New York, 1951, pages 108-109.

FIGURE 2



TOTAL HEAD IN METERS
T-SCALE
WATER HORSEPOWER
MOTOR HORSEPOWER
H.P. SCALE
DISCHARGE FLOW-LITERS PER MINUTE
Q SCALE
PUMP SIZE — (OUTLET DIAM. IN CM)
PUMP SIZE SCALE

DETERMINING LIFT PUMP CAPABILITY

The height that a lift pump can raise water depends on altitude and, to a lesser extent, on water temperature. The graph in Figure 1 will help you to find out what a lift pump can do at various altitudes and water temperatures.

Tools

Measuring tape

Thermometer

If you know your altitude and the temperature of your water, Figure 1 will tell you the maximum allowable distance between the pump cylinder and the lowest water level expected. If the graph shows that lift pumps are marginal or will not work, then a force pump should be used. This involves putting the cylinder down in the well, close enough to the lowest expected water level to be certain of proper functioning.

The graph shows normal lifts. Maximum possible lifts under favorable conditions would be about 1.2 meters higher, but this would require slower pumping and would probably give much difficulty in "losing the prime."

Check predictions from the graph by measuring lifts in nearby wells or by experimentation.

Source:

Mechanical Engineer's Handbook, by Theodore Baumeister, 6th edition, McGraw-Hill Book Co., New York, copyright 1958. Used by permission. (Adapted.)

Example:

Suppose your elevation is 2000 meters and the water temperature is 25C. The graph shows that the normal lift would be 4 meters.

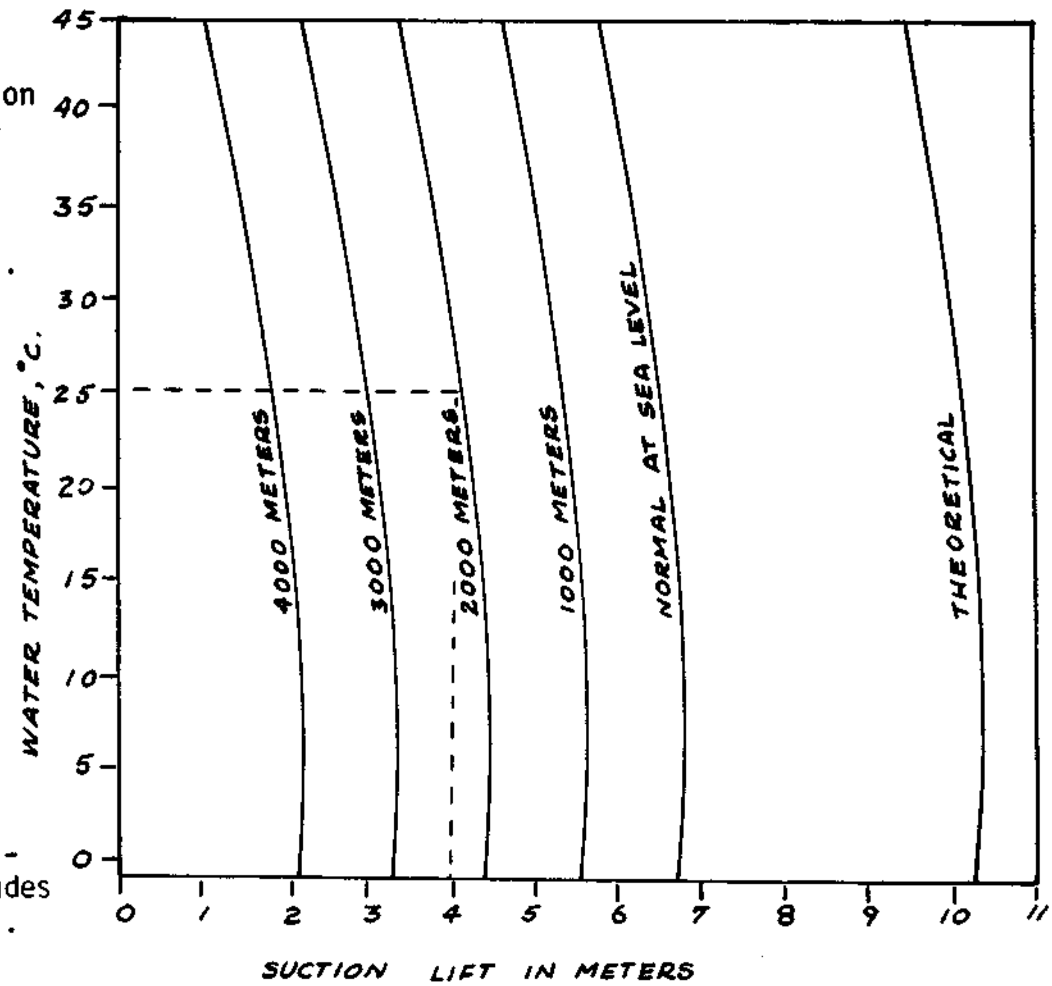


FIGURE 1

Figure 1. Graph showing lift pump capabilities at various altitudes and water temperatures. Broken lines indicate example given in text.

WATER, PRESSURE AND FLOW. Water is composed of two gases, hydrogen and oxygen, in the ratio of two volumes of the former to one of the latter. Water boils under atmospheric pressure at 212 degrees F. and freezes at 32 degrees F. Its greatest density is at 39.1 degrees F., when it weighs 62.425 pounds per cubic foot. The pressure in pounds per square inch of water that is not moving, against the sides of any pipe, vessel, container, or dam is due solely to the "head" or height of the surface of the water above the point at which the pressure is considered. The pressure is equal to 0.433 pound per square inch for every foot of the head, at a temperature of 62 degrees F. For higher temperatures, the pressure slightly decreases in the proportion indicated by the table "Weight of Water per Cubic Foot at Different Temperatures." The pressure per square inch is equal in all directions, downwards, upwards, and sideways. Water can be compressed only in a very slight degree, the compressibility being so slight that, even at the depth of a mile, a cubic foot of water weighs only about one-half pound more than at the surface.

Flow of Water in Pipes. — The quantity of water that will be discharged through a pipe depends primarily upon the head and also upon the diameter of the pipe, the character of the interior surface, and the number and shape of the bends. The head may be either the actual distance between the levels of the surface of water in a reservoir and the point of discharge, or it may be caused by mechanically applied pressure, as by pumping, in which case the head is calculated as the vertical distance corresponding to the pressure. One pound per square inch is equal to 2.309 feet head, or 1 foot head is equal to a pressure of 0.433 pound per square inch.

All formulas for finding the amount of water that will flow through a pipe in a given time are approximate. The formula below will give results within 5 or 10 per cent of actual results, if applied to pipe lines carefully laid and in a fair condition.

$$V = C\sqrt{\frac{hD}{L + 54\,D}},$$

in which

V = approximate mean velocity in feet per second;
C = coefficient from table;
D = diameter of pipe in feet;
h = total head in feet;
L = total length of pipe line in feet.

Values of Coefficient C

Diameter of Pipe		C	Diameter of Pipe		C
Feet	Inches		Feet	Inches	
0.1	1.2	23	2.0	24	57
0.2	2.4	30	2.5	30	60
0.3	3.6	34	3.0	36	62
0.4	4.8	37	3.5	42	64
0.5	6.0	39	4.0	48	66
0.6	7.2	42	5.0	60	68
0.7	8.4	44	6.0	72	70
0.8	9.6	46	7.0	84	72
0.9	10.8	47	8.0	96	74
1.0	12.0	48	10.0	120	77
1.5	18.0	53	....	....	....

Example. — A pipe line, 1 mile long, 12 inches in diameter, discharges water under a head of 100 feet. Find the velocity and quantity of discharge.

From the table, the coefficient C is found to be 48 for a pipe 1 foot in diameter; hence:

$$V = 48\sqrt{\frac{100 \times 1}{5280 + 54 \times 1}} = 6.57 \text{ feet per second.}$$

To find the discharge in cubic feet per second, multiply the velocity found by the area of cross-section of the pipe in square feet:

$$6.57 \times 0.7854 = 5.16 \text{ cubic feet per second.}$$

The loss of head due to a bend in the pipe is most frequently given in the equivalent length of straight pipe, which would cause the same loss in head as the bend.

Weight of Water per Cubic Foot at Different Temperatures

Temp. Deg. F.	Weight per Cubic Foot, Pounds	Temp. Deg. F.	Weight per Cubic Foot, Pounds	Temp. Deg. F.	Weight per Cubic Foot, Pounds	Temp. Deg. F.	Weight per Cubic Foot, Pounds
32	62.42	180	60.55	320	56.66	470	50.2
40	62.42	190	60.32	330	56.30	480	49.7
50	62.41	200	60.12	340	55.94	490	49.2
60	62.37	210	59.88	350	55.57	500	48.7
70	62.31	212	59.83	360	55.18	510	48.1
80	62.23	220	59.63	370	54.78	520	47.6
90	62.13	230	59.37	380	54.36	530	47.0
100	62.02	240	59.11	390	53.94	540	46.3
110	61.89	250	58.83	400	53.50	550	45.6
120	61.74	260	58.55	410	53.00	560	44.9
130	61.56	270	58.26	420	52.6	570	44.1
140	61.37	280	57.96	430	52.2	580	43.3
150	61.18	290	57.65	440	51.7	590	42.6
160	60.98	300	57.33	450	51.2	600	41.8
170	60.77	310	57.00	460	50.7	.....	.....

Volume of Water at Different Temperatures

Degrees F.	Volume	Degrees F.	Volume	Degrees F.	Volume
39.1	1.00000	104	1.00767	167	1.02548
50	1.00025	113	1.00967	176	1.02872
59	1.00083	122	1.01186	185	1.03213
68	1.00171	131	1.01423	194	1.03570
77	1.00286	140	1.01678	203	1.03943
86	1.00425	149	1.01951	212	1.04332
95	1.00586	158	1.02241	....	....

Experiments show that a right-angle bend should have a radius of about three times the diameter of the pipe. Assuming this curvature, then, if D is the diameter of the pipe in inches and L is the length of straight pipe in feet which causes the same loss of head as the bend in the pipe, the following formula gives the equivalent length of straight pipe that should be added to compensate for a right-angle bend:

$$L = 4\,D \div 3.$$

Thus the loss of head due to a right-angle bend in a 6-inch pipe would be equal to that in 8 feet of straight pipe. Experiments undertaken to determine the losses due to valves in pipe lines indicate that a fully open gate valve in a pipe causes a loss of head corresponding to that in a length of pipe equal to six diameters.