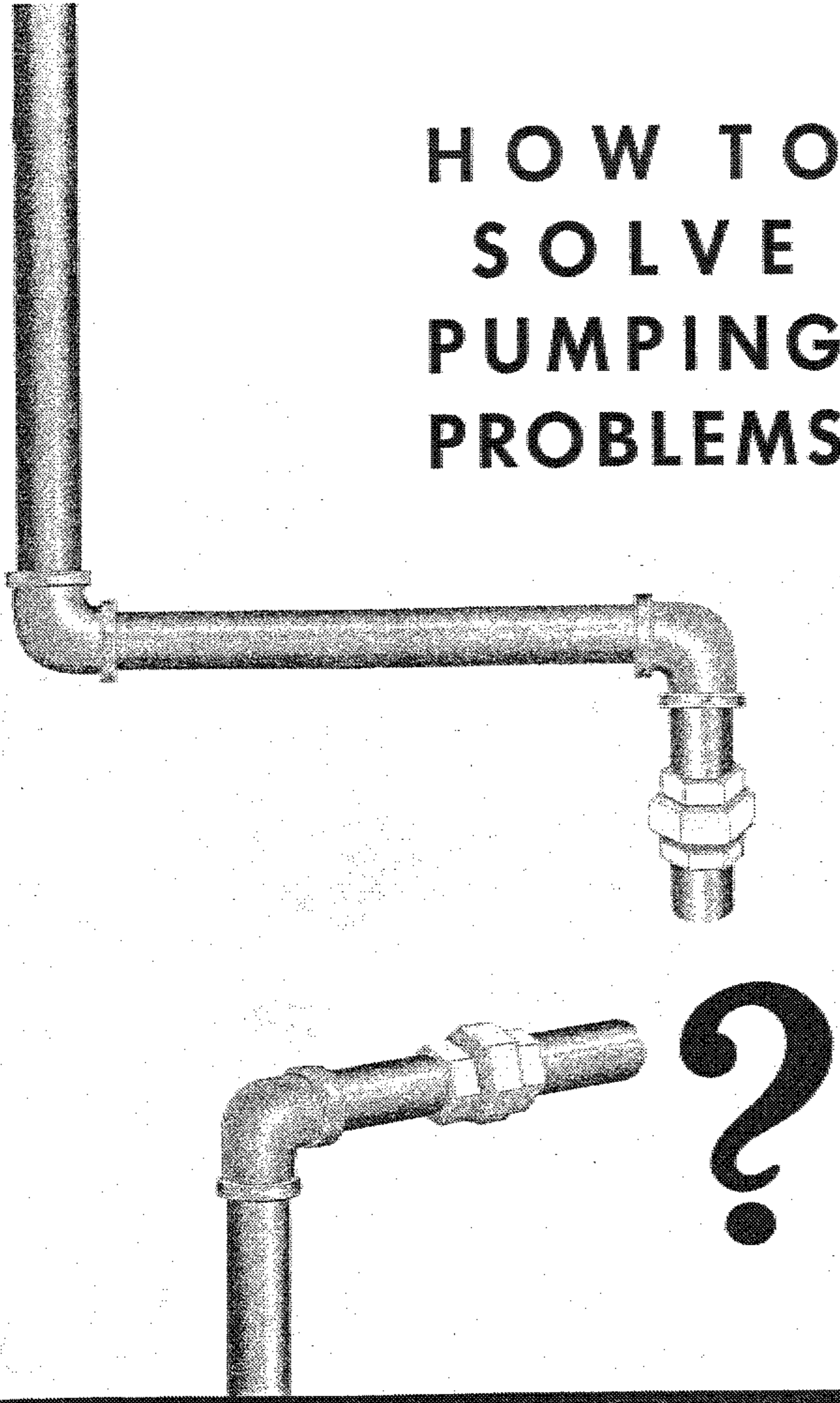
BULLETIN 85-14

HOW TO SOLVE PUMPING PROBLEMS



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INTRODUCTION

General Explanation of Rotary Gear Pumps

The external rotary gear pump is a positive displacement pump. The unmeshing of the gears produces a partial vacuum and atmospheric pressure forces the liquid into the pump. The liquid is carried between the gear teeth and the case to the opposite side of the pump. The meshing of the gears forces the liquid into the outlet line.

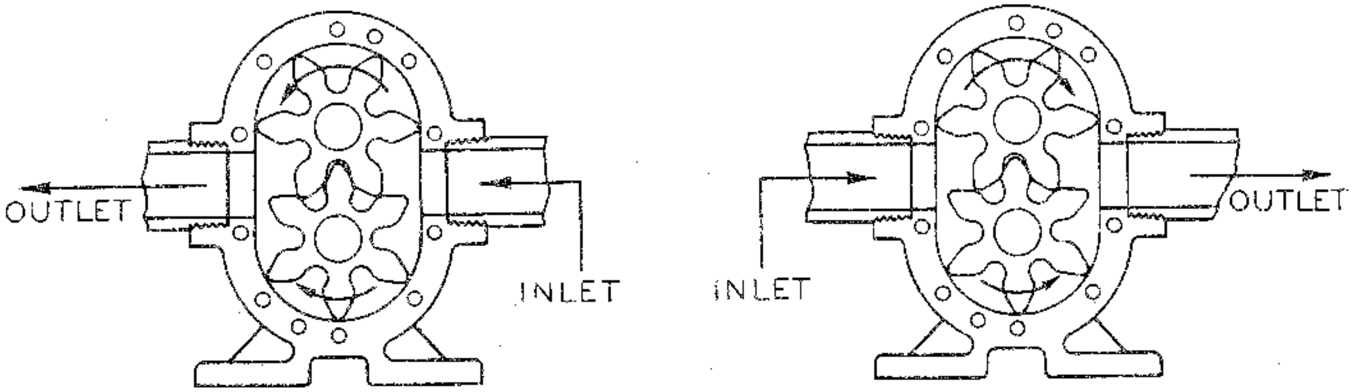


Fig. 1

The above illustration shows that the direction of rotation determines which of the openings will be inlet and outlet. By reversing rotation, the function of the ports will be reversed. Rotary gear pumps generally operate equally well when driven in either direction. However, where construction features such as built-in relief valve or bleed-back of shaft seal are involved, precautions must be taken to be sure shaft rotation is correct with respect to special features.

A rotary gear pump is self-priming. When the pump is operated, the inlet line is evacuated and atmospheric pressure forces the liquid into the pump. The atmospheric pressure available for that result is about 15 P.S.I. if the pump was capable of producing an absolute vacuum. However, it is not practical to make a commercial liquid handling pump create such high vacuum. Therefore, expressed in terms of pounds per square inch, the total lift, including pipe friction losses, should not exceed 7.5 P.S.I.

In other words, the energy required to push the liquid through the inlet line should not exceed one-half the energy available from the weight of the atmosphere. The weight of the atmosphere on the earth's surface can also be expressed in terms of inches of Mercury or feet of water. The 15 P.S.I. mentioned above is equal to 30″ of Hg. or 33 feet of water. Practical maximums for these other terms would be 15″ Hg. or 17 feet of water.

These values are less for volatile liquids such as gasoline, napthas and for liquids of low specific gravity.

The self-priming characteristic of rotary gear pumps makes them particularly suited to applications where a positive lift is required.

The positive displacement feature of the rotary gear pump affords an exceptionally wide range of applications. They will effectively handle liquids ranging from as thin as gasoline or alcohol to as thick as heavy fuel oil or molasses. However, there are a number of factors that must be considered in making proper application in order to get the best results.

Factors of Pumping Problems

A. Rotary gear pumps are used for three purposes:

1. To transfer liquids.
2. To transfer liquids under pressure.
3. To generate hydraulic power to operate cylinders or hydraulic motors.

B. The Liquid to be Handled

1. Viscosity—In terms of SSU or other measurements. See conversion chart on pages 26 and 27.

2. Temperature—The temperature at which the liquid will be handled will determine its viscosity. For general transfer, the lowest temperature to be encountered should be used in calculation to determine the pump's highest power requirements. In extreme cases, such as unloading molasses or heavy fuel oils in winter, a means of heating the liquid will have to be furnished.

   In hydraulic systems where oil is constantly recirculated under pressure, the heat generated will reduce the viscosity of the oil to such an extent that cooling must be provided to maintain efficiency.

   For transfer work in mild climates or where the entire installation is within heated buildings, the average temperature can be used.

3. Characteristics—Corrosive or caustic qualities of the liquid handled will govern selection of the pump. Various types of material are used in construction of rotary gear pumps to handle many different conditions. See materials of construction, pages 33 and 34 or Manufacturer's Catalog.

   Generally rotary gear pumps depend on the liquid pumped to afford lubrication to the internal working parts. Consequently, liquids lacking in lubricating qualities or extremely thin liquids should be handled with caution. Sometimes these liquids can be pumped if pressures are well within the capacity of the pump and slow speeds are used. Consult your Roper representative for recommendations.

4. Foreign Matter—Presence of abrasives or other solid matter in the liquid will tend to reduce the service life of a rotary gear pump. Wherever practical, a strainer should be placed in the inlet line to protect the pump. The strainer must be cleaned regularly.

   Where a liquid is known to carry a small quantity of fine abrasive materials, the pump speed can be reduced to obtain a satisfactory service life.

The efficiency of rotary gear pumps depends on very close clearances between the pumping elements and the housing. Therefore, they are not recommended for handling liquids with high abrasive content.

C. Conditions at Pump Inlet

1. The static lift is the vertical distance the liquid must be raised, measured from the level of the liquid to the centerline of the pump. Use distance of maximum requirements.

2. Dynamic lift or pipe friction losses are determined by the rate of flow, viscosity of the liquid and the size of pipe. See charts, pages 11 through 21.

3. The total lift is the sum of the static lift and dynamic lift.

EXAMPLE: Assume a delivery rate of 20 G.P.M., a vertical lift of 10 feet using 2 inch pipe. Liquid oil with viscosity of 3,000 SSU and Specific Gravity of .8.

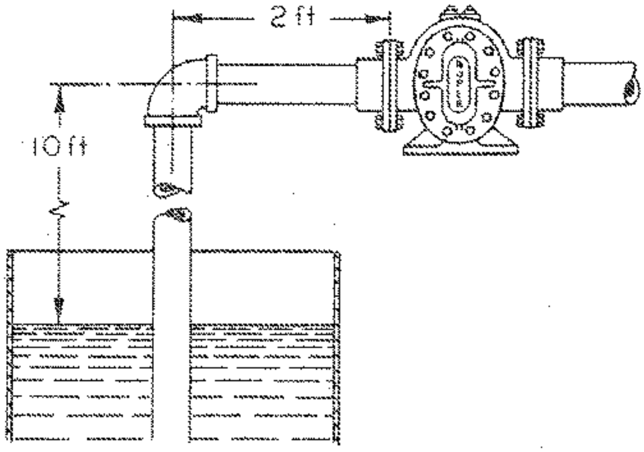


Fig. 2

From the pipe friction charts, the modulus for the stated problem is 20 for 100 feet of pipe. Loss in P.S.I. per 100 feet is 20 × .8 = 16.0 P.S.I. Total length of pipe in problem is 12 feet, therefore, .12 × 16.0 = 1.92 P.S.I. dynamic lift or friction loss in pipe. To convert static lift to P.S.I., multiply the number of vertical feet of the liquid must be raised (10 ft.) by .433 (1 ft. water = .433 P.S.I.) times Specific Gravity (relation of weight of liquid to weight of water) 10 feet × .433 × .8 = 3.46 P.S.I. static lift. Add the static lift of 3.46 P.S.I. and the dynamic lift of 1.92 P.S.I. resulting in 5.38 P.S.I. total lift.

Considering the weight of the atmosphere is about 15 P.S.I. (actually 14.7 P.S.I.), subtracting 5.38 P.S.I. from 14.7 P.S.I. leaves 9.32 P.S.I. This is the actual force available to push the liquid through the inlet piping when a partial vacuum is created by the unmeshing of the pump gear teeth.

The inlet conditions expressed in feet of liquid would be as follows: For dynamic lift or pipe friction loss, the modulus is again 20 per 100 feet of pipe. Loss in feet of liquid per 100 feet is 20 × 2.31 × Specific Gravity (.8) = 36.96 feet. Total length of pipe is 12 feet, therefore, .12 × 36.96 = 4.43 feet of liquid. To calculate static lift, multiply the number of feet the liquid must be raised (10 feet) by the Specific Gravity, 10 × .8 = 8 feet static lift. Add the pipe friction losses and the static lift for a total of 4.43 + 8 = 12.43 feet of liquid. Note: In conversion factor table to change from P.S.I. to feet of liquid, multiply P.S.I. by 2.31. From first example above, 5.38 P.S.I. × 2.31 = 12.43 feet of liquid determined in second example.

There are still other factors affecting pump inlet conditions. The presence of entrained or dissolved gases or leaky inlet pipes may reduce the delivery rate. Most liquids contain varying amounts of entrained and dissolved gases. A circuit where the liquid is repeatedly circulated and during each cycle is discharged through air will result in the dissolving and entrainment of air. The presence of air is indicated by bubbles in or on the liquid, and in extreme cases, by a thick layer of foam.

Liquids may also have gases or air in solution. Lubricating oils at atmospheric pressure and temperature may contain up to 10% of dissolved gas and air by volume; under similar conditions, gasoline may contain as much as 20% gases in solution.

Entrained and dissolved gas or air in liquids handled by rotary pumps are two of the most important factors affecting the pump's volumetric performance. When rotary pumps are operated with inlet pressures below atmospheric, the entrained gas in the liquid will expand and take up part of the pump displacement. On the discharge side of the pump, this gas is recompressed so that the volume discharge of liquid from the pump is less than its displacement.

If there are entrained gases or the liquid is volatile, the maximum lift should be less than 15 in. Hg., 7.5 P.S.I. or 17 ft. of water.

4. Flooded Inlet—Where the liquid supply is fed to the inlet of the pump by gravity or by another pump, the condition is commonly referred to as flooded inlet. This condition is desirable where installation conditions will permit, especially with highly viscous or heavy liquids. When the supply of liquid at the pump inlet, taking into account the viscosity and pipe friction losses, is equal to the rated outlet capacity of the pump the inlet condition is considered negligible for computation of power requirements.

D. Conditions at Pump Outlet

The outlet pressure required at the pump is de-

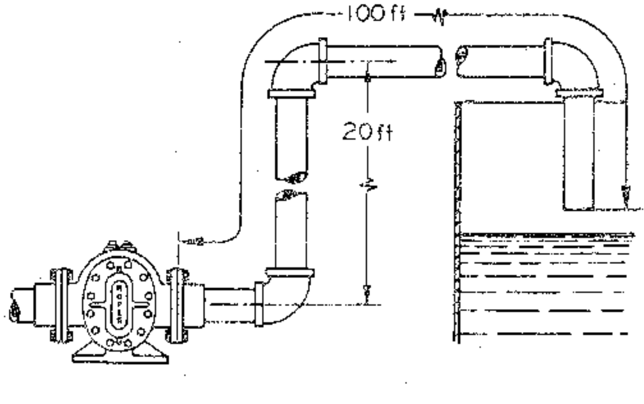


Fig. 3

termined by length and size of pipe, viscosity of the liquid, rate of flow and static lift.

1. Total Lift—Determined by same factors as at inlet side of pump. Static lift is measured vertically from the centerline of the pump to the highest point the liquid must be raised. This is added to the dynamic lift computed for the total length of the pipe.
2. Outlet Pressure—For transfer to open atmosphere, the pressure at the end of the line is negligible. For hydraulic applications, the pressure required to do the hydraulic work must be added to total lift.

EXAMPLE: Assume a problem for delivery of 20 G.P.M. at pump outlet of oil having viscosity 3,000 SSU and a specific gravity of .9. There being 100 feet of 2" pipe and a static lift of 20 feet.

From the previous example Fig. 2, the modulus is 20 × .9 = 18.0 P.S.I. The vertical lift 20 feet is 20 × .433 (1 ft. of water = .433 P.S.I.) × .9 = 7.8 P.S.I. Total of 25.8 P.S.I. pump outlet pressure.

3. Other factors influencing conditions at pump outlet are the characteristics of units in the line. Valves and fittings have flow rates different than straight pipe (see page 22.) Meters, air eliminators and other devices in the outlet line affect the final output and have capacity and pressure requirements. These other factors must be considered when computing outlet conditions at the pump.

Sum of Conditions at the Pump

The total head is a measure of the energy increase per unit of liquid given to it by the pump, and is thus the difference between the total outlet pressure and the total inlet lift. Where there is positive pressure on the inlet side of the pump, the total head is the outlet pressure minus the inlet pressure. Where the pump is depending on atmospheric pressure to supply the liquid or there is inlet lift, this value must be added to the outlet pressure to get total head or work performed by the pump.

(NOTE: The terms suction and discharge are also commonly used in referring to inlet and outlet respectively.) The terms inlet head and inlet lift by accepted usage are positive figures, although to be strictly correct, the inlet lift should be negative.

With the discharge head expressed in P.S.I., the formula for hydraulic horsepower, irrespective of specific gravity, is:

$$\text{Hyd. HP} = .000583 \times \text{GPM} \times \text{P.S.I.}$$

$$\text{And Pump Efficiency (\%)} = \frac{\text{Hyd. HP (output)}}{\text{Brake HP (input)}} \times 100$$

The above formulae can be used in estimating performance where actual test data is not available.

In practical usage, the inlet lift must be less than 17 feet of water or 15" of Mercury and, therefore, is negligible in the average pumping problem where it would constitute only a small percentage of the total head. However, in cases of extreme lift or very light or volatile liquids and small volume, this factor is important because it can affect the total performance required.

F. Factors of Pump Selection

When the requirements for the pump have been determined in terms of capacity (GPM) and pressure (PSI) the following factors must be considered in selecting the pump for the job.

1. The liquid (see "B" above) will determine materials of construction, whether the pump should be standard fitted, bronze fitted, all bronze, corrosion resistant, all iron or special construction. (See Materials of Construction, pages 33 and 34.)
2. Temperature—in addition to effect on viscosity of the liquid, temperature can also determine pump construction. Hot liquids may require special packing on pump shaft or special materials of construction for the pumping elements and bearings.

   Where the liquid must be heated before the pump can start operation, a steam jacket or other means of heating the pump may be needed.
3. Condition of Liquid—If any abrasive material is present in the liquid, the packed box construction on the drive shaft is recommended. In general practice, only liquids entirely free from abrasive material are pumped with units

having the rotary or mechanical seal construction.

4. Type of Duty—For continuous duty, a pump of generally heavier construction will be needed than for intermittent operation.
5. Space Allowance—The space available for the pump may influence the model selected. For applications where the pump is being used as a component part, size can be a critical factor. Where one make is being replaced by another make of pump; the dimensions, location of ports and shaft height must be considered.
6. Type of Mounting—Gear pumps are most commonly foot or flange mounted. Foot mounting is used where a separate power source is provided for the pump. Flange mounting is generally used where the pump is a component part and power is supplied by a take-off from the main power supply.

The Roper catalog can usually be depended upon to furnish the data for selecting the pump. It shows rated capacities for given conditions of operation, materials of construction, types of mounting, horsepower requirements, critical dimensions, availability of special features and recommendations for types of service.

G. Drives for Rotary Gear Pumps

Depending on the power and speed requirements, the pump and power source may be directly coupled or driven through a gear reduction. The speed reduction can also be accomplished with V belts, chain and sprocket or other means. These latter drives put a radial load on the pump drive shaft and precautions must be taken to be sure the pump is built to withstand the conditions set up by the drive. Improper alignment and excess radial loads can cause a pump to wear out rapidly.

H. Power for Driving Rotary Gear Pumps

Complete information about electric motors, internal combustion engines, steam turbines and hydraulic or air motors can be secured from the manufacturers of this equipment.

For your convenience, this booklet contains some helpful information.

1. Electric Motors—are probably the most common drive for rotary pumps. The Roper catalog will show horsepower requirements for a given set of conditions. Where the power required for the job falls between two standard motor sizes, it is best to use the larger size motor. Under certain conditions, an electric motor can be overloaded momentarily without serious damage. However, continuous duty under overload conditions will burn out the motor.

   The conditions of installation will indicate the type of motor to select. Where the installation is dry and clean, an open motor will probably be satisfactory. Where there is possibility of splashing or dripping, a motor designed to operate under these conditions should be selected. Likewise, if there is possibility of inflammable vapor being present, a totally enclosed, explosion proof motor will be required.

   Most states and cities have laws governing the conditions of installation for handling hazardous liquids. Before laying out an installation, it is well to consult all regulations governing handling of hazardous liquids for that locality.

   Be sure to investigate the type of current and loads permissible at the installation before ordering the motors.
2. Internal Combustion Engines—are used for power where electric current is not available or portability is required.

   In estimating the size of engine needed for a job, it will be necessary to allow a reasonable safety factor. A gasoline engine should not be operated continuously at its maximum capacity, but an allowance of 20 to 25% should be made for losses due to atmospheric conditions, wear and to insure a reasonable life of the engine. Also added torque is needed for starting and abnormal application conditions. This means that according to the present practice of power ratings, a gasoline engine should be selected with twice the rating of the electric motor for the same job. For best performance, an engine should not be operated at less than about 30% of its top rated speed.
3. Power Take-Offs—are commonly used on equipment where the pump is part of the unit, and the required speed, power and control can be made available.

SAMPLE PROBLEMS

A. Hydraulic System—Operate a cylinder

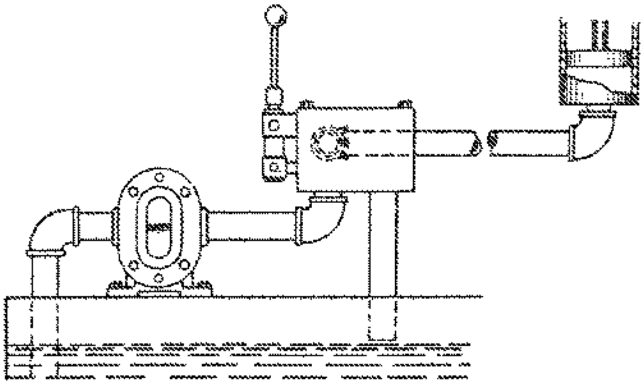


Fig. 4

The Problem—

To operate a hydraulic cylinder 4" diameter. Rate of travel = 9 ft. per min. Length of stroke = 20 in. Load on cylinder = 8,000 Lbs. Length of pipe to cylinder = 30 ft. Size of pipe to cylinder = ½ in. Medium Hydraulic Oil 500 SSU at operating temperature with specific gravity of .9.

1. Determine delivery in gallons per minute. A rate of 9 feet per minute will equal 9 × 12 or 108 inches per minute. Time required for a 20 inch stroke will be 20/108 = .185 min. or .185 × 60 = 11.1 seconds. Consult chart on cylinder displacement. A 4 inch cylinder with 20 inch stroke has displacement of 1.088 gallons.

   Displacement of cylinder in gallons divided by time in minutes equals gallons per minute, thus: 1.088/.185 = 5.88 G.P.M. capacity required.

2. Determine operating pressure required at the pump.
   a. A 4 inch cylinder has an area of 12.56 square inches. With a load of 8,000 pounds the pressure at the cylinder is 8,000/12.5 = 636 P.S.I.
   b. The dynamic lift or pipe friction loss must be computed for the conditions between the pump and cylinder. (Assume the valve to have the same friction loss as the pipe and be included in the measurement of distance.)

      Consult friction loss chart for ½" pipe for capacity 5.88 G.P.M. on oil 500 SSU and find modulus about 100 for 100 feet of pipe. Modulus × specific gravity equals loss in P.S.I. per 100 feet of pipe. 100 × .9 = 90 P.S.I. For 30 feet of pipe the loss is 90 × .30 = 27 P.S.I.
   c. Total operating pressure at the pump is cylinder pressure plus friction loss in the pipe. (Static lift is negligible.)

Cylinder Pressure	636 PSI
Dynamic Lift	27 PSI
Total Operating Pressure	663 PSI

3. Inlet loss can be assumed to be negligible since the oil supply is close to the pump and the pipe size is the same as the pump opening.

4. With the conditions at the pump established, we can look to the Roper catalog for a pump to fill these requirements.

   First we must find a pump that will be capable of developing somewhat more than 663 P.S.I. at a rated capacity of at least 5.88 G.P.M. on oil at 500 SSU.

   It is not likely that we will find a pump with exactly these characteristics. For the purpose of illustration we find a line of pumps offered at 1000 P.S.I. rating and a size is shown nominally rated at 5 G.P.M. Upon checking the performance data, this pump is rated on 300 SSU oil at 800 PSI to have an output of 6.15 G.P.M. at 1740 R.P.M. with a horsepower requirement of 4.54 Hp. In this case, the overage in delivery will only affect the rate of travel of the piston. Referring to (1.) above,

$$\frac{\text{(Gals) Displacement}}{\text{(Min) Time}} = \text{G.P.M. or}$$

$$\frac{1.088}{\text{Time}} = 6.15 \text{ G.P.M.}$$

$$\frac{1.088}{6.15} = .177 \text{ min} \times 60 = 10.62 \text{ seconds}$$

Therefore, the stroke will be completed in about 1 second less time than originally calculated and is negligible.

Conclusion—

Pump selected nominally rated 5 G.P.M. at 1000 P.S.I. Motor required 4.54 Hp or actually 5 Hp at 1800 R.P.M.

B. General Transfer—Unload Tank Car

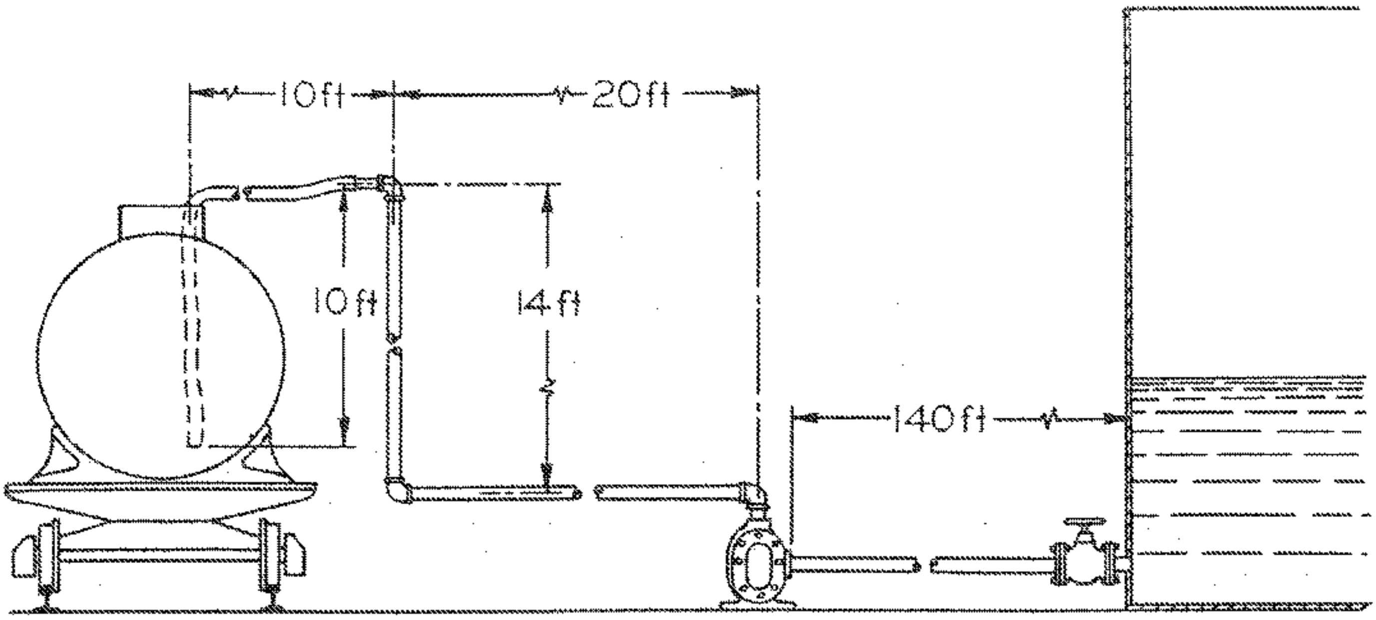


Fig. 5

The Problem—

To unload a tank car of 10,000 gallons capacity in 2½ hours into a 20,000 gallon tank 33 feet high. Liquid to be pumped = #3 fuel oil. Pumping temperature = 30° F to 70° F. Viscosity at 100° F = 45 SSU max. 110 SSU. Specific Gravity = .9 SG.

1. Determine capacity required by dividing gallons by time in minutes. 10,000 gals./2½ hrs. = 60 min. = 66.6 G.P.M.

2. Determine conditions at pump inlet for 20 feet of 2 in. suction hose and 34 ft. of 2 in. pipe.

   a. Dynamic lift (friction loss). Consulting friction loss chart for hose 66.6 G.P.M. will have a loss of approximately 6 P.S.I. per 100 ft. of hose for a liquid 1 SG thus 6 × .20 × .9 = 1.08 P.S.I. friction loss in hose.

   Modulus for 2" pipe is 6.5 for 66.6 G.P.M. at 100 SSU per 100 feet of pipe. 6.5 × .34 × .9 = 1.99 P.S.I. friction loss in pipe.

   Total dynamic lift = 3.07 P.S.I.

   b. Static lift for this problem actually has a positive value. The vertical difference in height between the pump and bottom of the car is 4 ft. Therefore, 4 ft. × .433 (1 ft. water = .433 PSI) × .9SG = 1.55 P.S.I.

   c. Total Inlet conditions

   The dynamic lift 3.07 P.S.I. minus the head of 1.55 = 1.5 P.S.I.

3. Determine conditions at pump outlet. Assume the extreme case where the car being unloaded will fill the tank full.

   a. Dynamic lift computed for 140 feet of 2 in. pipe: 6.5 (modulus) × 1.4 × .9 SG = 8.19 P.S.I.

   b. Static lift calculated to top of tank: 33 ft. × .433 × .9 = 12.86 P.S.I.

   c. Total Outlet conditions

   Dynamic lift = 8.19 P.S.I.
   Static lift = 12.86 P.S.I.
   21.05 P.S.I.

4. With conditions at the pump established.

   Total inlet 1.50 P.S.I.
   Total outlet 21.05 P.S.I.
   22.55 P.S.I.

   Capacity required 66.6 G.P.M.

   Look in the Roper catalog for a pump to handle somewhat more than 22.55 P.S.I. at a capacity of 66.6 G.P.M. We find a pump offered for bulk plant work nominally rated 93 G.P.M. at 60 P.S.I. running at 545 R.P.M. In checking the performance data for our problem, we find a rating for this pump 20 P.S.I. delivering 96 G.P.M. requiring maximum of 2 HP. This pump has a built-in gear reduction on the pumping unit, therefore, we can use a standard 1800 R.P.M. 2 HP motor.

Conclusion—

Pump selected nominally rated 93 G.P.M. at 60 P.S.I. Motor required 2 HP 1800 R.P.M.

Since we have computed the problem for extreme conditions of viscosity and pressure, we are assured satisfactory performance under normal operation.

C. Pressure Transfer—Supply Oil Burners

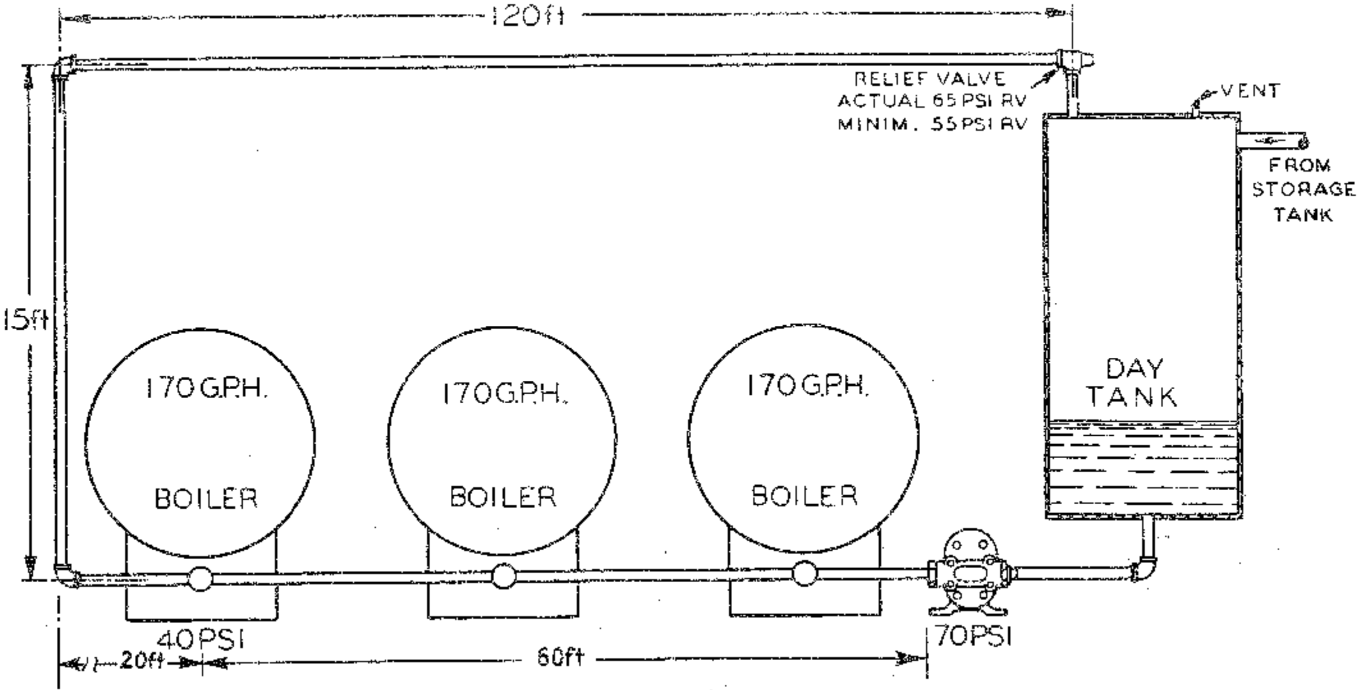


Fig. 6

The Problem—

To supply fuel oil to the burners on three boilers. Liquid to be pumped = #5 Fuel Oil. Pumping temperature =70° F to 100° F. Viscosity at 100° F = 130 SSU max. 500 SSU. Specific Gravity =.9 SG. Abrasive Present = occasionally. Capacity required at each burner = 170 G.P.H. Pressure at most distant burner = 40 P.S.I. Type of Duty = Continuous Operation.

1. Determine capacity required. Each burner requires 170 gallons per hour: 170 G.P.H. × 3 burners = 510 G.P.H. 510 G.P.H. × 2 safety factor = 1020 G.P.H. 1020 G.P.H./60 min. = 17 G.P.M. The safety factor is introduced to assure a full supply to the burners, and for circulation purposes.
2. Determine conditions at pump inlet. For this problem, we are assuming a flooded inlet. In practice, it is well to check this factor for each installation.
3. Determine conditions at pump outlet.
   a. Dynamic pipe friction loss from pump to last burner is friction loss for 100 ft. of 1½ in. pipe × length (in decimal equivalent of 100 ft.) × specific gravity. 7 × .60 × .9 = 3.78 P.S.I.
   b. Dynamic pipe friction loss from last burner to relief valve: 7 × 1.55 × .9 = 9.77.
   c. Static lift in line from last burner to relief valve. 15 ft. × .433 (conversion factor) × 9 SG = 5.85 P.S.I.
   d. As part of the conditions in outlet line, we must consider the pressure required at the last burner which is 40 P.S.I.
   e. Total outlet conditions: Line loss to last burner = 3.78 P.S.I. Dynamic loss last burner to relief valve = 9.77 P.S.I. Static lift for 15 ft. = 5.85 P.S.I. Burner requirement = 40.00 P.S.I. TOTAL: 59.40 P.S.I. With a relief valve safety factor of 10 P.S.I., the total operating pressure at the pump is 70 P.S.I.
   f. Relief valve setting is established for the pressure required at last burner and line losses from burner to relief valve: 40 P.S.I. + 5.85 P.S.I. (static lift) + 9.77 P.S.I. (dynamic lift) = 55.6 P.S.I. + 10 P.S.I. (safety factor) = 65 P.S.I. relief valve setting.

In this problem, we have introduced the factors of continuous duty and occasional presence of abrasive material. Therefore, we would select a pump that would deliver about twice the capacity required at the pressure and run it at half the normal rated speed.

Look in the Roper catalog for a pump that would have a normal rating of about 34 G.P.M. at 100 P.S.I.

In checking, we find a series of pumps recommended for fuel oil transfer with a maximum of 150 P.S.I. at 1740 R.P.M. At a pressure of 100 P.S.I., we find a pump nominally rated 30 G.P.M. which will deliver 35 G.P.M. at 100 P.S.I. requiring 3.2 HP. Therefore, we have a unit which will deliver the desired 17 G.P.M. at the pressure required when operated at half speed or 865 RPM and require about one-half the power or 1½ HP.

Conclusion—

Pump selected nominally rated at 30 G.P.M. at 150 P.S.I.

Motor required 1½ HP at 865 R.P.M.

TECHNICAL DATA

LOSS IN POUNDS PER 100 FEET OF SMOOTH BORE RUBBER HOSE

(Data shown is for liquid having specific gravity of 1 and a viscosity of 30 SSU.)

U. S. Gal. Per Min.	ACTUAL INSIDE DIAMETER IN INCHES							
	¾	1	1¼	1½	2	2½	3	4
15	30.0	8.9	2.5	1.1	0.4	0.1		
20	53.0	14.0	4.3	1.8	0.7	0.2		
25	79.0	22.0	6.5	2.9	1.0	0.3		
30	112.0	31.0	9.2	4.0	1.4	0.4	0.1	
40		53.0	15.0	6.7	2.4	0.6	0.3	
50		80.0	24.0	10.0	3.6	1.0	0.5	
60		101.0	35.0	14.0	5.1	1.4	0.6	
70			45.0	19.0	6.6	1.8	0.8	
80			58.0	24.0	8.6	2.3	1.1	
90			71.0	30.0	11.0	3.0	1.4	0.3
100			88.0	37.0	12.5	3.5	1.7	0.4
125			132.0	55.0	20.0	5.3	2.5	0.6
150			183.0	78.0	27.0	7.5	3.5	0.7
175				100.0	37.0	10.0	4.6	1.1
200				133.0	46.0	13.0	5.9	1.4
250					70.0	19.0	9.1	2.1
300					95.0	27.0	12.0	2.9
350					126.0	36.0	17.0	4.0
400						46.0	21.0	5.1
500						70.0	32.0	7.4
600						105.0	46.0	10.0
700						148.0	62.0	13.0
800						190.0	79.0	17.0
900							97.0	22.0
1000							116.0	27.0
1250							170.0	43.0
1500							226.0	61.0
1750								80.0
2000								100.0

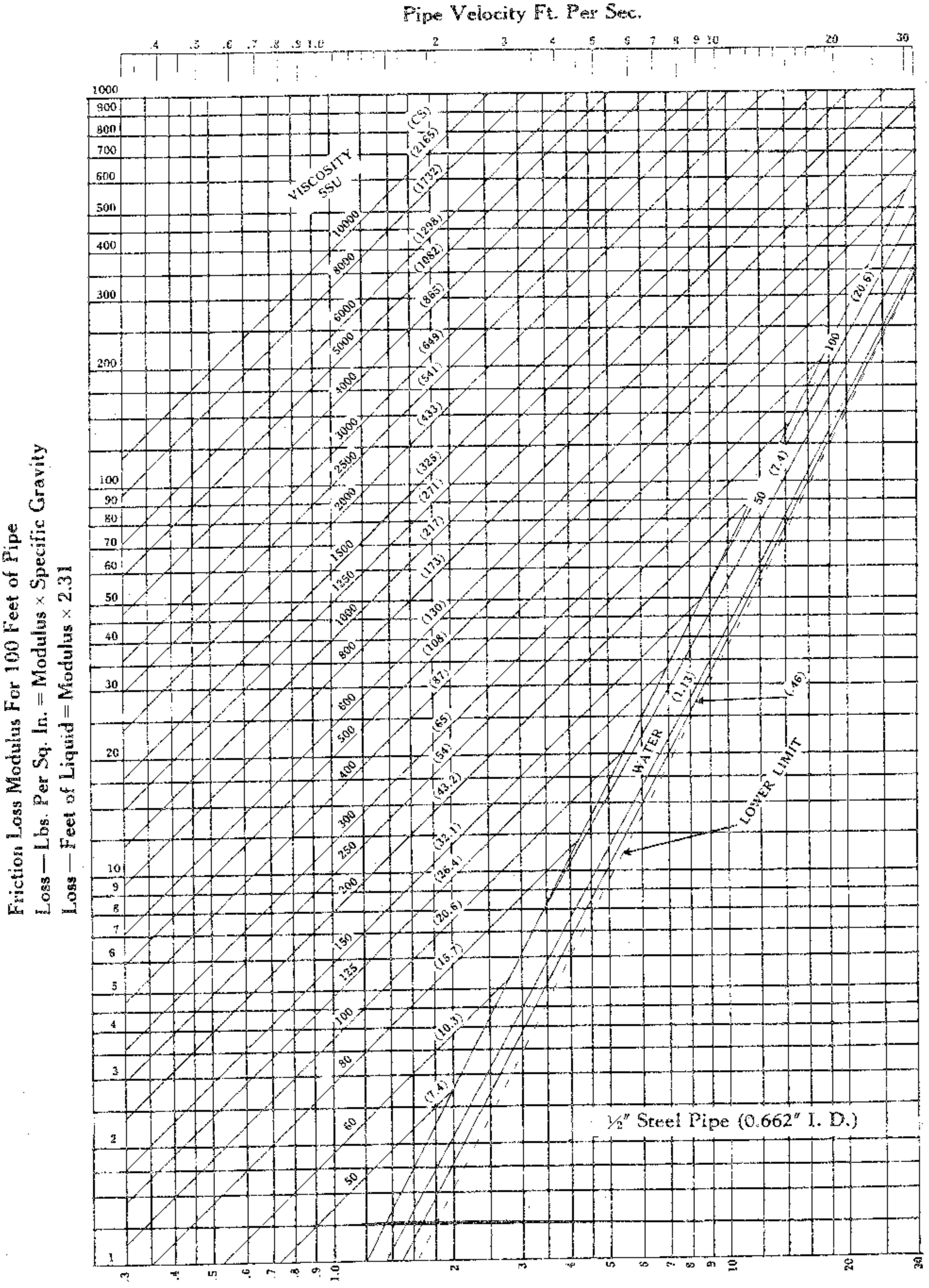
Note: Friction loss in smooth bore hose is approximately the same as corresponding sizes of steel pipe. To compute friction loss under conditions other than shown on above chart, see the following pages.

How to Compute Friction Loss in Steel Pipe

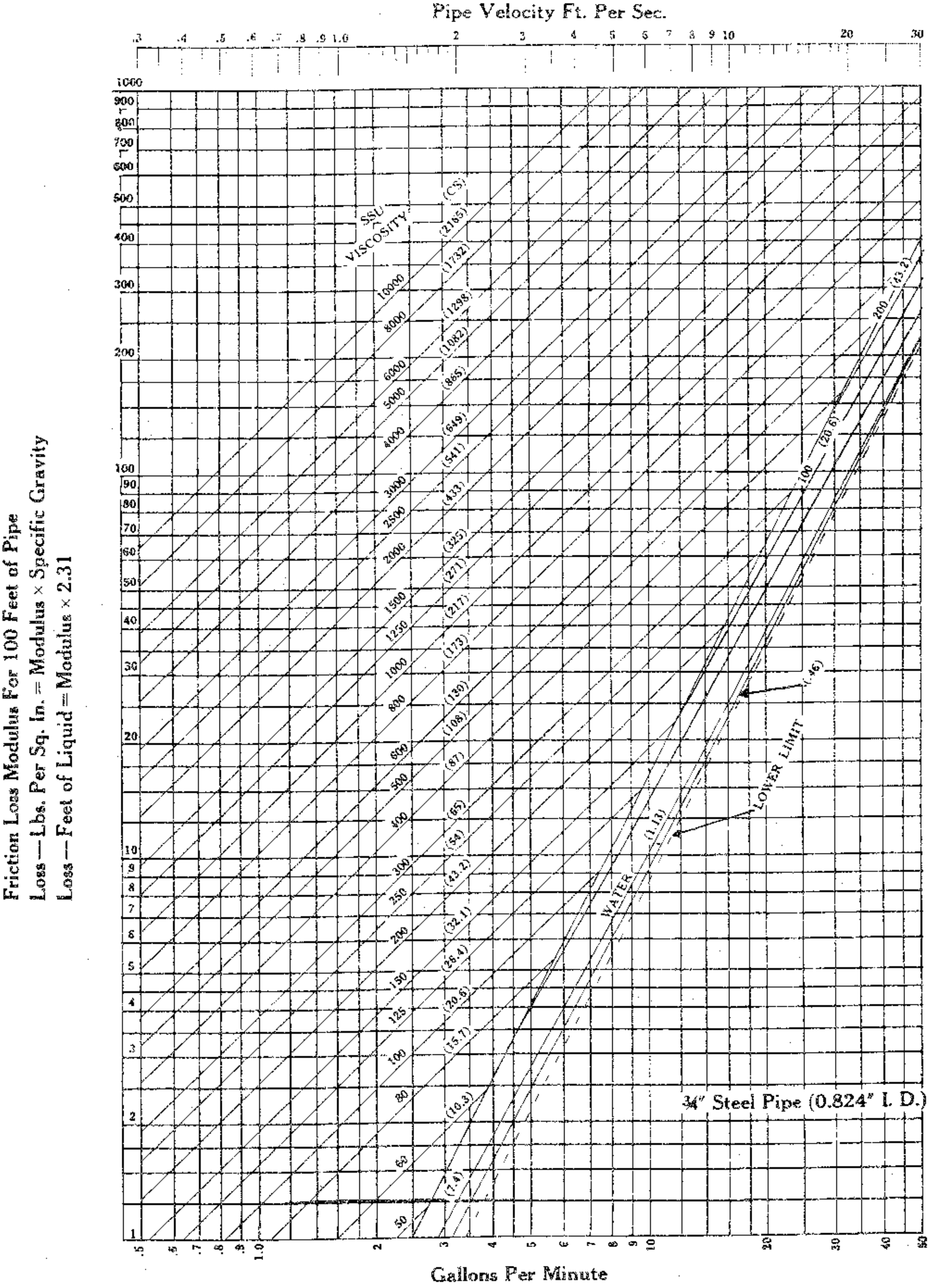
On the following pages are charts showing the friction loss through various sizes of pipe and at various viscosities and delivery rates. Turn to the chart for the proposed installations, follow the vertical line with the desired delivery rate to the point where it intersects the line indicating the viscosity of the liquid to be pumped. Read the modulus value directly to the left. To obtain friction loss per 100 feet of pipe in pounds per square inch, multiply the modulus value by the specific gravity of the liquid.

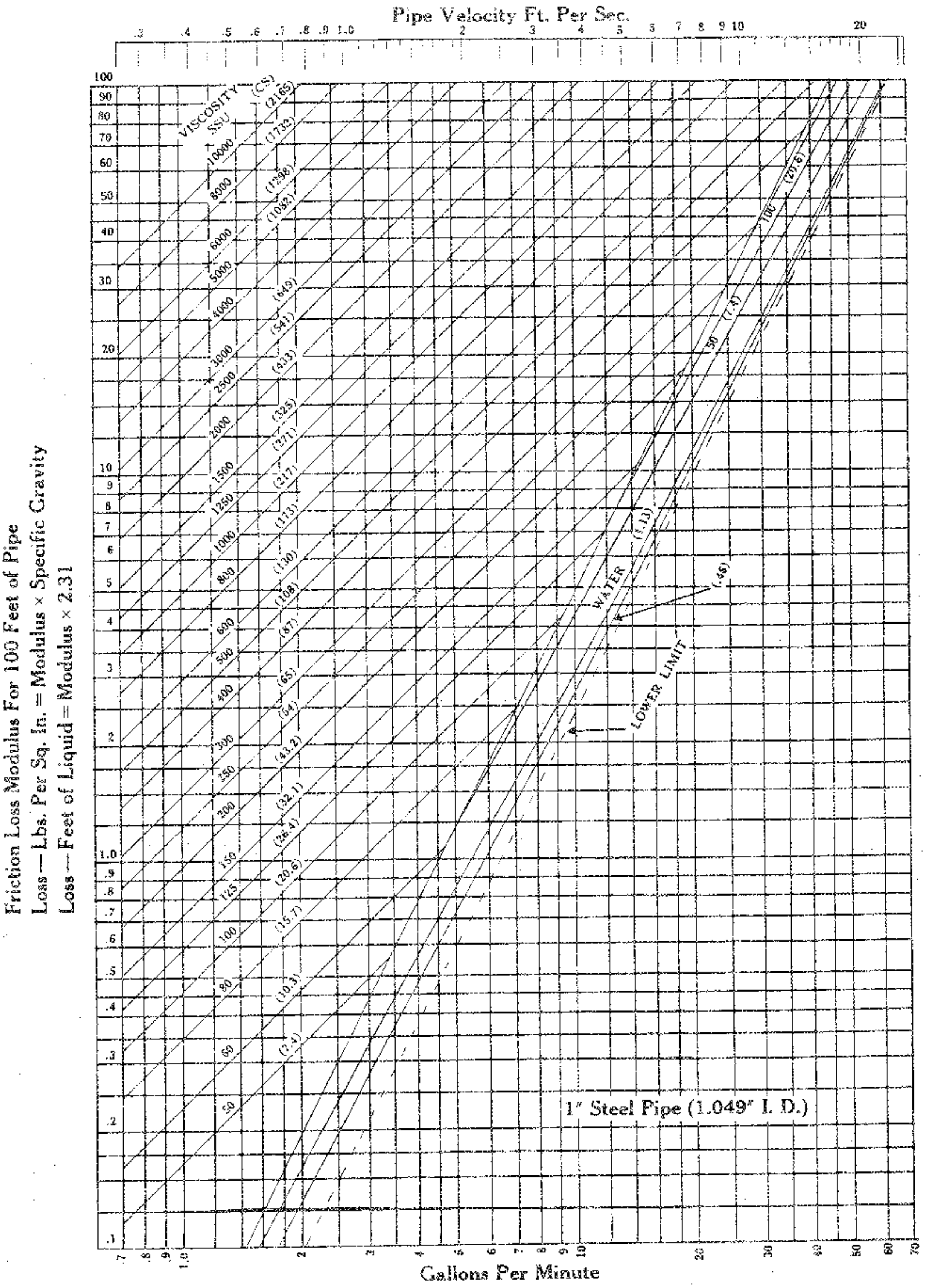
For example, assume pipe size 1½ inches, an oil with specific gravity .9 and viscosity 2,000 SSU with delivery rate 5 G.P.M. Refer to chart for 1½ inch pipe and find a modulus value of 9. Therefore, 9 × .9 = 8.1 P.S.I. loss per 100 feet of pipe.

The relation of the modulus to viscosity is in direct proportion at a given G.P.M., i.e., at 1 G.P.M., SSU 1,000 = Modulus 40; SSU 10,000 = Modulus 400; SSU 2,000 = Modulus 80 and SSU 20,000 = Modulus 800, etc. Thus the Modulus can be computed for viscoities not shown on the chart.

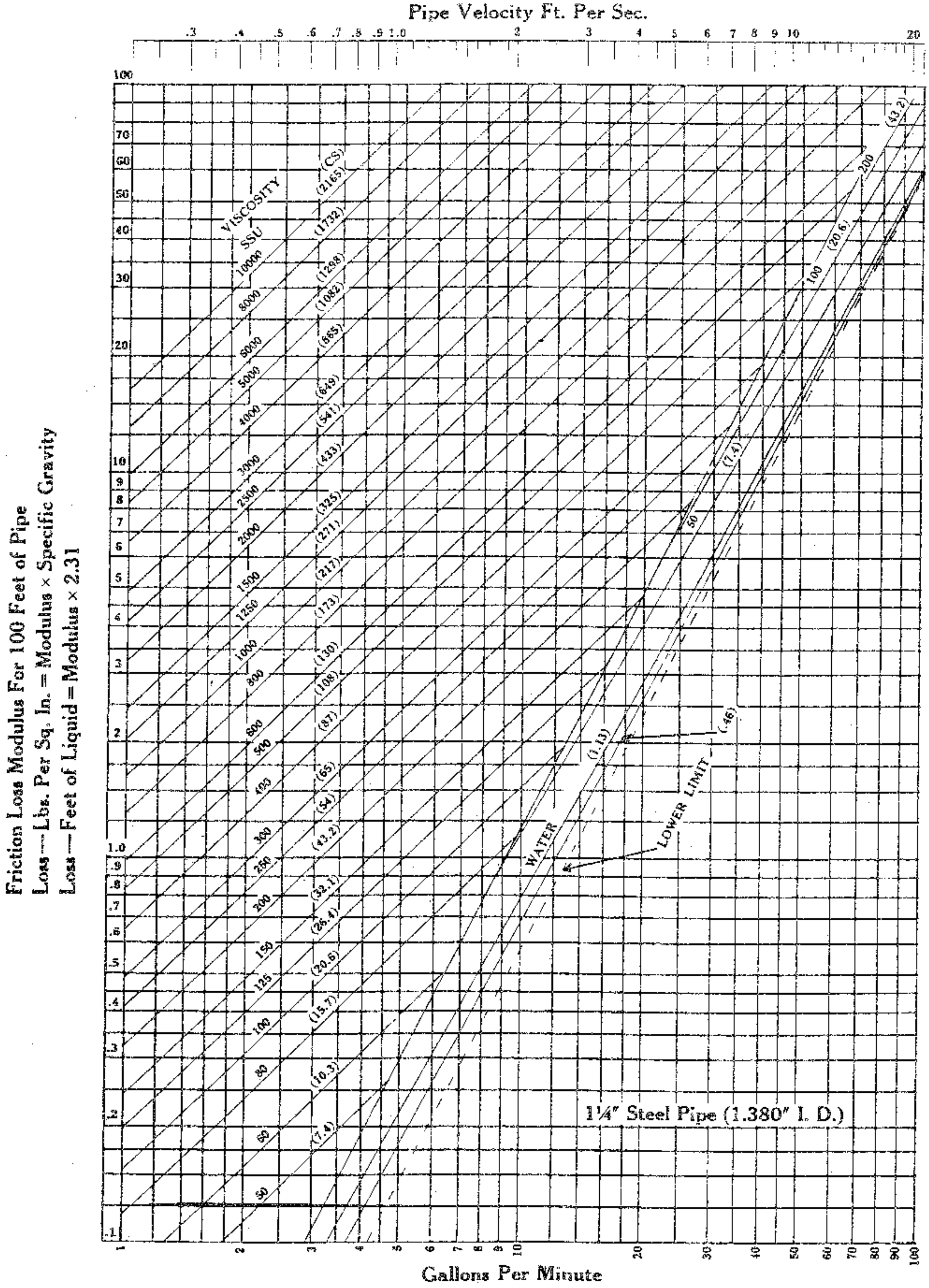


½″ Steel Pipe (0.662″ I. D.)

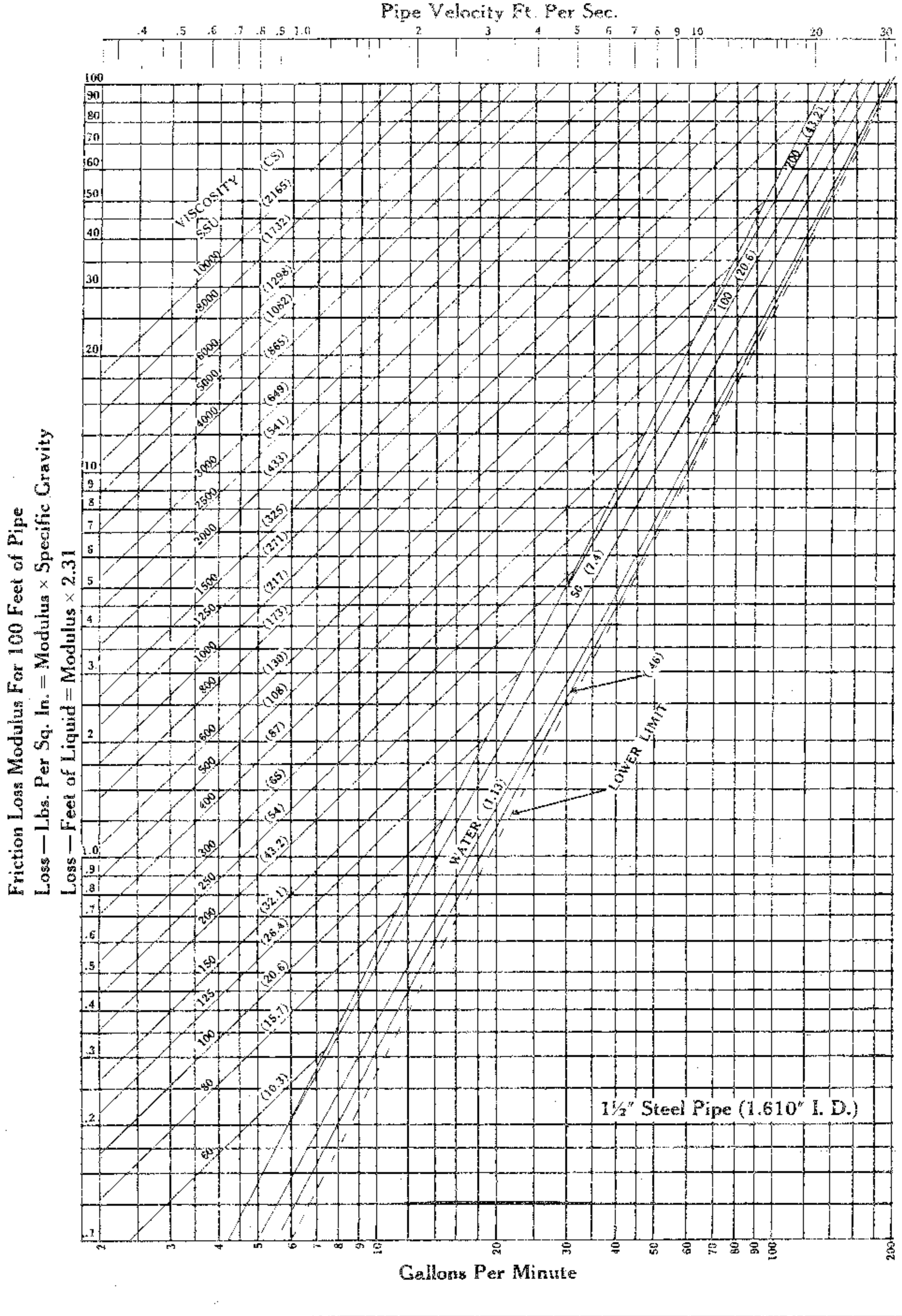

Pipe Velocity Ft. Per Sec.
.3 .4 .5 .6 .7 .8 .9 1.0 2 3 4 5 6 7 8 9 10 20 30
Friction Loss Modulus For 100 Feet of Pipe
Loss — Lbs. Per Sq. In. = Modulus × Specific Gravity
Loss — Feet of Liquid = Modulus × 2.31
1000 900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3 2 1
SSU VISCOSITY
(CS)
10000 (2165)
8000 (1732)
6000 (1298)
5000 (1082)
4000 (865)
3000 (649)
2500 (541)
2000 (433)
1500 (325)
1250 (271)
1000 (217)
800 (173)
600 (130)
500 (108)
400 (87)
300 (65)
250 (54)
200 (43.2)
150 (32.1)
125 (26.4)
100 (20.6)
80 (15.7)
60 (10.3)
50 (7.4)
200 (43.2)
100 (20.6)
(.46)
LOWER LIMIT
(1.13)
WATER
¾″ Steel Pipe (0.824″ I. D.)
.5 .6 .7 .8 .9 1.0 2 3 4 5 6 7 8 9 10 20 30 40 50
Gallons Per Minute

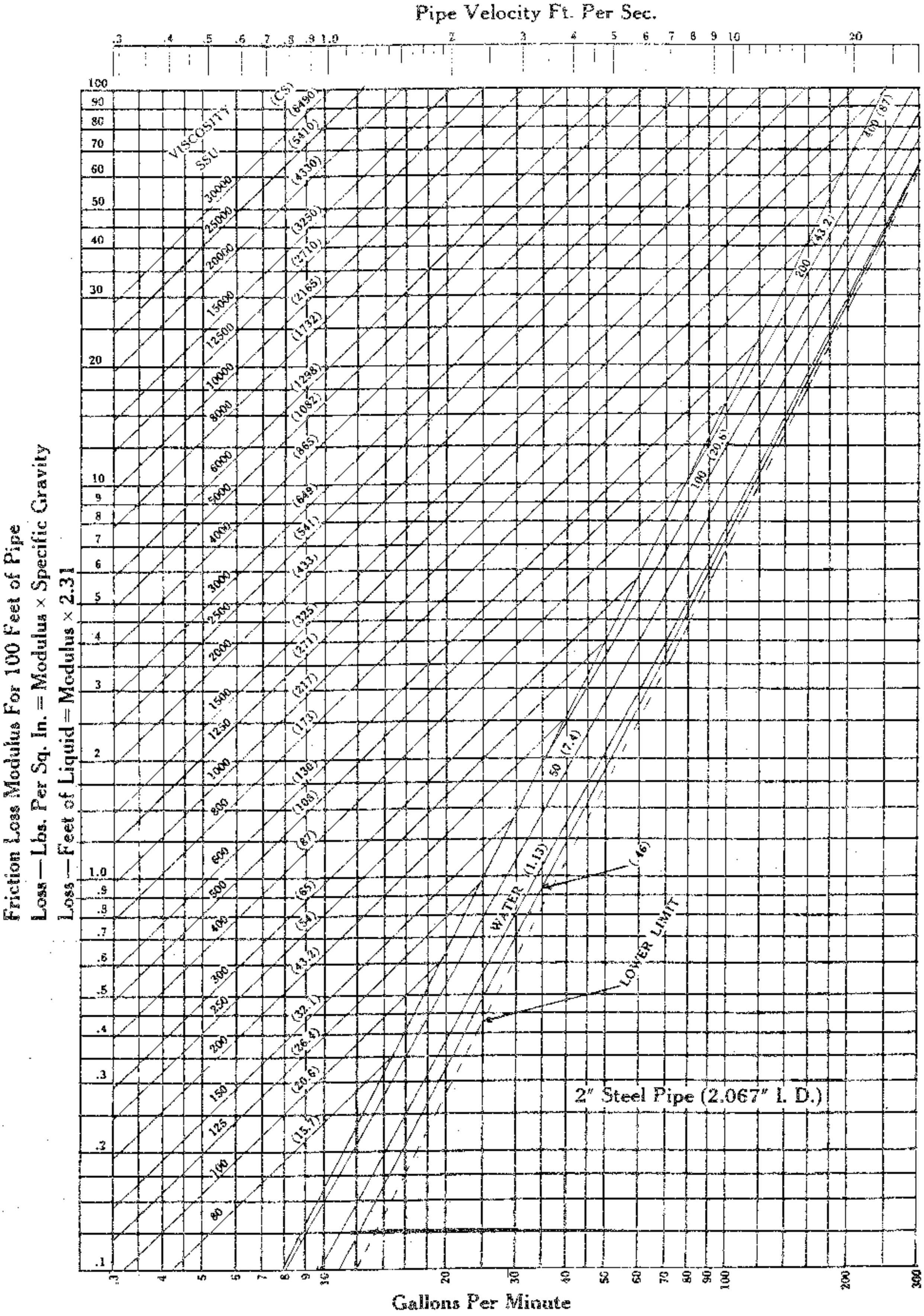


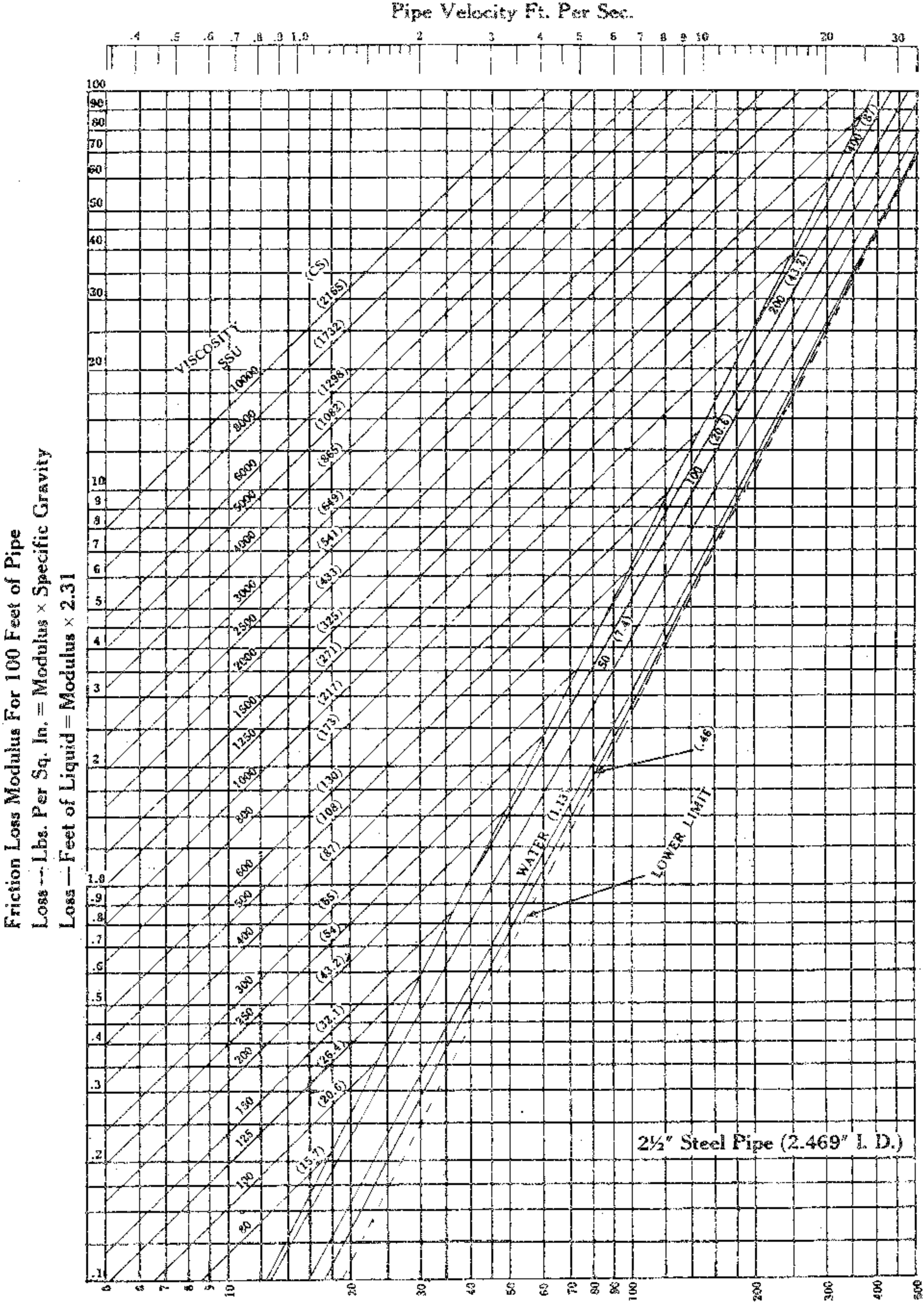
1" Steel Pipe (1.049" I. D.)



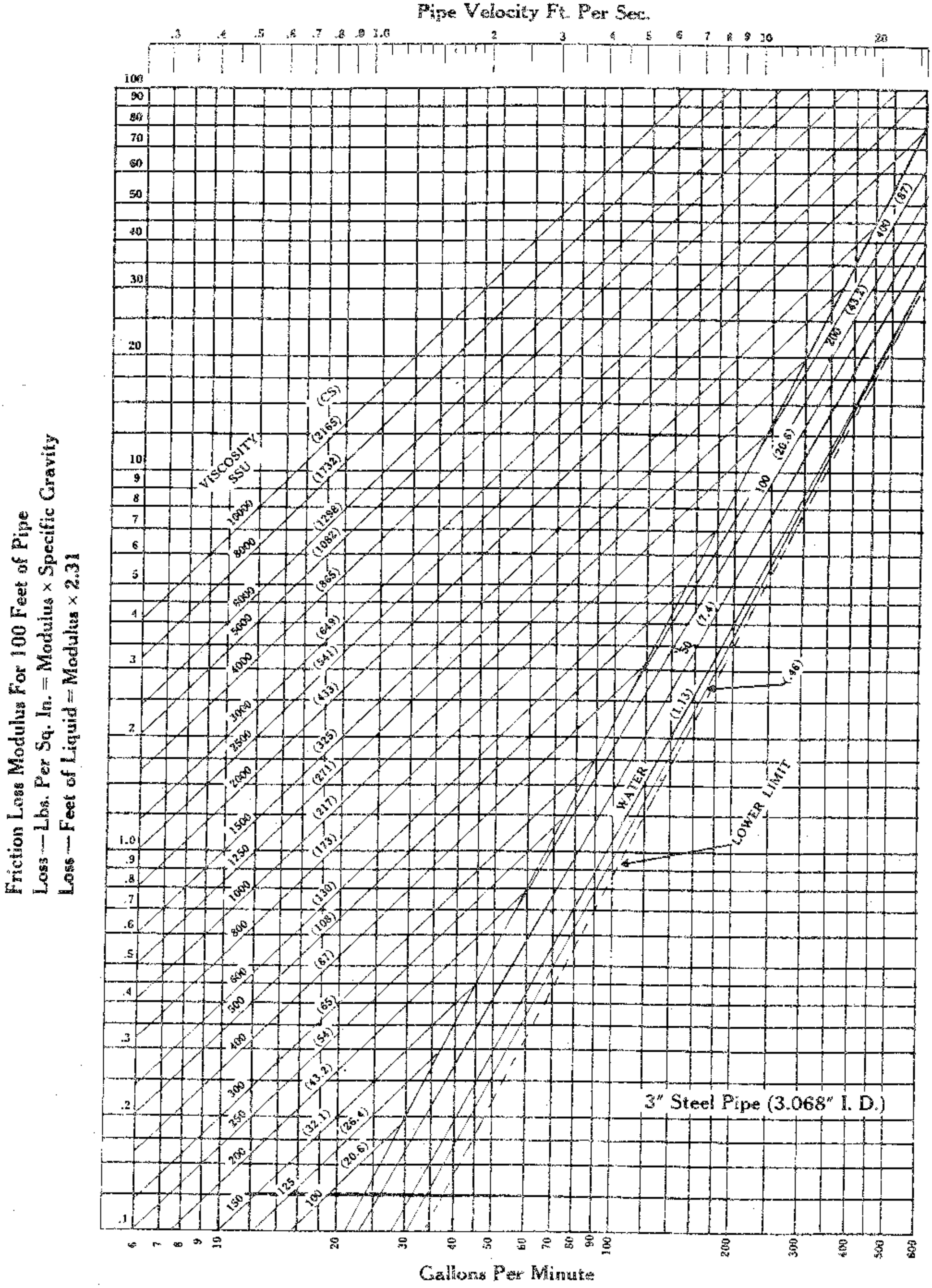
1¼″ Steel Pipe (1.380″ I. D.)

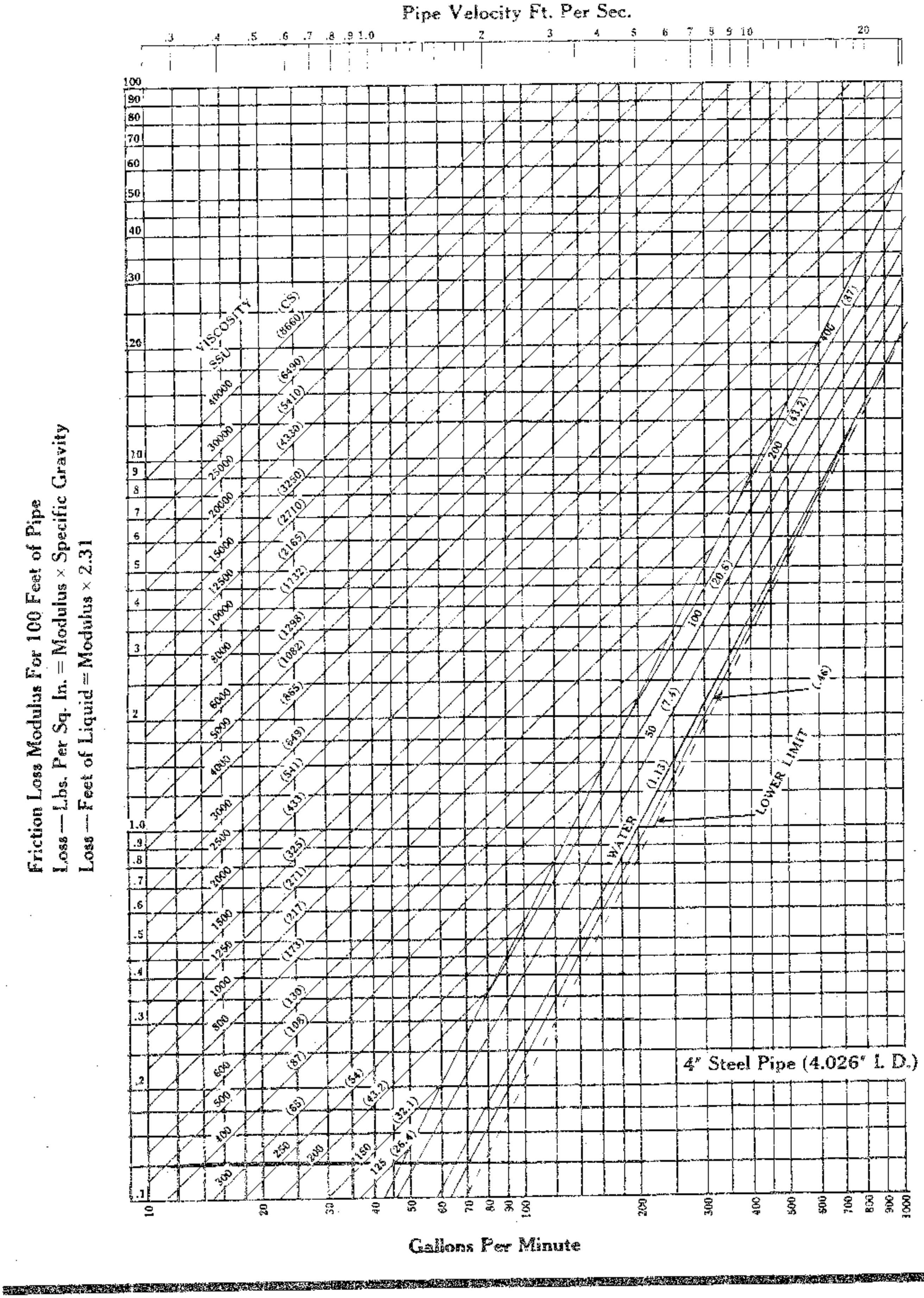

Pipe Velocity Ft. Per Sec.
.4 .5 .6 .7 .8 .9 1.0 2 3 4 5 6 7 8 9 10 20 30
Friction Loss Modulus For 100 Feet of Pipe
Loss — Lbs. Per Sq. In. = Modulus × Specific Gravity
Loss — Feet of Liquid = Modulus × 2.31
100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3 2 1.0 .9 .8 .7 .6 .5 .4 .3 .2 .1
VISCOSITY SSU
(CS)
10000 (2165)
8000 (1732)
6000 (1298)
5000 (1082)
4000 (865)
3000 (649)
2500 (541)
2000 (433)
1500 (325)
1250 (271)
1000 (217)
800 (173)
600 (130)
500 (108)
400 (87)
300 (65)
250 (54)
200 (43.2)
150 (32.1)
125 (26.4)
100 (20.6)
80 (15.7)
60 (10.3)
200 (43.2)
100 (20.6)
50 (7.4)
(.46)
LOWER LIMIT
WATER (1.13)
1½" Steel Pipe (1.610" I. D.)
2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 90 100 200
Gallons Per Minute

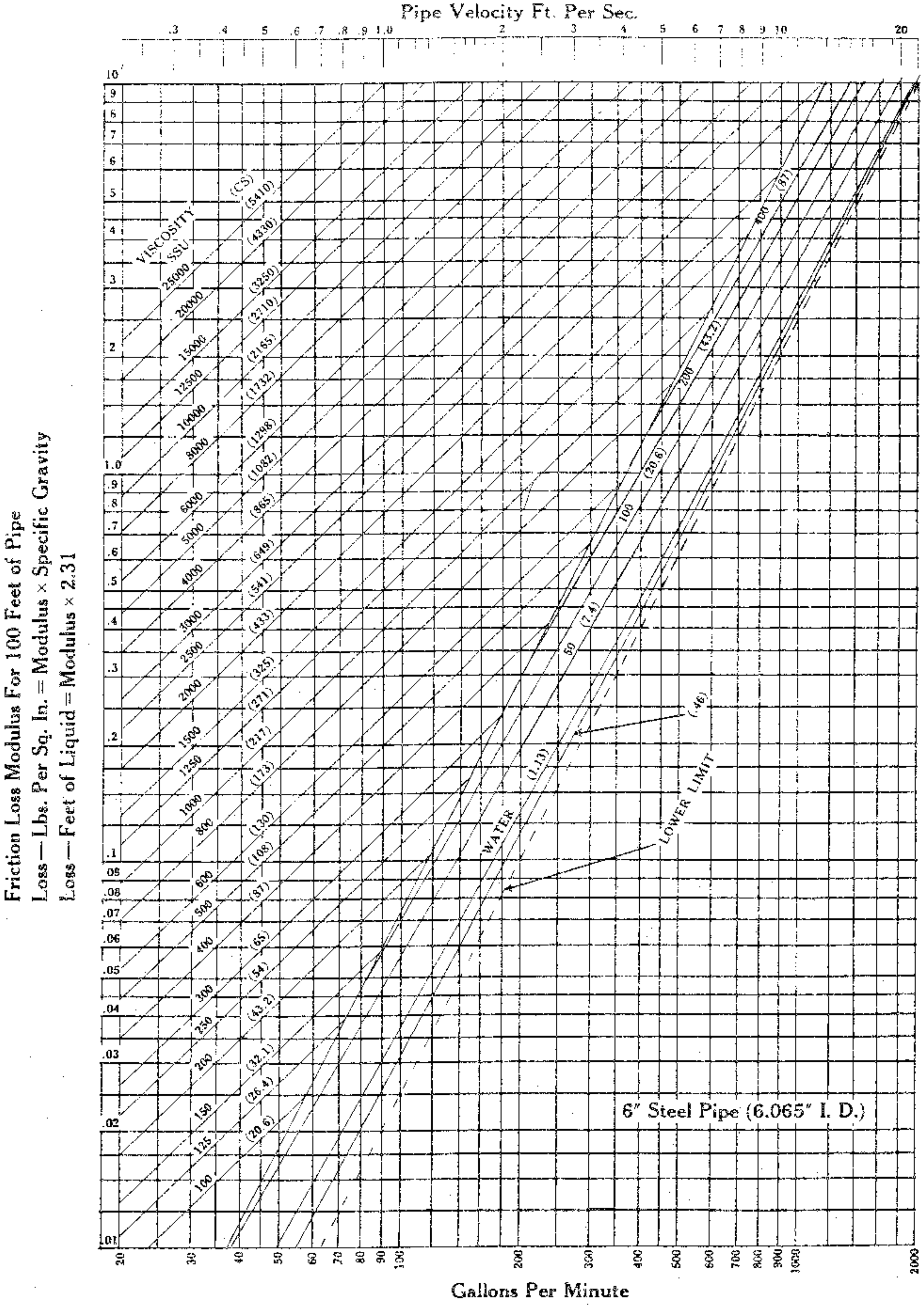

Pipe Velocity Ft. Per Sec.
.3 .4 .5 .6 .7 .8 .9 1.0 2 3 4 5 6 7 8 9 10 20
Friction Loss Modulus For 100 Feet of Pipe
Loss — Lbs. Per Sq. In. = Modulus × Specific Gravity
Loss — Feet of Liquid = Modulus × 2.31
100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3 2 1.0 .9 .8 .7 .6 .5 .4 .3 .2 .1
VISCOSITY
SSU
(CS)
30000 (6490)
25000 (5410)
20000 (4330)
15000 (3250)
12500 (2710)
10000 (2165)
8000 (1732)
6000 (1298)
5000 (1082)
4000 (865)
3000 (649)
2500 (541)
2000 (433)
1500 (325)
1250 (271)
1000 (217)
800 (173)
600 (130)
500 (108)
400 (87)
300 (65)
250 (54)
200 (43.2)
150 (32.1)
125 (26.4)
100 (20.6)
80 (15.7)
400 (87)
200 (43.2)
100 (20.6)
50 (7.4)
WATER (1.13)
(.46)
LOWER LIMIT
2" Steel Pipe (2.067" I. D.)
3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 90 100 200 300
Gallons Per Minute



2½″ Steel Pipe (2.469″ I. D.)


Pipe Velocity Ft. Per Sec.
.3
.4
.5
.6
.7
.8
.9
1.0
2
3
4
5
6
7
8
9
10
20
Friction Loss Modulus For 100 Feet of Pipe
Loss — Lbs. Per Sq. In. = Modulus × Specific Gravity
Loss — Feet of Liquid = Modulus × 2.31
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
VISCOSITY SSU
(CS)
10000
(2165)
8000
(1732)
6000
(1298)
5000
(1082)
4000
(865)
3000
(649)
2500
(541)
2000
(433)
1500
(325)
1250
(271)
1000
(217)
800
(173)
600
(130)
500
(108)
400
(87)
300
(65)
250
(54)
200
(43.2)
150
(32.1)
125
(26.4)
100
(20.6)
400 (87)
200 (43.2)
100 (20.6)
50 (7.4)
(1.13)
(.46)
WATER
LOWER LIMIT
3″ Steel Pipe (3.068″ I. D.)
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
Gallons Per Minute

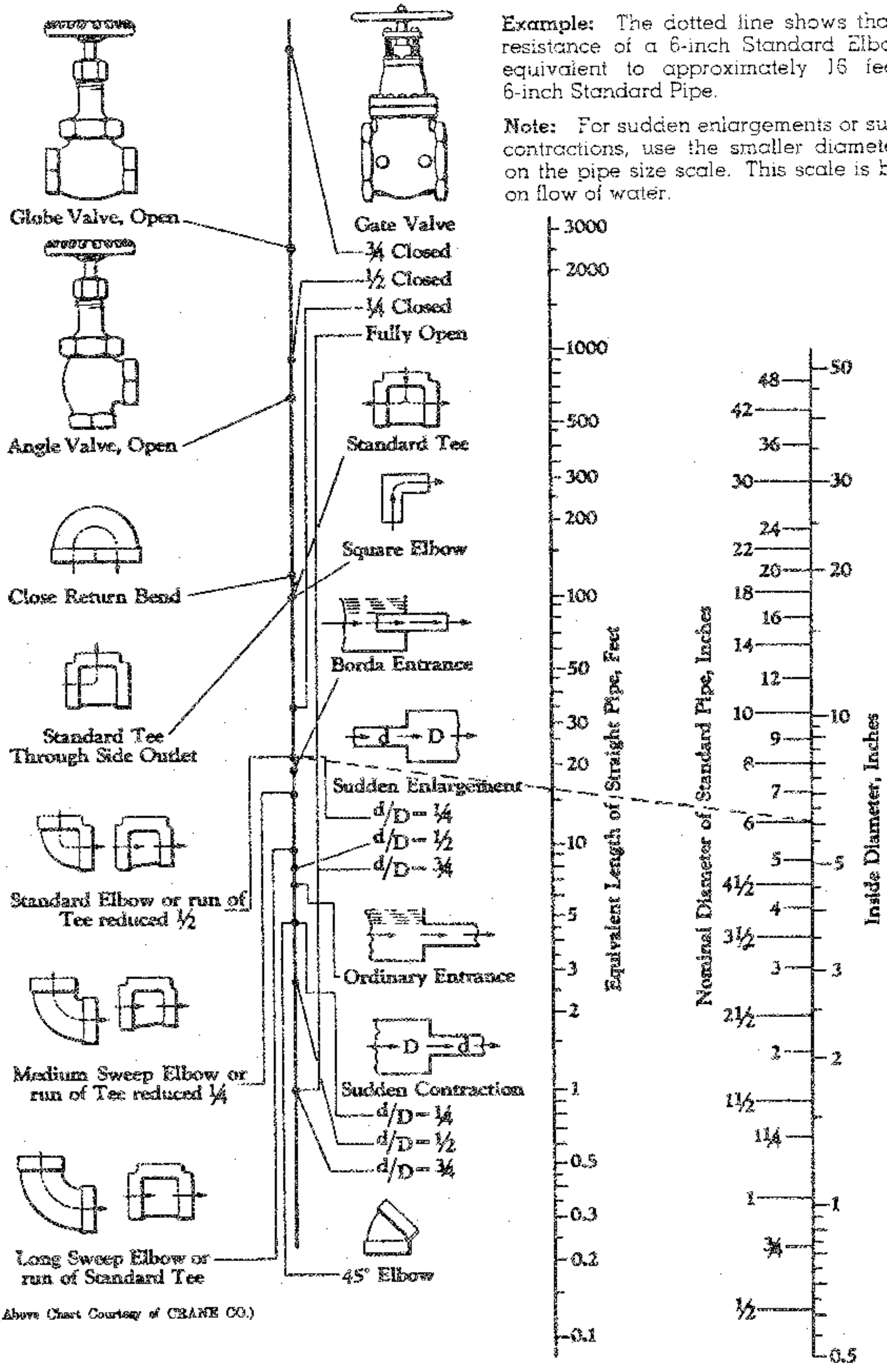

Pipe Velocity Ft. Per Sec.
.3
.4
.5
.6
.7
.8
.9
1.0
2
3
4
5
6
7
8
9
10
20
Friction Loss Modulus For 100 Feet of Pipe
Loss — Lbs. Per Sq. In. = Modulus × Specific Gravity
Loss — Feet of Liquid = Modulus × 2.31
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
VISCOSITY
SSU
(CS)
40000
30000
25000
20000
15000
12500
10000
8000
6000
5000
4000
3000
2500
2000
1500
1250
1000
800
600
500
400
300
250
200
150
125
100
50
200
400
(8660)
(6490)
(5410)
(4330)
(3250)
(2710)
(2165)
(1732)
(1298)
(1082)
(865)
(649)
(541)
(433)
(325)
(271)
(217)
(173)
(130)
(108)
(87)
(65)
(54)
(43.2)
(32.1)
(26.4)
(20.6)
(7.4)
(1.13)
(43.2)
(87)
(.46)
WATER
LOWER LIMIT
4" Steel Pipe (4.026" I. D.)
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
Gallons Per Minute


Pipe Velocity Ft. Per Sec.
.3
.4
.5
.6
.7
.8
.9
1.0
2
3
4
5
6
7
8
9
10
20
Friction Loss Modulus For 100 Feet of Pipe
Loss — Lbs. Per Sq. In. = Modulus × Specific Gravity
Loss — Feet of Liquid = Modulus × 2.31
10
9
8
7
6
5
4
3
2
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
.09
.08
.07
.06
.05
.04
.03
.02
.01
VISCOSITY
SSU
(CS)
25000
20000
15000
12500
10000
8000
6000
5000
4000
3000
2500
2000
1500
1250
1000
800
600
500
400
300
250
200
150
125
100
(5410)
(4330)
(3250)
(2710)
(2165)
(1732)
(1298)
(1082)
(865)
(649)
(541)
(433)
(325)
(271)
(217)
(173)
(130)
(108)
(87)
(65)
(54)
(43.2)
(32.1)
(26.4)
(20.6)
400
(87)
200
(43.2)
100
(20.6)
50
(7.4)
(.46)
(1.13)
WATER
LOWER LIMIT
6" Steel Pipe (6.065" I. D.)
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
2000
Gallons Per Minute

RESISTANCE OF VALVES AND FITTINGS TO FLOW OF FLUIDS

Example: The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 feet of 6-inch Standard Pipe.

Note: For sudden enlargements or sudden contractions, use the smaller diameter, **d**, on the pipe size scale. This scale is based on flow of water.



(Above Chart Courtesy of CRANE CO.)

SINGLE ACTING CYLINDER DISPLACEMENT

Dia. of Cyl. In.	Area, Square Inches	Length of Stroke in Inches																Dia. of Cyl. In.
		2	3	4	5	6	7	8	9	10	12	14	15	16	18	20	24	
		Displacement per Stroke in Gallons																
1/2	.196	.002	.003	.003	.004	.005	.006	.007	.008	.009	.010	.012	.013	.014	.015	.017	.020	1/2
5/8	.307	.003	.004	.005	.007	.008	.009	.011	.012	.013	.016	.019	.020	.021	.024	.027	.032	5/8
3/4	.442	.004	.006	.008	.010	.011	.013	.015	.017	.019	.023	.027	.029	.031	.034	.038	.046	3/4
7/8	.601	.005	.008	.010	.013	.016	.018	.021	.023	.026	.031	.036	.039	.042	.047	.052	.062	7/8
1	.785	.007	.010	.014	.017	.020	.024	.027	.031	.034	.041	.048	.051	.054	.061	.068	.082	1
1-1/8	.994	.009	.013	.017	.022	.026	.030	.034	.039	.043	.052	.060	.065	.069	.077	.086	.103	1-1/8
1-1/4	1.227	.011	.016	.021	.027	.032	.037	.043	.048	.053	.064	.074	.079	.085	.096	.106	.127	1-1/4
1-3/8	1.485	.013	.019	.026	.032	.039	.044	.051	.058	.064	.077	.089	.096	.103	.116	.128	.154	1-3/8
1-1/2	1.767	.015	.023	.031	.038	.046	.054	.061	.069	.077	.092	.107	.115	.122	.138	.153	.184	1-1/2
1-3/4	2.405	.021	.031	.042	.052	.063	.073	.083	.094	.104	.125	.146	.156	.170	.187	.208	.249	1-3/4
2	3.142	.027	.041	.054	.068	.082	.095	.109	.122	.136	.163	.190	.204	.218	.245	.272	.326	2
2-1/4	3.976	.034	.052	.069	.086	.103	.121	.138	.155	.172	.206	.241	.258	.275	.309	.344	.413	2-1/4
2-1/2	4.909	.043	.064	.085	.106	.128	.149	.170	.191	.213	.255	.298	.319	.340	.383	.425	.510	2-1/2
2-3/4	5.940	.051	.077	.103	.129	.154	.180	.206	.231	.257	.309	.360	.386	.411	.463	.514	.617	2-3/4
3	7.069	.061	.092	.122	.153	.184	.214	.245	.275	.306	.367	.428	.459	.489	.551	.612	.734	3
3-1/4	8.296	.072	.108	.144	.179	.215	.251	.287	.323	.359	.431	.503	.539	.575	.647	.718	.862	3-1/4
3-1/2	9.621	.083	.125	.167	.208	.249	.292	.333	.375	.417	.499	.583	.625	.666	.750	.833	.999	3-1/2
3-3/4	11.045	.096	.143	.191	.239	.287	.335	.382	.430	.478	.574	.669	.717	.765	.861	.956	1.147	3-3/4
4	12.566	.109	.163	.218	.272	.326	.381	.435	.490	.544	.653	.762	.816	.870	.079	1.088	1.306	4
4-1/4	14.186	.123	.184	.246	.307	.368	.429	.491	.553	.614	.737	.860	.921	.982	1.105	1.228	1.473	4-1/4
4-1/2	15.904	.138	.207	.275	.344	.413	.482	.551	.619	.689	.826	.964	1.033	1.102	1.239	1.377	1.652	4-1/2
4-3/4	17.721	.153	.230	.307	.384	.460	.537	.614	.690	.767	.920	1.073	1.150	1.227	1.380	1.534	1.841	4-3/4
5	19.635	.170	.255	.340	.425	.510	.595	.680	.765	.850	1.020	1.190	1.275	1.360	1.530	1.700	2.040	5
5-1/4	21.648	.187	.281	.375	.469	.562	.656	.750	.843	.937	1.124	1.311	1.406	1.499	1.686	1.874	2.249	5-1/4
5-1/2	23.758	.206	.309	.411	.514	.617	.720	.823	.926	1.029	1.234	1.440	1.543	1.646	1.851	2.057	2.468	5-1/2
5-3/4	25.967	.225	.337	.449	.562	.674	.787	.899	1.011	1.124	1.349	1.573	1.686	1.798	2.022	2.248	2.698	5-3/4
6	28.274	.246	.367	.489	.612	.734	.857	.979	1.102	1.224	1.469	1.714	1.836	1.958	2.203	2.448	2.938	6
6-1/4	30.680	.266	.398	.531	.664	.797	.929	1.062	1.195	1.328	1.593	1.859	1.992	2.124	2.390	2.656	3.188	6-1/4
6-1/2	33.183	.287	.431	.574	.718	.861	1.006	1.149	1.293	1.436	1.796	2.011	2.155	2.298	2.589	2.873	3.447	6-1/2
6-3/4	35.785	.309	.465	.619	.775	.929	1.084	1.239	1.394	1.549	1.858	2.168	2.323	2.479	2.788	3.098	3.716	6-3/4
7	38.485	.333	.499	.666	.833	.999	1.166	1.333	1.499	1.666	1.999	2.332	2.499	2.666	2.999	3.332	3.998	7
7-1/2	44.179	.383	.574	.765	.956	1.148	1.339	1.530	1.721	1.913	2.295	2.678	2.869	3.060	3.443	3.825	4.590	7-1/2
7-3/4	47.173	.408	.613	.817	1.021	1.225	1.429	1.633	1.837	2.042	2.450	2.858	3.063	3.267	3.675	4.084	4.900	7-3/4
8	50.266	.435	.652	.870	1.088	1.306	1.523	1.741	1.958	2.176	2.611	3.046	3.264	3.482	3.917	4.352	5.222	8
8-1/2	56.745	.491	.736	.982	1.225	1.473	1.719	1.964	2.210	2.456	2.947	3.439	3.684	3.929	4.420	4.912	5.894	8-1/2
8-3/4	60.132	.520	.780	1.041	1.301	1.561	1.822	2.082	2.342	2.603	3.123	3.644	3.904	4.164	4.685	5.206	6.247	8-3/4
9	63.617	.551	.826	1.101	1.377	1.652	1.928	2.203	2.479	2.754	3.305	3.856	4.131	4.406	4.957	5.508	6.609	9
9-1/2	70.882	.613	.920	1.227	1.534	1.840	2.147	2.454	2.761	3.068	3.681	4.295	4.602	4.908	5.523	6.136	7.364	9-1/2
9-3/4	74.662	.646	.969	1.293	1.616	1.939	2.262	2.585	2.908	3.232	3.878	4.525	4.848	5.171	5.817	6.464	7.756	9-3/4
10	78.540	.680	1.020	1.360	1.700	2.040	2.380	2.720	3.060	3.400	4.080	4.760	5.100	5.440	6.120	6.800	8.160	10
10-1/4	82.516	.716	1.074	1.432	1.790	2.148	2.506	2.864	3.222	3.580	4.296	5.012	5.370	5.728	6.444	7.160	8.592	10-1/4
10-1/2	86.590	.750	1.125	1.500	1.875	2.250	2.625	3.000	3.375	3.750	4.500	5.250	5.625	6.000	6.750	7.500	9.000	10-1/2
10-3/4	90.762	.786	1.179	1.572	1.965	2.358	2.751	3.144	3.537	3.930	4.716	5.502	5.895	6.288	7.074	7.860	9.432	10-3/4
11	95.033	.823	1.234	1.646	2.057	2.464	2.879	3.291	3.726	4.114	4.937	5.760	6.171	6.582	7.405	8.228	9.874	11
11-1/4	99.402	.860	1.290	1.720	2.152	2.580	3.012	3.440	3.873	4.300	5.160	6.024	6.454	6.880	7.746	8.600	10.320	11-1/4
11-1/2	103.869	.899	1.348	1.798	2.248	2.697	3.147	3.597	4.046	4.496	5.396	6.295	6.744	7.194	8.093	8.992	10.790	11-1/2
11-3/4	108.434	.939	1.409	1.878	2.349	2.818	3.285	3.756	4.227	4.695	5.636	6.576	7.046	7.512	8.454	9.390	11.272	11-3/4
12	113.098	.979	1.468	1.958	2.448	2.938	3.422	3.917	4.406	4.896	5.875	6.854	7.344	7.833	8.813	9.792	11.750	12
12-1/4	117.859	1.018	1.527	2.036	2.545	3.054	3.563	4.072	4.580	5.090	6.108	7.126	7.635	8.144	9.160	10.180	12.216	12-1/4
12-1/2	122.718	1.062	1.593	2.124	2.655	3.186	3.717	4.241	4.779	5.310	6.372	7.434	7.965	8.488	9.558	10.620	12.744	12-1/2
12-3/4	127.676	1.104	1.656	2.208	2.760	3.312	3.864	4.416	4.967	5.520	6.624	7.728	8.280	8.832	9.934	11.040	13.248	12-3/4
13	132.733	1.149	1.723	2.297	2.872	3.445	4.022	4.596	5.170	5.745	6.894	8.042	8.619	9.196	10.342	11.492	13.790	13
13-1/4	137.886	1.194	1.791	2.388	2.985	3.582	4.179	4.776	5.373	5.970	7.164	8.358	8.955	9.552	10.758	11.940	14.328	13-1/4
13-1/2	143.139	1.238	1.857	2.476	3.095	3.714	4.333	4.952	5.571	6.190	7.428	8.666	9.285	9.704	11.142	12.380	14.856	13-1/2
13-3/4	148.489	1.288	1.932	2.576	3.220	3.864	4.508	5.152	5.796	6.440	7.728	9.008	9.660	10.304	11.592	12.880	15.456	13-3/4
14	153.938	1.332	1.998	2.665	3.331	3.997	4.664	5.330	5.996	6.663	7.994	9.328	9.994	10.660	11.995	13.326	15.991	14
14-1/4	159.486	1.382	2.073	2.764	3.456	4.146	4.837	5.528	6.219	6.910	8.292	9.774	10.360	11.056	12.438	13.820	16.584	14-1/4
14-1/2	165.130	1.430	2.142	2.858	3.574	4.284	5.004	5.718	6.426	7.148	8.578	10.008	10.722	11.424	12.862	14.296	17.136	14-1/2
14-3/4	170.873	1.478	2.211	2.956	3.696	4.424	5.172	5.912	6.650	7.390	8.868	10.374	11.080	11.824	13.300	14.780	17.736	14-3/4
15	176.715	1.530	2.295	3.060	3.825	4.590	5.355	6.120	6.885	7.650	9.178	10.710	11.475	12.240	13.770	15.300	18.360	15
15-1/4	182.654	1.582	2.373	3.164	3.956	4.746	5.537	6.328	7.119	7.910	9.492	11.174	11.870	12.766	14.238	15.820	18.994	15-1/4
15-1/2	188.692	1.632	2.448	3.264	4.080	4.896	5.712	6.528	7.343	8.160	9.792	11.424	12.420	13.156	14.686	16.320	19.694	15-1/2
15-3/4	194.828	1.686	2.529	3.372	4.215	5.058	5.901	6.744	7.585	8.430	10.116	11.802	12.640	13.488	15.170	16.860	20.232	15-3/4
16	201.062	1.740	2.610	3.481	4.351	5.221	6.092	6.962	7.832	8.703	10.443	12.184	13.054	13.924	15.665	17.406	20.887	16
16-1/4	207.394	1.792	2.688	3.584	4.480	5.377	6.272	7.168	8.063	8.960	10.754	12.544	13.440	14.336	16.128	17.920	21.508	16-1/4
16-1/2	213.825	1.850	2.775	3.700	4.625	5.550	6.474	7.400	8.323	9.250	11.100	12.948	13.870	14.800	16.648	18.500	22.200	16-1/2
16-3/4	220.353	1.912	2.868	3.824	4.781	5.736	6.693	7.648	8.604	9.560	11.472	13.386	14.340	15.296	17.205	19.120	22.944	16-3/4
17	226.980	1.965	2.949	3.932	4.916	5.898	6.882	7.864	8.848	9.830	11.796	13.764	14.739	15.728	17.796	19.660	23.592	17
17-1/4	233.705	2.024	3.036	4.048	5.059	6.072	7.083	8.096	9.105	10.120	12.144	14.166	15.180	16.192	18.210	20.240	24.288	17-1/4
17-1/2	240.528	2.082	3.123	4.164	5.207	6.246	7.290	8.328	9.371	10.410	12.492	14.580	15.620	16.656	18.742	20.820	24.984	17-1/2
17-3/4	247.450	2.140	3.210	4.280	5.357	6.420	7.499	8.560	9.641	10.700	12.840	14.098	16.070	17.120	19.262	21.400	25.680	17-3/4
18	254.469	2.202	3.303	4.404	5.509	6.606	7.713	8.808	9.915	11.010	13.212	15.426	16.530	17.616	19.830	22.020	26.424	18
18-1/4	261.587	2.266	3.399	4.532	5.662	6.798	7.927	9.064	10.197	11.330	13.596	15.864	16.990	18.128	20.394	22.660	27.192	18-1/4
18-1/2	268.803	2.328	3.492	4.656	5.820	6.984	8.147	9.312	10.476	11.640	13.968	16.294	17.460	18.624	20.952	23.280	27.936	18-1/2
18-3/4	276.117	2.392	3.588	4.784	5.970	7.176	8.370	9.568	10.754	11.960	14.352	16.740	17.940	19.136	21.508	23.920	28.714	18-3/4
19	283.529	2.456	3.684	4.912	6.137	7.368	8.592	9.824	11.052	12.280	14.736	17.194	18.410	19.648	22.104	24.560	29.472	19
19-1/4	291.039	2.520	3.780	5.040	6.299	7.560	8.819	10.080	11.340	12.600	15.120	16.638	18.900	20.160	22.680	25.200	30.240	19-1/4
19-1/2	298.648	2.586	3.879	5.172	6.465	7.758	9.051	10.344	11.637	12.930	15.516	18.102	19.390	20.688	23.274	25.860	31.132	19-1/2
19-3/4	306.355	2.654	3.981	5.308	6.633	7.962	9.286	10.616	11.943	13.270	15.924	18.570	19.900	21.232	23.886	26.540	31.848	19-3/4
20	314.160	2.720	4.080	5.440	6.800	8.160	9.520	10.880	12.240	13.600	16.320	19.040	20.400	21.760	24.480	27.200	32.640	20

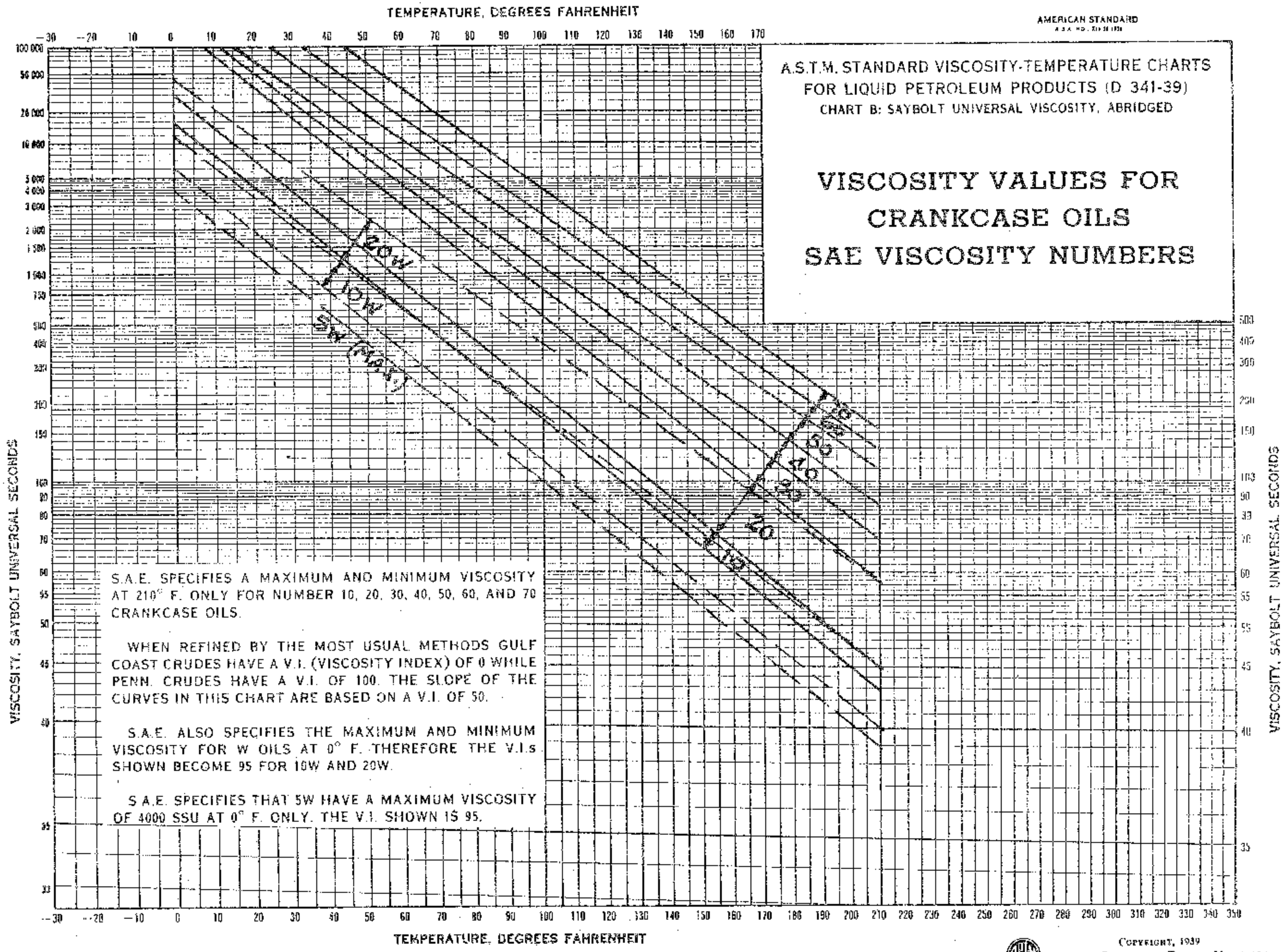
Notes: $\text{G.P.M.} = \dfrac{\text{Displacement (gallons)}}{\text{Time in minutes}}$

$\text{P.S.I.} = \dfrac{\text{Total Load (lbs.)}}{\text{Cyl. Area (sq. in.)}}$

AMERICAN STANDARD

A.S.T.M. STANDARD VISCOSITY-TEMPERATURE CHARTS
FOR LIQUID PETROLEUM PRODUCTS (D 341-39)
CHART B: SAYBOLT UNIVERSAL VISCOSITY, ABRIDGED

VISCOSITY VALUES FOR CRANKCASE OILS SAE VISCOSITY NUMBERS



S.A.E. SPECIFIES A MAXIMUM AND MINIMUM VISCOSITY AT 210° F. ONLY FOR NUMBER 10, 20, 30, 40, 50, 60, AND 70 CRANKCASE OILS.

WHEN REFINED BY THE MOST USUAL METHODS GULF COAST CRUDES HAVE A V.I. (VISCOSITY INDEX) OF 0 WHILE PENN. CRUDES HAVE A V.I. OF 100. THE SLOPE OF THE CURVES IN THIS CHART ARE BASED ON A V.I. OF 50.

S.A.E. ALSO SPECIFIES THE MAXIMUM AND MINIMUM VISCOSITY FOR W OILS AT 0° F. THEREFORE THE V.I.s SHOWN BECOME 95 FOR 10W AND 20W.

S.A.E. SPECIFIES THAT 5W HAVE A MAXIMUM VISCOSITY OF 4000 SSU AT 0° F. ONLY. THE V.I. SHOWN IS 95.

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AMERICAN SOCIETY FOR TESTING MATERIALS
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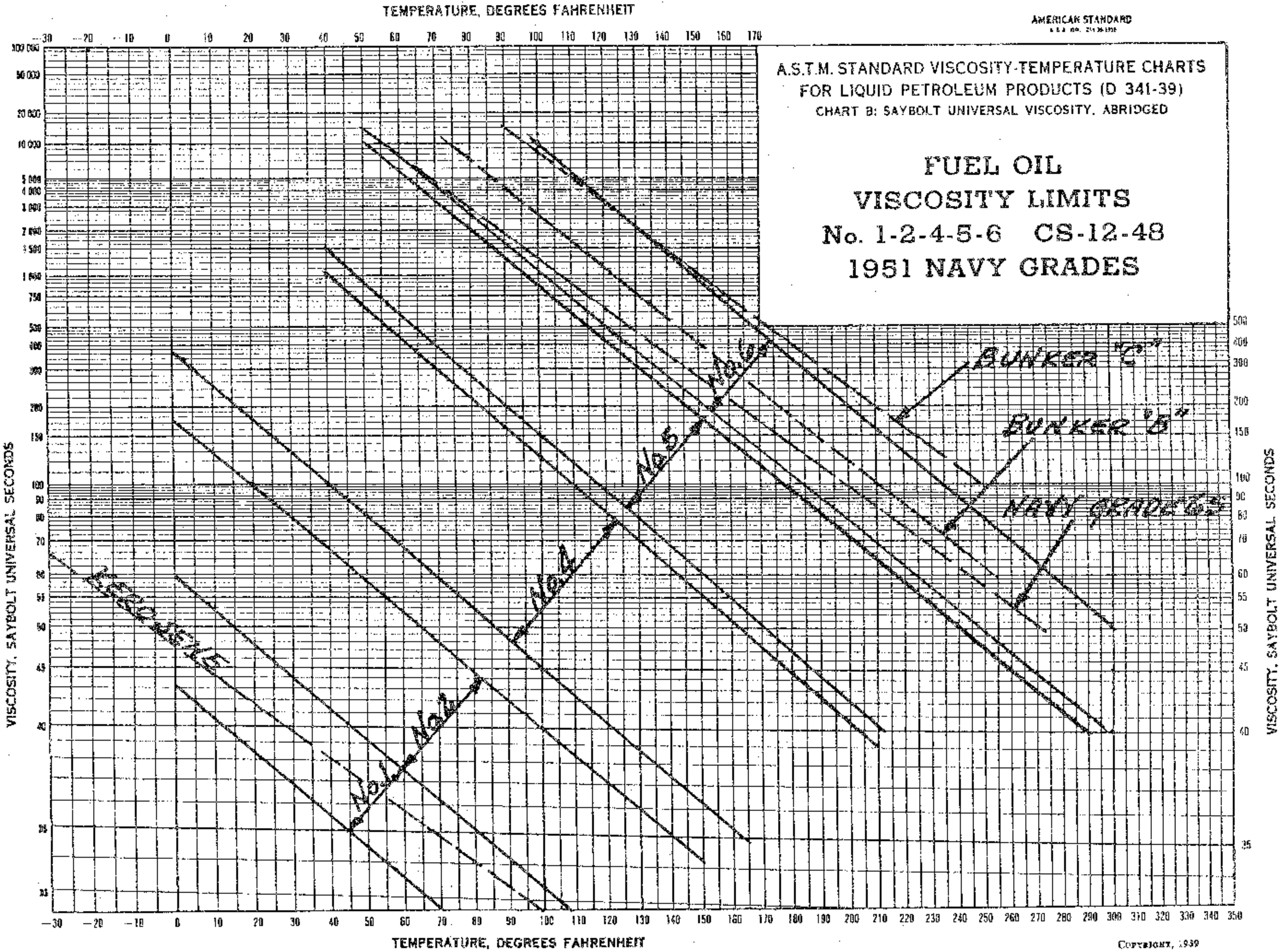
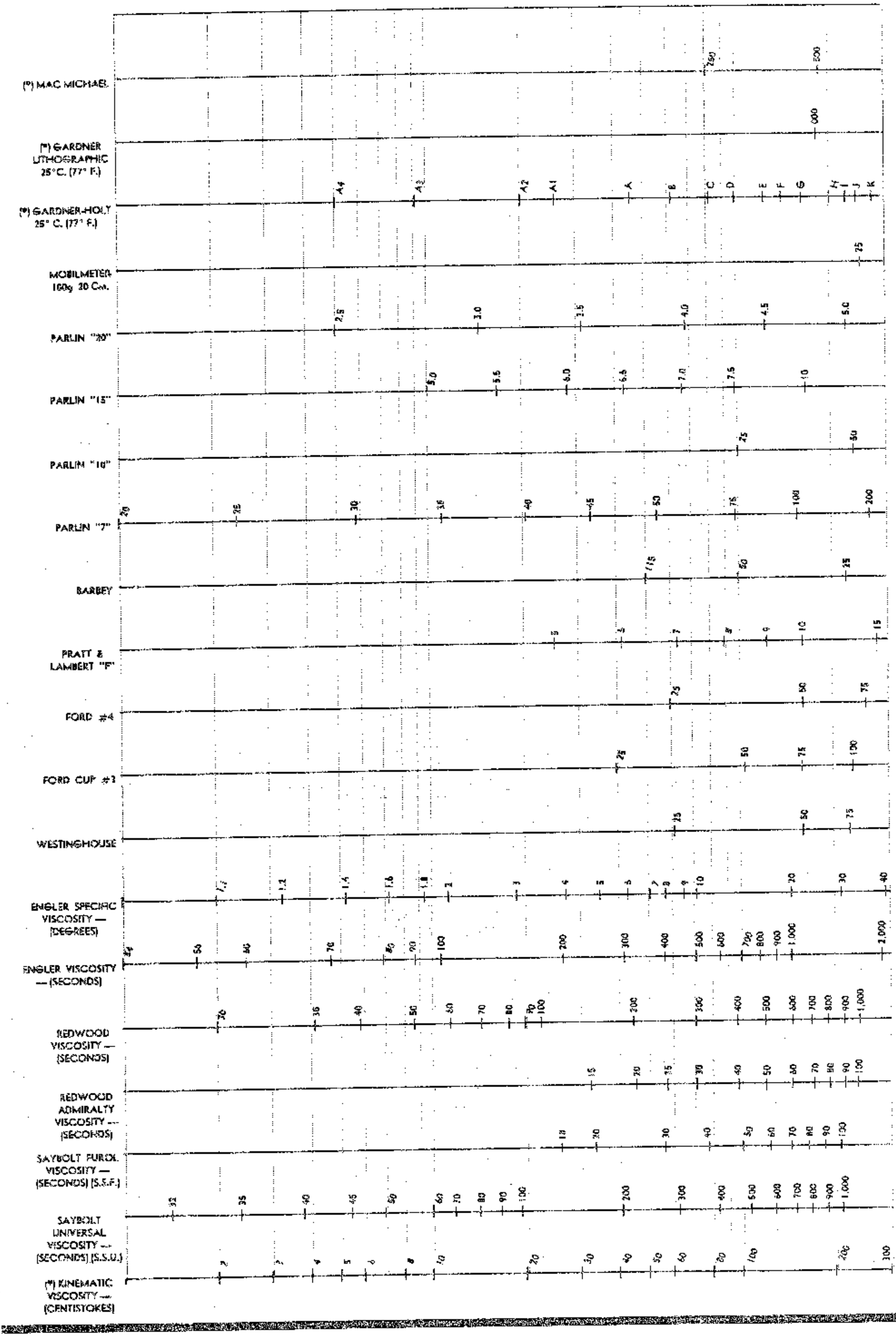
AMERICAN STANDARD

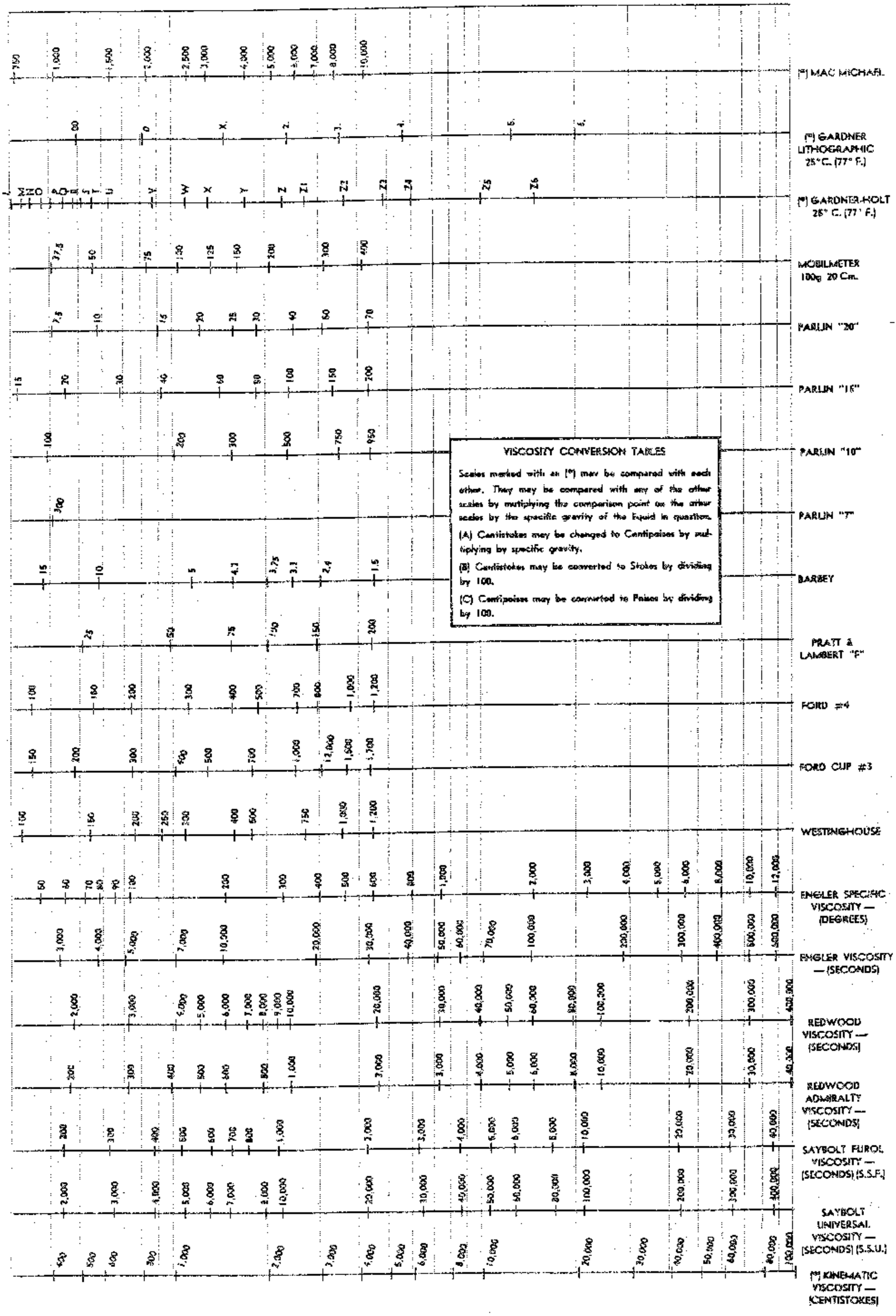


A.S.T.M. STANDARD VISCOSITY-TEMPERATURE CHARTS
FOR LIQUID PETROLEUM PRODUCTS (D 341-39)
CHART B: SAYBOLT UNIVERSAL VISCOSITY, ABRIDGED

FUEL OIL
VISCOSITY LIMITS
No. 1-2-4-5-6 CS-12-48
1951 NAVY GRADES

PRINTED IN U.S.A.


(*) MAC MICHAEL 250 500
(*) GARDNER LITHOGRAPHIC 25°C. (77° F.) 600
(*) GARDNER-HOLT 25° C. (77° F.) A4 A3 A2 A1 A B C D E F G H I J K
MOBILMETER 100g 20 Cm. 25
PARLIN "20" 2.5 3.0 3.5 4.0 4.5 5.0
PARLIN "15" 5.0 5.5 6.0 6.5 7.0 7.5 10
PARLIN "10" 25 50
PARLIN "7" 20 25 30 35 40 45 50 75 100 200
BARBEY 115 50 25
PRATT & LAMBERT "F" 3 5 7 8 9 10 15
FORD #4 25 50 75
FORD CUP #3 25 50 75 100
WESTINGHOUSE 25 50 75
ENGLER SPECIFIC VISCOSITY — (DEGREES) 1.1 1.2 1.4 1.6 1.8 2 3 4 5 6 7 8 9 10 20 30 40
ENGLER VISCOSITY — (SECONDS) 54 55 60 70 80 90 100 200 300 400 500 600 700 800 900 1,000 2,000
REDWOOD VISCOSITY — (SECONDS) 30 35 40 50 60 70 80 90 100 200 300 400 500 600 700 800 900 1,000
REDWOOD ADMIRALTY VISCOSITY — (SECONDS) 15 20 25 30 40 50 60 70 80 90 100
SAYBOLT FUROL VISCOSITY — (SECONDS) (S.S.F.) 15 20 30 40 50 60 70 80 90 100
SAYBOLT UNIVERSAL VISCOSITY — (SECONDS) (S.S.U.) 32 35 40 45 50 60 70 80 90 100 200 300 400 500 600 700 800 900 1,000
(*) KINEMATIC VISCOSITY — (CENTISTOKES) 2 3 4 5 6 8 10 20 30 40 50 60 80 100 200 300



VISCOSITY CONVERSION TABLES

Scales marked with an (*) may be compared with each other. They may be compared with any of the other scales by multiplying the comparison point on the other scales by the specific gravity of the liquid in question.

(A) Centistokes may be changed to Centipoises by multiplying by specific gravity.

(B) Centistokes may be converted to Stokes by dividing by 100.

(C) Centipoises may be converted to Poises by dividing by 100.

VISCOSITIES & SPECIFIC GRAVITY OF COMMON LIQUIDS

Viscosity Shown in SSU Unless Marked * for Centistokes

Liquid	Sp. Gr. at 60° F	Viscosity*	Temp. ° F
ASPHALTS:			
Unblended or virgin asphalts	1.1 to 1.5	2,500 to 12,000	250
Blended Asphalt:			
RS-1, MS-1 or SS-1 emulsified primer or binder	Approx. 1.0	155 to 1,000	77
RC-0, MC-0 or SC-0 cutbacks or binders	Approx. 1.0	737 to 1,500	77
RC-1, MC-1 or SC-1 cutbacks or binders	Approx. 1.0	2,400 to 5,000	100
RC-2, MC-2 or SC-2 cutbacks or binders	Approx. 1.0	2,400 to 5,000	122
RC-3, MC-3 or SC-3 cutbacks or binders	Approx. 1.0	6,000 to 13,000	122
RC-4, MC-4 or SC-4 cutbacks or binders	Approx. 1.0	8,000 to 20,000	140
RC-5, MC-5 or SC-5 cutbacks or binders	Approx. 1.0	28,000 to 85,000	140
Asphalt Emulsion Type I			
Federal Specification	Approx. 1.0	1,000 to 7,000	77
Asphalt Emulsion Type II, V & VI Federal Specification	Approx. 1.0	155 to 1,000	77
CHEMICALS:			
Acetic Acid (100%)	1.049--1.055	*1.13	68
Acetone (100%)	.792	* .41	68
Alcohol-Ethyl (100%)	.79	*1.54	68
Benzol	.879 @ 68° F	* .744	68
Black Liquor (typical)	1.30	5,000	122
Carbon Tetrachloride	1.594 @ 68° F	* .612	68
Caustic Soda Solutions:			
20% NaOH	1.22	39.4	65
30% NaOH	1.33	58.1	65
40% NaOH	1.43	110.1	65
Ethyl Acetate	.90 @ 68° F	* .49	68
Freon	1.37 to 1.49 @ 70° F	* .27–.32	70
Glycerine (100%)	1.26 @ 68° F	2,950	68 6
Glycol:			
Propylene	1.038 @ 68° F	240.6	70
Triethylene	1.125 @ 68° F	185.7	70
Diethylene	1.12	149.7	70
Ethylene	1.125	88.4	70
Phenol (Carbolic Acid)	.95 to 1.08	65	65
Silicate of Soda	40° B	365	100
Sulfuric Acid (100%)	1.83	75.7	68
FISH AND ANIMAL OILS:			
Bone Oil	.918	220	130
Cod Oil	.928	150	100
Lard	.96	287	100
Lard Oil	.912 to .925	190 to 220	100
Menhadden Oil	.933	140	100
Neatsfoot Oil	.917	230	100
Sperm Oil	.883	110	100
Whale Oil	.925	163 to 184	100

Liquid	Sp. Gr. at 60° F	Viscosity*	Temp. ° F
MINERAL OILS:			
Automobile Crankcase Oils (Average Midcontinent Paraffin Base):			
SAE 10	**.880 to .935	170 to 220	100
SAE 20	**.880 to .935	220 to 550	100
SAE 30	**.880 to .935	550 to 800	100
SAE 40	**.880 to .935	800 to 1,100	100
SAE 50	**.880 to .935	1,100 to 1,800	100
SAE 60	**.880 to .935	1,800 to 2,500	100
SAE 70	**.880 to .935	2,500 to 4,000	100
Automobile Transmission Lubricants:			
SAE 80	**.880 to .935	100,000 max	0
SAE 90	**.880 to .935	800 to 1,500	100
SAE 140	**.880 to .935	950 to 2,300	130
SAE 250	**.880 to .935	Over 2,300	130
Crude Oils:			
Texas, Oklahoma	.81 to .916	40 to 783	60
Wyoming, Montana	.86 to .88	74 to 1,215	60
California	.78 to .92	40 to 4,840	60
Pennsylvania	.8 to .85	46 to 215	60
Diesel Engine Lubricating Oils (Based on Average Midcontinent Paraffin Base):			
Federal Specification No. 9110	**.880 to .935	165 to 240	100
Federal Specification No. 9170	**.880 to .935	300 to 410	100
Federal Specification No. 9250	**.880 to .935	470 to 590	100
Federal Specification No. 9370	**.880 to .935	800 to 1,100	100
Federal Specification No. 9500	**.880 to .935	490 to 600	130
Diesel Fuel Oils:			
No. 2D	**.82 to .95	32.6 to 45.5	100
No. 3D	**.82 to .95	45.5 to 65	100
No. 4D	**.82 to .95	140 max	100
No. 5D	**.82 to .95	400 max	122
Fuel Oils:			
No. 1	**.82 to .95	34 to 40	70
No. 2	**.82 to .95	36 to 50	70
No. 3	**.82 to .95	35 to 45	100
No. 5A	**.82 to .95	50 to 125	100
No. 5B	**.82 to .95	125 to 400	100
No. 6	**.82 to .95	450 to 3,000	122
Fuel Oil—Navy Specification	**.989 max	110 to 225	122
Fuel Oil—Navy II	1.0 max	1,500 max	122
Gasoline	.68 to .74	* .46 to .88	60
Gasoline (Natural)	76.5° API	* .41	68
Gas Oil	28° API	73	70
Insulating Oil:			
Transformer, switches and circuit breakers		115 max	70
Kerosene	.78 to .82	35	68
Machine Lubricating Oil (Average Pennsylvania Paraffin Base):			
Federal Specification No. 8	**.880 to .935	112 to 160	100
Federal Specification No. 10	**.880 to .935	160 to 235	100
Federal Specification No. 20	**.880 to .935	235 to 365	100

VISCOSITIES & SPECIFIC GRAVITY OF COMMON LIQUIDS

(Continued)

Liquid	Sp. Gr. at 60° F	Viscosity*	Temp. ° F
Federal Specification No. 30	**.880 to .935	385 to 550	100
Mineral Lard Cutting Oil:			
Federal Specification Grade 1		140 to 190	100
Federal Specification Grade 2		190 to 220	100
Petrolatum	.825	100	130
Turbine Lubricating Oil:			
Federal Specification	.91 Average	400 to 440	100
VEGETABLE OILS:			
Castor Oil	.96 @ 68° F	1,200 to 1,500	100
China Wood Oil	.943	1,425	69
Cocoanut Oil	.925	140 to 148	100
Corn Oil	.924	135	130
Cotton Seed Oil	.88 to .925	176	100
Linseed Oil, Raw	.925 to .939	143	100
Olive Oil	.912 to .918	200	100
Palm Oil	.924	221	100
Peanut Oil	.920	195	100
Rape Seed Oil	.919	250	100
Rosin Oil	.980	1,500	100
Rosin (Wood)	1.09 (Avg.)	500 to 20,000	200
Sesame Oil	.923	184	100
Soja Bean Oil	.927 to .98	165	100
Turpentine	.86 to .87	33	60
SUGAR, SYRUPS, MOLASSES, ETC.			
Corn Syrups	1.4 to 1.47	5,000 to 500,000	100
Glucose	1.35 to 1.44	35,000 to 100,000	100
Honey (Raw)		340	100
Molasses "A"	1.40 to 1.46	1,300 to 23,000	100
Molasses "B"	1.43 to 1.48	6,400 to 60,000	100
Molasses "C"	1.46 to 1.49	17,000 to 250,000	100
Sucrose Solutions (Sugar Syrups)			
60 Brix	1.29	230	70
62 Brix	1.30	310	70
64 Brix	1.31	440	70
66 Brix	1.326	650	70
68 Brix	1.338	1,000	70
70 Brix	1.35	1,650	70
72 Brix	1.36	2,700	70
74 Brix	1.376	5,500	70
76 Brix	1.39	10,000	70
TARS:			
Tar-Coke Oven	1.12+	3,000 to 8,000	71
Tar-Gas House	1.16 to 1.30	15,000 to 300,000	70
Road Tar:			
Grade RT-2	1.07+	200 to 300	122
Grade RT-4	1.08+	400 to 700	122
Grade RT-6	1.09+	1,000 to 2,000	122
Grade RT-8	1.13+	3,000 to 8,000	122
Grade RT-10	1.14+	20,000 to 60,000	122
Grade RT-12	1.15+	114,000 to 456,000	122
Pine Tar	1.06	2,500	100
MISCELLANEOUS			
Corn Starch Solutions:			
22° B.	1.18	150	70
24	1.20	600	70
25	1.21	1,400	70
Ink—Printers	1.00 to 1.38	2,500 to 10,000	100
Tallow	.918 (Avg.)	56	212
Milk	1.02 to 1.05	* 1.13	68
Varnish—Spar	.9	1,425	68
Water—Fresh	1.0	* 1	66

**Depends on origin or percent and type of solvent

The Viscosities shown are at one temperature only. Should the liquid be handled at a different temperature, this can be approximated by laying a straight edge on the viscosity graphs (pages 24 & 25) parallel to the curves shown and reading the viscosity at temperature desired.

SPECIFIC GRAVITY

Formula for calculating and converting specific gravity:

$$\text{Specific Gravity} = \frac{141.5}{131.5 + \text{Degrees API}}$$

$$\text{Specific Gravity} = \frac{140}{130 + \text{Degrees Baume}}$$

(For liquids lighter than water)

$$\text{Specific Gravity} = \frac{145}{145 - \text{Degrees Baume}}$$

(For liquids heavier than water)

The above formulas show the relationship between API degrees and Baume degrees and specific gravity. The specific gravity is measured by means of hydrometers. The most common of these hydrometers are the API and Baume. The API (American Petroleum Institute) is recommended for use by the petroleum industry and supersedes the Baume for liquids lighter than water.

Brix is an arbitrary hydrometer scale for expressing the specific gravity of liquids, especially sugar solutions; and, according to the formula, specific gravity = 400/400 + n at 15.6° C where "n" is the reading on the scale. This hydrometer actually shows directly the percent of sugar by weight at the temperature indicated on the instrument, usually 17.5° C; that is, degrees Brix is the percent sugar.

Baume is an arbitrary hydrometer scale. There are two types—one for liquids heavier than water and one for liquids lighter than water. One used on liquids heavier than water sinks to 0° in pure water, corresponding to a specific gravity of 1, in the lighter than water scale 0° Baume is equivalent to the gravity of a 10% salt solution.

CONVERSION TABLE BAUME — SPECIFIC GRAVITY — WEIGHT PER GALLON

FOR LIQUIDS HEAVIER THAN WATER

BAUMÉ	SPECIFIC GRAVITY	WGHT. PER GAL.	BAUMÉ	SPECIFIC GRAVITY	WGHT. PER GAL.	BAUMÉ	SPECIFIC GRAVITY	WGHT. PER GAL.	BAUMÉ	SPECIFIC GRAVITY	WGHT. PER GAL.	BAUMÉ	SPECIFIC GRAVITY	WGHT. PER GAL.
0	1.000	8.33	10	1.074	8.95	20	1.160	9.67	30	1.260	10.50	40	1.381	11.51
1	1.006	8.38	11	1.082	9.02	21	1.169	9.74	31	1.271	10.59	45	1.450	12.08
2	1.014	8.45	12	1.090	9.08	22	1.178	9.82	32	1.283	10.69	50	1.526	12.72
3	1.021	8.51	13	1.098	9.15	23	1.188	9.90	33	1.294	10.78	55	1.611	13.42
4	1.028	8.57	14	1.106	9.22	24	1.198	9.98	34	1.306	10.88	60	1.705	14.21
5	1.035	8.62	15	1.115	9.29	25	1.208	10.07	35	1.318	10.98	65	1.812	15.10
6	1.043	8.69	16	1.124	9.37	26	1.218	10.15	36	1.330	11.08	70	1.933	16.11
7	1.050	8.75	17	1.132	9.43	27	1.228	10.23	37	1.342	11.18	....	....	....
8	1.058	8.82	18	1.141	9.51	28	1.239	10.32	38	1.355	11.29	....	....	....
9	1.066	8.88	19	1.150	9.58	29	1.250	10.42	39	1.367	11.39	....	....	....

FOR LIQUIDS LIGHTER THAN WATER

A. P. I.	SPECIFIC GRAVITY	WGHT. PER GAL.	A. P. I.	SPECIFIC GRAVITY	WGHT. PER GAL.	A. P. I.	SPECIFIC GRAVITY	WGHT. PER GAL.	A. P. I	SPECIFIC GRAVITY	WGHT. PER GAL.	A. P. I.	SPECIFIC GRAVITY	WGHT. PER GAL.
10	1.000	8.33	31	0.871	7.25	52	0.771	6.42	73	0.692	5.76	91	.636	5.29
11	0.993	8.27	32	0.865	7.21	53	0.767	6.39	74	0.689	5.73	92	.633	5.27
12	0.986	8.21	33	0.860	7.16	54	0.763	6.35	75	0.685	5.70	93	.630	5.25
13	0.979	8.16	34	0.855	7.12	55	0.759	6.32	76	0.682	5.68	94	.628	5.22
14	0.973	8.10	35	0.850	7.08	56	0.755	6.28	77	0.679	5.65	95	.625	5.20
15	0.966	8.04	36	0.845	7.03	57	0.751	6.25	78	0.675	5.62	96	.622	5.18
16	0.959	7.99	37	0.840	6.99	58	0.747	6.22	79	0.672	5.60	97	.619	5.15
17	0.953	7.94	38	0.835	6.95	59	0.743	6.18	80	0.669	5.57	98	.617	5.13
18	0.946	7.88	39	0.830	6.91	60	0.739	6.15	81	0.666	5.54	99	.614	5.11
19	0.940	7.83	40	0.825	6.87	61	0.735	6.12	82	0.663	5.52	100	.611	5.09
20	0.934	7.78	41	0.820	6.83	62	0.731	6.09	83	0.660	5.49	.....	....	....
21	0.928	7.73	42	0.816	6.79	63	0.728	6.06	84	0.657	5.47	.....	....	....
22	0.922	7.68	43	0.811	7.75	64	0.724	6.03	85	0.654	5.44	.....	....	....
23	0.916	7.63	44	0.806	6.71	65	0.720	5.99	86	0.651	5.42	.....	....	....
24	0.910	7.58	45	0.802	6.68	66	0.717	5.96	87	0.648	5.39	.....	....	....
25	0.904	7.53	46	0.797	6.64	67	0.713	5.93	88	0.645	5.37	.....	....	....
26	0.898	7.48	47	0.793	6.60	68	0.709	5.90	89	0.642	5.34	.....	....	....
27	0.893	7.43	48	0.788	6.56	69	0.706	5.87	90	0.639	5.32	.....	....	....
28	0.887	7.39	49	0.784	6.53	70	0.702	5.85	....	....	....	.....	....	....
29	0.882	7.34	50	0.780	6.49	71	0.699	5.82	....	....	....	.....	....	....
30	0.876	7.30	51	0.775	6.46	72	0.695	5.79	....	....	....	.....	....	....

The specific gravity of a substance is its weight as compared with the weight of an equal bulk of pure water.
For making specific gravity determinations the temperature of the water is usually taken at 62° F. when 1 cubic foot of water weighs 62.355 lbs.
Water is at its greatest density at 39.2° F. or 4° Centigrade.

CONVERSION TABLE BRIX TO SPECIFIC GRAVITY AND BAUMÉ

Brix	Sp. Gr.	Bé	Brix	Sp. Gr.	Bé	Brix	Sp. Gr.	Bé	Brix	Sp. Gr.	Bé	Brix	Sp. Gr.	Bé
0	1.00	0	24	1.101	13.35	48	1.220	26.30	64	1.314	34.64	79	1.410	32.10
2	1.01	1.13	26	1.110	14.45	50	1.230	27.38	66	1.326	35.66	80	1.420	42.60
4	1.02	2.24	28	1.120	15.54	51	1.238	27.91	68	1.340	36.67	82	1.430	43.50
6	1.02	3.37	30	1.130	16.63	52	1.244	28.43	70	1.351	37.66	84	1.440	44.50
8	1.03	4.49	32	1.140	17.73	53	1.249	28.96	71	1.357	38.17	86	1.460	45.44
10	1.04	5.60	34	1.150	18.81	54	1.255	29.48	72	1.364	38.66	88	1.470	46.40
12	1.046	6.71	36	1.160	19.90	55	1.261	30.00	73	1.370	39.16	90	1.480	47.30
14	1.057	7.81	38	1.170	20.98	56	1.267	30.53	74	1.376	39.65	92	1.500	48.20
16	1.066	8.94	40	1.180	22.10	57	1.272	31.05	75	1.383	40.15	94	1.510	49.10
18	1.074	10.04	42	1.190	23.13	58	1.278	31.56	76	1.389	40.64	96	1.530	50
20	1.083	11.15	44	1.200	24.20	60	1.290	32.60	77	1.396	41.12	98	1.540	51
22	1.092	12.30	46	1.210	25.26	62	1.302	33.60	78	1.403	41.61	100	1.560	52

CONVERSION FACTORS

To convert from	To	Multiply By
Atmospheres	PSI	14.7
Atmospheres	Feet of water	33.9
Atmospheres	Inches of Mercury	29.9
Barrels (U.S. liq.)	Gallons (U.S.)	31.5
Barrels of Oil	Gallons (U.S.)	42.0
B.T.U.	H.P. hr.	.0003929
Centimeters	feet	.03280
Centimeters	inches	.3937
Centimeters /min.	feet/min.	1.9684
Centimeters /sec.	feet/sec.	.03280
Centipoises	poises	.01
Centistokes	stokes	.01
Cubic centimeters	cu. ft.	3.5314×10^{-5}
Cubic centimeters	cu. in.	.06102
Cubic centimeters	gallons (liq.)	.000264
Cubic feet	gallons (liq.)	7.4805
Cubic feet	cubic in.	1728
Cubic feet/min.	g.p.m.	7.4805
Cubic inches	gallons	.004329
Cubic inches	cubic cm.	16.387
Cubic inches	cubic ft.	.0005787
Cubic meters	gallons (liq.)	264.17
Cubic meters	cu. cm.	1×10^{6}
Cubic meters	cu. ft.	35.31
Cubic meters	cu. in.	61,023.38
Degrees	Revolutions	.00277778
Dynes	Pounds	2.24809×10^{-6}
Dynes/sq. cm.	p.s.i.	1.45038×10^{-5}
Fathom	feet	6
Feet	centimeters	30.48006
Feet	meters	.3048006
Feet of water	atmosphere	.02949
Feet of water	psi	.433
Feet of water	inches of Hg.	.884
Feet/hr.	miles/hour	.00018939
Feet min.	meters/min.	.3048
Feet/min.	miles/hour	.01136
Feet/second	miles per hour	.681818
Foot pounds	H.P. hr.	5.0505×10^{-7}
Foot pounds/min.	Horsepower	3.0303×10^{-5}
Gallons	cubic cm.	3,785.43
Gallons	cubic in.	231
Gallons	gallon (Imp.)	.83268
Gallons	cu. ft.	.13368
Gallons/min.	cu. ft./min.	.13368
Horsepower	ft. lbs./min.	33,000
Horsepower	ft. lbs./sec.	550
Inches	feet	.083333
Inches	meters	.254
Inches	millimeters	25.40005
Inches	mils	1000
Inches of Hg.	atmospheres	.033327
Inches of Hg.	ft. of water	1.1309
Inches of Hg.	psi	.489
Kilograms	pounds (avdp.)	2.2046
Kilograms/sq. cm.	psi	14.2233
Kilograms/sq. mm.	psi	1422.33
Liters	gallons	.264178
Meters	feet	3.2808
Meters	inches	39.37

To convert from	To	Multiply By
Poise	centipoise	100.0
Pounds water	gallons	.11985
PSI	atmospheres	.06804
PSI	Inches of Hg.	2.04179
PSI	feet of water	2.31
Square inches	sq. cm.	6.4516
Square inches	sq. ft.	.006944
Square inches	sq. mm.	645.163
Square millimeters	sq. in.	.0015499

FAHRENHEIT-CENTIGRADE CONVERSION TABLE

Fahr.	Centi.	Fahr.	Centi.	Fahr.	Centi.
—20	—28.9	88	31.1	196	91.1
—18	—27.8	90	32.2	198	92.2
—16	—26.7	92	33.3	200	93.3
—14	—25.6	94	34.4	202	94.4
—12	—24.4	96	35.6	204	95.6
—10	—23.3	98	36.7	206	96.7
—8	—22.2	100	37.8	208	97.8
—6	—21.1	102	38.9	210	98.9
—4	—20.	104	40.	212	100.
—2	—18.9	106	41.1	214	101.1
0	—17.8	108	42.2	216	102.2
2	—16.7	110	43.3	218	103.3
4	—15.6	112	44.4	220	104.4
6	—14.4	114	45.6	222	105.6
8	—13.3	116	46.7	224	106.7
10	—12.2	118	47.8	226	107.8
12	—11.1	120	48.9	228	108.9
14	—10.	122	50.	230	110.
16	—8.9	124	51.1	232	111.1
18	—7.8	126	52.2	234	112.2
20	—6.7	128	53.3	236	113.3
22	—5.6	130	54.4	238	114.4
24	—4.4	132	55.6	240	115.6
26	—3.3	134	56.7	242	116.7
28	—2.2	136	57.8	244	117.8
30	—1.1	138	58.9	246	118.9
32	0.	140	60.	248	120.
34	1.1	142	61.1	250	121.1
36	2.2	144	62.2	252	122.2
38	3.3	146	63.3	254	123.3
40	4.4	148	64.4	256	124.4
42	5.6	150	65.6	258	125.6
44	6.7	152	66.7	260	126.7
46	7.8	154	67.8	262	127.8
48	8.9	156	68.9	264	128.9
50	10.	158	70.	266	130.
52	11.1	160	71.1	268	131.1
54	12.2	162	72.2	270	132.2
56	13.3	164	73.3	272	133.3
58	14.4	166	74.4	274	134.4
60	15.6	168	75.6	276	135.6
62	16.7	170	76.7	278	136.7
64	17.8	172.	77.8	280	137.8
66	18.9	174	78.9	282	138.9
68	20.	176	80.	284	140.
70	21.1	178	81.1	286	141.1
72	22.2	180	82.2	288	142.2
74	23.3	182	83.3	290	143.3
76	24.4	184	84.4	292	144.4
78	25.6	186	85.6	294	145.6
80	26.7	188	86.7	296	146.7
82	27.8	190	87.8	298	147.8
84	28.9	192	88.9	300	148.9
86	30.	194	90.		

ELECTRICAL DATA

Poles	60 Cycles	50 Cycles	40 Cycles	25 Cycles
2	3600	3000	2400	1500
4	1800	1500	1200	750
6	1200	1000	800	500
8	900	750	600	375
10	720	600	480	300
12	600	500	400	250

DIRECT CURRENT

$$\text{Kilowatts} = \frac{\text{Volts} \times \text{Amperes}}{1{,}000}$$

$$\text{Horsepower} = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency}}{746}$$

$$\text{Kilowatts} = \frac{\text{Horsepower} \times 746}{1{,}000 \times \text{Efficiency}}$$

ALTERNATING CURRENT

Single-phase W = EI × P.F.
Two-phase W = 2EI × P.F.
Three-phase W = 1.732EI × P.F.

W = Watts; E = average volts between line terminals;
I = average line current;
P.F. = power factor expressed as a decimal fraction.

$$\text{KVA} = \frac{\text{Volts} \times \text{Amperes}}{1{,}000}$$

$$\text{KW} = \text{KVA} \times \text{P.F.}$$

$$\text{Horsepower} = \frac{\text{KW} \times \text{Efficiency}}{746}$$

MOTOR SPEEDS

The synchronous speed of any A.C. motor is fixed by the frequency of the applied voltage and the number of pair of poles. Therefore, the maximum synchronous speed is equal to the frequency. For instance, in a 60-cycle system, it will be equal to 60 revolutions per second or 3,600 revolutions per minute. According to the number of pair of poles, the synchronous speed of the motor will be equal to the maximum speed divided by 1, 2, 3, 4, etc., or for 60-cycle,

$$\frac{3{,}600}{2} \times 1{,}800 \text{ RPM.,} \qquad \frac{3{,}600}{3} \times 1{,}200 \text{ RPM.,}$$

$$\frac{3{,}600}{4} \times 900 \text{ RPM., etc.}$$

Synchronous motors, as the name implies, run at synchronous speeds, regardless of the load. Squirrel-cage or wound-rotor induction motors lose speed as the load increases. The difference in speed between no load and full load is about 3 to 5%, rather more for very small motors and less for very large motors.

In belt drive calculations, it is necessary to figure on the full load speed, which is the actual speed of the motor when running under normal conditions at full or nearly full capacity.

Direct current motors also vary in speed under load changes and according to voltage. Constant speed D.C. motors operating at full-line voltage usually are made in the following speeds according to type and horsepower = 2,100 RPM., 1,750 RPM., 1,375 RPM., 1,150 RPM., 1,050 RPM., 1,000 RPM., 850 RPM., 575 RPM. Adjustable speed D.C. motors are made in various speed combinations ranging between 300-1,200 RPM., and 700-2,100 RPM.

NEMA

FRAME ASSIGNMENTS

While no horsepower and speed ratings have been assigned to fractional-horsepower frames, some tables of integral horsepower and speed ratings assigned to motor frames are shown as follows:

SINGLE-PHASE MOTORS

open — HORIZONTAL AND VERTICAL

Design L, 60 cycles, class B insulation system, open type, 1.15 service factor.

hp	speed, rpm 3600	1800	1200
3/4	...	.....	145T
1	....	143T	182T
1-1/2	143T	145T	184T
2	145T	182T	
3	182T	184T	
5	184T	213T	
7-1/2	213T	215T	

POLYPHASE SQUIRREL-CAGE MOTORS

open type — fan-cooled — HORIZONTAL AND VERTICAL

designs A and B—class B insulation system totally-enclosed fan-cooled type, 1.00 service factor, 60-cycles

hp	speed, rpm 3600	1800	1200	900
½		...		143T
¾	.	...	143T	145T
1	...	143T	145T	182T
1½	143T	145T	182T	184T
2	145T	145T	184T	213T
3	182T	182T	213T	215T
5	184T	184T	215T	254T
7½	213T	213T	254T	256T
10	215T	215T	256T	284T
15	254T	254T	284T	286T
20	256T	256T	286T	324T
25	284TS	284T	324T	326T
30	286TS	286T	326T	364T
40	324TS	324T	364T	365T
50	326TS	326T	365T	404T
60	364TS	364TS*	404T	405T
75	365TS	365TS*	405T	444T
100	405TS	405TS*	444T	445T
125	444TS	444TS*	445T	.
150	445TS	445TS*	.....	..

designs A and B—class B insulation system, open type 1.15 service factor, 60 cycles

hp	speed, rpm 3600	1800	1200	900
½	...	....	.	143T
¾	....	.....	143T	145T
1	.....	143T	145T	182T
1½	143T	145T	182T	184T
2	145T	145T	184T	213T
3	145T	182T	213T	215T
5	182T	184T	215T	254T
7½	184T	213T	254T	256T
10	213T	215T	256T	284T
15	215T	254T	284T	286T
20	254T	256T	286T	324T
25	256T	284T	324T	326T
30	284TS	286T	326T	364T
40	286TS	324T	364T	365T
50	324TS	326T	365T	404T
60	326TS	364TS*	404T	405T
75	354TS	365TS*	405T	444T
100	365TS	404TS*	444T	445T
125	404TS	405TS*	445T	.
150	405TS	444TS*	. .	. .
200	444TS	445TS*	.	.....

MATERIALS FOR PUMPING VARIOUS LIQUIDS

Rotary pumps are used to handle all kinds of liquids over a wide range of capacities and pressures. Viscosities cover the range from gasoline, water, all petroleum products, paint, white lead and molasses. Rotary pumps are generally manufactured in the following materials of construction.

STANDARD FITTED — Case is cast iron, internal working parts to suit individual manufacturer's design.

ALL IRON — All parts of the pump in direct contact with the liquid pumped are made of iron or ferrous metal.

BRONZE FITTED — Iron casing with bronze pumping elements.

ALL BRONZE — All parts in direct contact with liquid pumped are made of bronze.

CORROSION RESISTING — All parts of pump in direct contact with the liquid pumped are of materials of suitable mechanical requirements offering maximum resistance to corrosive action of liquid.

For materials in Roper Rotary Pumps consult our catalog, copies sent free on request.

PUMPING HOT LIQUIDS materially shortens the life of any rotary pump. If a hot liquid is to be pumped consult our engineering department.

CONSTRUCTION GENERALLY USED

LIQUID	PUMP CONSTRUCTION
Acetic Acid	Corrosion Resisting
Acetone	Standard Fitted
Acid Mine Water	Corrosion Resisting
Acholhol (medicinal)	All Bronze
Alcohol (commercial)	Standard Fitted
Alum	All Bronze
Aluminum Chloride	Corrosion Resisting
Aluminum Sulphate	Corrosion Resisting
Ammonia	All Iron
Ammonium Bicarbonate	All Iron
Ammonium Chloride	Corrosion Resisting
Ammonium Nitrate	All Iron
Ammonium Sulphate	All Iron
Aniline Water	Standard Fitted
Asphaltum	Standard Fitted
Barium Chloride	All Iron
Barium Nitrate	All Iron
Beer	All Bronze
Beer Wort	All Bronze
Beet Juice	All Bronze
Benzene (coal tar)	Standard Fitted
Benzine (oil Dist.)	Standard Fitted
Bichloride of Mercury	Corrosion Resisting
Blood	Standard Fitted
Body Deadener	Special Construction
Brine (Calcium)	All Iron
Brine (Sod. Chl.)	All Bronze
Brine (Sodium)	All Bronze
Butane	Standard Fitted
Cachaza	Bronze Fitted
Calcium Acid Sulphate (conc.)	All Bronze
Calcium Acid Sulphate (dil.)	Bronze Fitted
Calcium Brine plus Sod. Chl.	All Bronze
Calcium Chlorate	Corrosion Resisting
Calcium Chloride	Corrosion Resisting
Calcium Magn. So. Chl.	All Bronze
Cane Juice	Standard Fitted
Carbolic Acid (dil.)	Standard Fitted
Carbonate of Soda	All Iron
Carb. Acid Gas in H_2O	All Bronze
Carbon Tetrachloride	Standard Fitted
Carbon Bisulphide	All Iron
Caustic Cl. of Magn.	Corrosion Resisting
Caustic Cyanogen	All Iron
Caustic Potash	All Iron
Caustic Soda	All Iron

CONSTRUCTION GENERALLY USED — Continued

LIQUID	PUMP CONSTRUCTION
Caustic Strontia	All Iron
Caustic Zinc Chloride	Corrosion Resisting
Cellulose	Corrosion Resisting
Cellulose Acetate	Corrosion Resisting
Chloride of Zinc	Corrosion Resisting
Cider	All Bronze
Citric Acid	Corrosion Resisting
Coal Tar Oil	Standard Fitted
Copperas (Green Vit.)	Corrosion Resisting
Copper Sulphate (Blue Vit.)	Corrosion Resisting
Creosote	Standard Fitted
Creosote Oils	Standard Fitted
Cyanic Acids	All Iron
Cyanic Liquors	All Iron
Cyanide	All Iron
Cyanide Potassium	All Iron
Cyanogen	All Iron
Distillery Wort	All Bronze
Dog Food	Special Construction
Duco (hot)	Special Construction
Dye Wood Liquors	Bronze Fitted
Ethyl Acetate	Standard Fitted
Ethyl Chloride	All Bronze
Ethylene Chloride	All Bronze
Ethylene Glycol	Standard Fitted
Fatty Acids	Corrosion Resisting
Ferrous Chloride	Corrosion Resisting
Ferrous Sulphate	Corrosion Resisting
Fuel Oil (See Petr. Oils)	Standard Fitted
Furfural	Standard Fitted
Gasoline	Standard Fitted
Glue	Standard Fitted
Glycerine	Standard Fitted
Grape Juice	All Bronze
Gun Cotton Brine	All Bronze
Heptane	Standard Fitted
Hydrocyanic Acid	Bronze Fitted
Hydroflusilic Acid	All Bronze
Iron Pyritic Acid	All Bronze
Kerosene	Standard Fitted
Lard	All Iron
Lime Water	All Iron
Linseed Oil	Standard Fitted
Lye (Caustic)	All Iron
Lye (Salty)	Corrosion Resisting
Magnesuim Sulphate	All Iron
Mash	Bronze Fitted
Methanol	Standard Fitted
Milk of Lime	All Iron
Molasses	Standard Fitted
Mustard	Corrosion Resisting
Naphtha	Standard Fitted
Nitric Acid (diluted)	Corrosion Resisting
Paraffin (hot)	Standard Fitted
Peroxide of Hydrogen	Corrosion Resisting

LIQUID	PUMP CONSTRUCTION
Petroleum Oil	Standard Fitted
Petroleum Ether	Bronze Fitted
Potash	Corrosion Resisting
Potassium Carbonate	All Iron
Potassium Chloride	Corrosion Resisting
Potassium Cyanide	All Iron
Potassium Nitrate	All Iron
Potassium Sulphate	All Bronze
Propane	Standard Fitted
Rapeseed Oil	All Bronze
Rhigolene (oil dust)	Standard Fitted
Sal Ammoniac	Corrosion Resisting
Salt Brine (3% salt)	Standard Fitted
Salt Brine (over 3% salt)	Corrosion Resisting
Sea Water	Standard Fitted
Soap Water	All Iron
Soda Ash (cold)	All Iron
Sodium Bicarbonate	All Iron
Sodium Hydroxide	Corrosion Resisting
Sodium Hyposulphite	Corrosion Resisting
Sodium Nitrate	All Iron
Sodium Sulphide	Corrosion Resisting
Sodium Sulphate	Corrosion Resisting
Starch	Standard Fitted
Strontium Nitrate	All Iron
Sugar	All Bronze
Sulphide of Hydrogen	Corrosion Resisting
Sulphide of Sodium (hot)	Corrosion Resisting
Sulphur Dioxide	Corrosion Resisting
Sulphur in Water	All Bronze
Sulphuric Acid (conc.)	Corrosion Resisting
Sulphuric Acid (fuming)	Corrosion Resisting
Sulphuric Acid (diluted)	Corrosion Resisting
Sulphurous Acid (conc.)	Corrosion Resisting
Sulphurous Acid (diluted)	Corrosion Resisting
Sweet Water	All Bronze
Syrup	All Bronze
Tan Liquor	All Bronze
Tar	Standard Fitted
Tar & Ammonia in Water	Standard Fitted
Tomato Pulp	Corrosion Resisting
Trisodium Phosphate	All Iron
Turpentine Oil	Standard Fitted
Urine	All Bronze
Vegetable Oil (general)	Standard Fitted
Vinegar	All Bronze
Vitriol, Blue	Corrosion Resisting
Vitriol, Green	Corrosion Resisting
Water (constant duty)	Standard Fitted
Water (intermittent duty)	All Bronze
Whiskey	All Bronze
Wine	All Bronze
Wood Pulp	Bronze Fitted
Yeast	All Bronze
Zinc Chloride	Corrosion Resisting
Zinc Nitrate	All Bronze
Zinc Sulphate	All Bronze

Additional detailed information on all pumping data can be obtained from your Roper representative, or by contacting Roper Pump Company, Commerce, Georgia 30529, Phone (404) 355-5551

CONVERTING FEET HEAD OF WATER INTO PRESSURE

Feet Head	Pounds Per Square Inch	Feet Head	Pounds Per Square Inch	Feet Head	Pounds Per Square Inch
1	.43	60	25.98	200	86.62
2	.87	70	30.32	225	97.45
3	1.30	80	34.65	250	108.27
4	1.73	90	38.98	275	119.10
5	2.17	100	43.31	300	129.93
6	2.60	110	47.64	325	140.75
7	3.03	120	51.97	350	151.58
8	3.46	130	56.30	400	173.24
9	3.90	140	60.63	500	216.55
10	4.33	150	64.96	600	259.85
20	8.66	160	69.29	700	303.16
30	12.99	170	73.63	800	346.47
40	17.32	180	77.96	900	389.78
50	21.65	190	82.29	1,000	433.09

CONVERTING PRESSURE INTO FEET HEAD OF WATER

Pounds Per Square Inch	Feet Head	Pounds Per Square Inch	Feet Head	Pounds Per Square Inch	Feet Head
1	2.31	40	92.36	170	392.52
2	4.62	50	115.45	180	415.61
3	6.93	60	138.54	190	438.90
4	9.24	70	161.63	200	461.78
5	11.54	80	184.72	225	519.51
6	13.85	90	207.81	250	577.24
7	16.16	100	230.90	275	643.03
8	18.47	110	253.98	300	692.69
9	20.78	120	277.07	325	750.41
10	23.09	125	288.62	350	808.13
15	34.63	130	300.16	375	865.89
20	46.18	140	323.25	400	922.58
25	57.72	150	346.34	500	1154.48
30	69.27	160	369.43	1,000	2308.

Equivalent Values of Pressure

Inches of Mercury — Feet of Water — Pounds per Sq. In.

Inches of Mercury	Feet of Water	Pounds per Sq. In.	Inches of Mercury	Feet of Water	Pounds per Sq. In.	Inches of Mercury	Feet of Water	Pounds per Sq. In.
1	1.13	0.49	11	12.45	5.39	21	23.78	10.3
2	2.26	0.98	12	13.57	5.87	22	24.86	10.8
3	3.39	1.47	13	14.70	6.37	23	26.00	11.28
4	4.52	1.95	14	15.82	6.85	24	27.15	11.75
5	5.65	2.44	15	16.96	7.35	25	28.26	12.25
6	6.78	2.93	16	18.09	7.84	26	29.40	12.73
7	7.91	3.42	17	19.22	8.33	27	30.52	13.23
8	9.04	3.91	18	20.35	8.82	28	31.65	13.73
9	10.17	4.40	19	21.75	9.31	29	32.80	14.22
10	11.30	4.89	20	22.60	9.80	29.929	33.947	14.6969

Atmospheric Pressure, Barometer Reading and Equivalent Head of Water at Different Altitudes

Altitude Above Sea Level in Feet	Atmospheric Pressure Pounds Per Sq. In.	Barometer Reading Inches of Mercury	Equivalent Head of Water Feet
0	14.7	29.929	33.95
1000	14.2	28.8	32.7
2000	13.6	27.7	31.6
3000	13.1	26.7	30.2
4000	12.5	25.7	29.1
5000	12.1	24.7	27.9
6000	11.7	23.8	27.0
7000	11.2	22.9	25.9
8000	10.8	22.1	24.9
9000	10.4	21.2	24.0
10000	10.0	20.4	23.1

For Ft. Hd. of liquid, multiply Ft. Hd. of water by specific gravity of liquid pumped.