

# **Schedule (Thickness) of Steel Pipe Used in Obtaining Resistance of Valves and Fittings of Various Pressure Classes by Test\***

| Valve or Fitting<br>ASA Pressure Classification |                            | Schedule No.<br>of Pipe<br>Thickness                               |
|-------------------------------------------------|----------------------------|--------------------------------------------------------------------|
| Steam Rating                                    | Cold Rating                |                                                                    |
| 250-Pound and Lower                             | 500 psig                   | Schedule 40                                                        |
| 300-Pound to 600-Pound                          | 1440 psig                  | Schedule 80                                                        |
| 900-Pound                                       | 2160 psig                  | Schedule 120                                                       |
| 1500-Pound                                      | 3600 psig                  | Schedule 160                                                       |
| 2500-Pound                                      | 1/2 to 6"<br>8" and larger | 6000 psig<br>3600 psig<br>xx (Double Extra Strong)<br>Schedule 160 |

\*These schedule numbers have been arbitrarily selected only for the purpose of identifying the various pressure classes of valves and fittings with specific pipe dimensions for the interpretation of flow test data; they should not be construed as a recommendation for installation purposes.

## **Representative Equivalent Length in Pipe Diameters (L/D) of Various Valves and Fittings**

| Description of Product                        |                                                            |                                                                                              |                                                | Equivalent Length<br>in Pipe Diameters<br>(L/D) |
|-----------------------------------------------|------------------------------------------------------------|----------------------------------------------------------------------------------------------|------------------------------------------------|-------------------------------------------------|
| Globe<br>Valves                               | Stem Perpendicular<br>to Run                               | With no obstruction in flat, bevel, or plug type seat)                                       | Fully open                                     | 340                                             |
|                                               |                                                            | With wing or pin guided disc                                                                 | Fully open                                     | 450                                             |
|                                               | Y-Pattern                                                  | (No obstruction in flat, bevel, or plug type seat                                            | Fully open                                     | 175                                             |
|                                               |                                                            | - With stem 60 degrees from run of pipe line<br>- With stem 45 degrees from run of pipe line | Fully open                                     | 145                                             |
| Angle Valves                                  |                                                            | With no obstruction in flat, bevel, or plug type seat                                        | Fully open                                     | 145                                             |
|                                               |                                                            | With wing or pin guided disc                                                                 | Fully open                                     | 200                                             |
| Gate<br>Valves                                | Wedge, Disc,<br>Double Disc,<br>or Plug Disc               |                                                                                              | Fully open                                     | 13                                              |
|                                               |                                                            |                                                                                              | Three-quarters open                            | 35                                              |
|                                               |                                                            |                                                                                              | One-half open                                  | 160                                             |
|                                               |                                                            |                                                                                              | One-quarter open                               | 900                                             |
|                                               | Pulp Stock                                                 |                                                                                              | Fully open                                     | 17                                              |
|                                               |                                                            |                                                                                              | Three-quarters open                            | 50                                              |
|                                               |                                                            |                                                                                              | One-half open                                  | 260                                             |
|                                               |                                                            |                                                                                              | One-quarter open                               | 1200                                            |
| Conduit Pipe Line Gate, Ball, and Plug Valves |                                                            |                                                                                              | Fully open                                     | 3**                                             |
| Check<br>Valves                               | Conventional Swing                                         |                                                                                              | 0.5'...Fully open                              | 135                                             |
|                                               | Clearway Swing                                             |                                                                                              | 0.5'...Fully open                              | 50                                              |
|                                               | Globe Lift or Stop; Stem Perpendicular to Run or Y-Pattern |                                                                                              | 2.0'...Fully open                              | Same as Globe                                   |
|                                               | Angle Lift or Stop                                         |                                                                                              | 2.0'...Fully open                              | Same as Angle                                   |
|                                               | In-Line Ball                                               |                                                                                              | 2.5 vertical and 0.25 horizontal'...Fully open | 150                                             |
| Foot Valves with Strainer                     |                                                            | With poppet lift-type disc                                                                   | 0.3'...Fully open                              | 420                                             |
|                                               |                                                            | With leather-hinged disc                                                                     | 0.4'...Fully open                              | 75                                              |
| Butterfly Valves (8-inch and larger)          |                                                            |                                                                                              | Fully open                                     | 40                                              |
| Cocks                                         | Straight-Through                                           | Rectangular plug port area equal to 100% of pipe area                                        | Fully open                                     | 18                                              |
|                                               | Three-Way                                                  | Rectangular plug port area equal to<br>80% of pipe area (fully open)                         | Flow straight through<br>Flow through branch   | 44<br>140                                       |
| Fittings                                      | 90 Degree Standard Elbow                                   |                                                                                              |                                                | 30                                              |
|                                               | 45 Degree Standard Elbow                                   |                                                                                              |                                                | 16                                              |
|                                               | 90 degree Long Radius Elbow                                |                                                                                              |                                                | 20                                              |
|                                               | 90 Degree Street Elbow                                     |                                                                                              |                                                | 50                                              |
|                                               | 45 Degree Street Elbow                                     |                                                                                              |                                                | 26                                              |
|                                               | Square Corner Elbow                                        |                                                                                              |                                                | 57                                              |
|                                               | Standard Tee                                               | With flow through run                                                                        |                                                | 20                                              |
|                                               |                                                            | With flow through branch                                                                     |                                                | 60                                              |
| Close Pattern Return Bend                     |                                                            |                                                                                              |                                                | 50                                              |
| Pipe                                          | 90 Degree Pipe Bends                                       |                                                                                              |                                                | See Page A-27                                   |
|                                               | Miter Bends                                                |                                                                                              |                                                | See Page A-27                                   |
|                                               | Sudden Enlargements and Contractions                       |                                                                                              |                                                | See Page A-26                                   |
|                                               | Entrance and Exit Losses                                   |                                                                                              |                                                | See Page A-26                                   |

\*\*Exact equivalent length is equal to the length between flange faces or welding ends.

\*Minimum calculated pressure drop (psi) across valve to provide sufficient flow to lift disc fully.

### Type 3. Pump Discharge

#### a. Single line pump discharge

Criteria:  $\Delta P/100'$  (PSI) = 5.0 max.  
Velocity (FPM) = 700 max.

Remarks: Carbon steel pump discharge piping is sized within the limits of the above criteria and with an economic consideration of piping material costs compared to pumping costs depending on whether the pump discharge line is considering to be "low pressure level" or "high pressure level". The dividing line is as follows:

"Low pressure level" includes pump discharge lines with design pressure of 1400 psig and design temperature of 150°F (or other combinations of pressure and temperature to give equal or lesser required pipe thickness and flange ratings). For pump discharge lines in this pressure-temperature range, optimum sizing is as indicated by curves added to the liquid line sizing chart PD 435-C for sp.gr. 0.6 to 1.0.

"High pressure level" includes design pressure and design temperature combinations resulting in pipe thicknesses and flange ratings greater than above. Due to the high cost of heavy wall pipe and heavy flanges, pump discharge lines in the "high pressure level" category are more likely to be sized close to the limit of the above criteria.

max ✓

Alloy pump discharge piping is more likely to be sized at or above the limits of the above criteria due to the very high cost of alloy materials. However, at velocities in excess of 700 FPM, the increased erosion rate may require heavier pipe wall thickness at an increased material cost.

As long as the flow remains turbulent, the optimum size for a given flow rate is practically independent of viscosity. For laminar flow, the above curves on PD 435-C do not exactly represent optimum diameters, but it is suggested that they be used for sizing anyway, observing especially the limitation of 5.0 psi/100' maximum  $\Delta P$  corrected for viscosity. The flow can be assumed to be laminar at Reynolds Numbers below 2000 and turbulent at 2000 and higher. The Reynolds Number can be calculated as follows:

$$\text{Reynolds Number} = \frac{(3160)(Q)}{(d)(\text{cstks})}$$

Where Q = flowing GPM

d = i.d. (inches)

cstks = flowing viscosity in centistokes

- b. Downstream of a pump discharge with different conditions than at the pump.

Criteria:

- 1)  $\Delta P/100'$  (PSI) = 5.0 max.
- 2) If 100% liquid, velocity (FPM) = 700 max.

- 3) If 100% vapor, velocity (FPM)  $= 6000/\sqrt{\rho_v}$   
where  $\rho_v$  = flowing density, lb/ft<sup>3</sup>
- 4) If the line is the transfer line of a fired reboiler heater or other pumped reboiler, and it is desired to minimize heater outlet temperature:

$\Delta P/100'$  (PSI) max. = 2.5% of column bottom absolute pressure.

- 5) If the material in the line is in vertical upward two-phase flow, such as feed to a column or inlet to a crude heater, check to avoid slug flow. If it is impossible to satisfy this criterion (which sets a maximum permissible diameter) and also limitations 1 and 4 above, the solution will be to take (and allow for) more pressure drop, or to revise relative amounts of vapor and liquid to specify more vapor.

Remarks: Economic considerations involved in sizing carbon steel pump discharge system piping at "low pressure level" and "high pressure level" and alloy pump discharge system piping should be similar to Type 3a above.

- c. Branches from a pump discharge.

Criteria: Treat as Type 3a.

Remarks: Be aware that the common pump must satisfy the pressure drop in all branches. It is possible that a low capacity branch might be sized for a high pressure drop while the high capacity branches require a low pressure drop. The common pump would be required to provide sufficient discharge pressure to satisfy the pressure drop of the low capacity branch, while control valves in the high capacity lines would handle greater than desired pressure drops.

- d. Branches downstream of a pump discharge with different conditions than at the pump.

Criteria: Treat as Type 3b.

Remarks: Consider pressure drop balance as discussed for Type 3c.

**Type 4.** Liquid to Non-pumped Reboiler.

Criteria:  $\Delta P/100' \text{ (PSI)} = 0.15 \text{ to } 0.20$

Remarks: This type is to be sized in conjunction with the return line from the same reboiler.

**Type 5. Reboiler Return to Column**

Criteria:

- 1) Kettle type:  $\Delta P/100'$  (PSI) = 0.20 max.
- 2) Thermosyphon or once-through type, non-kettle, non-pumped. For pumped types, see Type 3b.

$$\Delta P/100' \text{ (PSI)} = 0.10 - 0.20 \text{ max.}$$

Remarks: Maximum permissible size = 30" nominal. If calculated diameter is above this number, divide flow in half and size for this reduced flow.

For non-kettle types (two-phase flow), the line should be checked for slug flow. If slug flow is indicated, the solution will be to take (and allow for) more pressure drop, or to revise the relative amounts of vapor and liquid to specify more vapor.

**Type 6. Column Overhead Vapor**

- a. All except FCC main column and crude vacuum column overhead vapor lines.

Criteria: limiting equations

$$\Delta P/100' \text{ (PSI)} = 0.20\sqrt{p} \left( \frac{100}{160 + 8.34d} \right) \text{ max.}$$

$$\text{Velocity (FPM)} = 6000/\sqrt{\rho_v} \text{ max.}$$

Use half of the above limiting pressure drop for columns where minimum pressure is critical.

$p$  = receiver pressure, psia

$d$  = i.d., inches

$\rho_v$  = overhead vapor flowing density, lb/ft<sup>3</sup>

Remarks: Sizing of the above column overhead vapor lines is based upon an approach to economic optimization within fixed limitations of pressure drop and velocity. The equations have been developed for carbon steel material. Alloy overhead vapor lines should be sized slightly tighter due to the higher material cost, but still within the criteria of the limiting equations.

b. FCC main column overhead vapor

Criteria:  $\Delta P/100' \text{ (PSI)} = 0.10 \text{ max.}$

c. Crude vacuum column overhead

The method of sizing is as follows: Determine equivalent length of the line. Size line so that  $\Delta P$  over its entire length is not more than 7% of flash zone absolute pressure, limited to flash zone pressures of 35mm and greater.

**Type 7.** Column Hot Vapor By-Pass

Criteria:  $\Delta P/100'$  (PSI) = 0.5 max.

Remarks: For amount of vapors thru hot vapor by-pass, use the following formula:

$$W = [(\text{Mol/hr})_1 + 0.06 (\text{Mol/hr})_2] [M_2]$$

$W$  = by-pass vapor, lb/hr

$(\text{Mol/hr})_1$  = normal mols/hr of net gas

$(\text{Mol/hr})_2$  = normal mols/hr of gross column overhead vapors

$M_2$  = mol weight of gross overhead vapors

**Type 8. Column Overhead Condenser Rundown**

- a. Totally condensing, single phase:

Criteria: Limiting equations

$$\Delta P/100 \text{ (PSI)} = 0.10\sqrt{p} \left( \frac{100}{53.3 + 2.78d} \right)_{\text{max.}}$$

$$\text{Velocity (FPM)} = 200 \text{ max.}$$

Use half of the above limiting pressure drop for columns where minimum pressure is critical.

p = receiver pressure, psia

d = i.d., inches

Remarks: Special attention should be given to the rundown line if it is part of a pressure relief route. This situation exists when pressure relief is via a vent or relief on the receiver rather than via a relief valve on the overhead vapor line or column proper. The rundown line should be at least as large as such a vent, and at least one size larger than the inlet of any relief valve on the receiver whose function is to protect the column. If several relief valves are on the receiver serving this function, the rundown line should be at least one size larger than a size whose inside cross sectional area equals the sum of the areas of the relief valve inlets.

- b. Totally condensing, with traces of a second liquid present and a piping arrangement that would permit pockets of the second liquid phase to accumulate.

Criteria and remarks: Column overhead condensers are often placed below the receiver in order to provide  $\Delta P$  to operate a hot vapor bypass. In cases like this, a moderately high velocity should exist in the run-down piping (350 FPM). This becomes important in column overhead systems where traces of a heavier liquid, such as water or HF can collect in the low points of a rundown line. The higher velocities tend to keep the line clear of a pocket of heavier liquid.

However, see the remarks under Type 8a above for a discussion of rundown lines when they are part of a pressure relief route. A conflict between the need for adequate liquid velocity during normal operation and the need of low  $\Delta P$  during pressure relief may influence the design of the pressure relief system.

- c. Partially condensing, vapor and liquid present.

$$\text{Criteria: } \Delta P/100' \text{ (PSI)} = 0.10\sqrt{p} \left( \frac{100}{53.3 + 2.78d} \right)_{\text{max.}}$$

Use half of the above limiting pressure drop for columns where minimum pressure is critical.

$p$  = receiver pressure, psia

$d$  = i.d., inches

Remarks: Because this two-phase flow line could be vertical upflow, the line should be checked for slug flow. If slug flow is indicated, a smaller diameter should be selected, until slug flow does not exist. However, if it is impossible to satisfy both the slug flow criteria and the max  $\Delta P/100'$  limitation given above, solution will be to analyze piping layout with an eye toward relaxation of the max.  $\Delta P/100'$  rule.

Special attention should be given to the rundown line if it is part of a pressure relief route, as described for Type 8a. If there is a conflict between diameter required for pressure relief and diameter required for avoidance of slug flow, consideration should be given to using several smaller lines in parallel or to revising the pressure relief arrangements.

#### **Type 9. Compressor Suction**

##### **a. Reciprocating compressor**

$$\text{Criteria: } \Delta P/100' \text{ (PSI)} = 0.043\sqrt{p} \text{ max.}$$

$$\Delta P/100' \text{ (PSI)} = 1.0 \text{ max.}$$

$$\text{Velocity (FPM)} = 2000 \sqrt{\frac{28.8}{MW}} \text{ max.}$$

$p$  = line pressure, psia

$MW$  = gas molecular weight

Remarks: Line is defined as being between a suction drum (or vessel serving as a suction drum) and the compressor. Lead-in lines to individual cylinders should also be sized according to the above criteria.

b. Centrifugal compressor

Criteria:  $\Delta P/100' \text{ (PSI)} = 0.043\sqrt{p} \text{ max.}$

$$\Delta P/100' \text{ (PSI)} = 1.0 \text{ max.}$$

$$\text{Velocity (FPM)} = 3540/\rho_v^{0.25} \text{ max.}$$

$p$  = line pressure, psia

$\rho_v$  = gas flowing density, lb/ft<sup>3</sup>

Remarks: Line is defined as being between a suction drum (or vessel serving as a suction drum) and the compressor.

**Type 10. Compressor Discharge**

a. Reciprocating compressor

$$\text{Criteria: } \Delta P/100' \text{ (PSI)} = 0.043\sqrt{p} \text{ max.}$$

$$\Delta P/100' \text{ (PSI)} = 1.0 \text{ max.}$$

$$\text{Velocity (FPM)} = 3000 \sqrt{\frac{28.8}{MW}} \text{ max.}$$

$p$  = line pressure, psia

$MW$  = gas molecular weight

Remarks: Line is defined as being between the compressor and a junction with a line carrying other fluids, or to a cooler or vessel. Lead-out lines from individual cylinders should also be sized according to the above criteria.

b. Centrifugal compressor

$$\text{Criteria: } \Delta P/100' \text{ (PSI)} = 0.043\sqrt{p} \text{ max.}$$

$$\Delta P/100' \text{ (PSI)} = 1.0 \text{ max.}$$

$$\text{Velocity (FPM)} = 6000/\sqrt{\rho_v} \text{ max.}$$

$$p = \text{line pressure, psia}$$

$$\rho_v = \text{gas flowing density, lb/ft}^3$$

Remarks: Line is defined as being between the compressor and a junction with a line carrying other fluids, or to a cooler or vessel.

**Type 11.** High Available Pressure Drop (25 psi or more available for piping friction within the battery limits).

Criteria: Use up, but do not exceed, the available pressure drop. Also, observe the following limitations, except for pressure relief:

1. 100% liquid  
 $\Delta P/100' \text{ (PSI)} = 7.0 \text{ max.}$   
 $\text{Velocity (FPM)} = 700 \text{ max.}$
2. 100% vapor  
 $\Delta P/100' \text{ (PSI)} = 7.0 \text{ max.}$   
 $\text{Velocity (FPM)} = 6000/\sqrt{\rho_v} \text{ max.}$
3. Vapor plus liquid  
 $\Delta P/100' \text{ (PSI)} = 5.0 \text{ max.}$

Remarks: Allow high piping  $\Delta P$ , but consider erosion, noise, and vaporization. For vaporizing materials, use downstream conditions for calculation of  $\Delta P$ .

**Type 12.**      Feed to a Column

**Criteria and Remarks:**

1.      If line is a pump discharge or is downstream of a pump discharge, treat as Type 3, except limit the 100% liquid case to a velocity of 500 FPM.
2.      If line has high available pressure drop (25 psi or more available for piping friction), treat as Type 11, except limit the 100% liquid case to a maximum velocity of 500 FPM.

3.      If line is other as indicated in 1 or 2 above:

$$\Delta P/100' \text{ (PSI)} = 3.0 \left( \frac{100}{114 + 10d} \right) \text{ max.}$$

- a.      If flow is 100% liquid:

$$\text{Velocity (FPM)} = 500 \text{ max.}$$

- b.      If flow is 100% vapor:

$$\text{Velocity (FPM)} = 6000/\sqrt{\rho_v} \text{ max.}$$

- c.      If flow is two-phase: Apply the criteria for slug flow. If it is impossible to satisfy both this criterion and the pressure drop of this item 3, the solution will be to take (and allow for) more pressure drop or to revise relative amounts of vapor and liquid to specify more vapor.

**Type 13. Vacuum Unit Heater Transfer**

The method of sizing is as follows: Determine equivalent length of the line. Determine heater outlet pressure, which is often 3.0 psia. Base line sizing calculations on only the vapor portion of the flow, but in calculations of pressure drop and velocity, use diameter of only 98% of the actual diameter to account for presence of liquid.

Observing sonic velocity limitation and allowing for changing pressure along the length of the line, size line to use up the available pressure drop between heater and flash zone. If pressure in downstream end of the line is raised because of sonic velocity limitation, the nozzle at the inlet to the column should be enlarged until sonic velocity or less can be attained in the nozzle at flash zone pressure.

**Type 14. Steam**

Criteria and Remarks:

1. Saturated, 15 psig and less:

Velocity (FPM) = 6000 max.

$\Delta P/100'$  (PSI) = 1.1 max.

Higher rates than these are permissible where high pressure drop is available, but velocity should be less than 10,000 FPM.

2. Saturated, over 15 psig:

$$\text{Velocity (FPM)} = 10,000 \text{ max.}$$

$$\Delta P/100' \text{ (PSI)} = 0.02 p \text{ max.}$$

p = pressure, psia

3. Superheated, over 200 psig

$$\text{Velocity (FPM)} = 15,000 \text{ max.}$$

$$\Delta P/100' \text{ (PSI)} = 0.012 p \text{ max.}$$

p = pressure, psia

**Type 15. Condensing Steam Turbine Exhaust**

The method of sizing is as follows:

Determine equivalent length of the line.

For convenience, calculations should be based on full weight flow from turbine as if it had a steam quality of 100%.

Operating pressure of turbine exhaust and condenser inlet must be known. Size line to use up the difference in pressure between turbine and condenser, except observe maximum velocity as follows:

$$\text{Velocity (FPM)} = 1200/\sqrt{\rho_v} \text{ max.}$$

$\rho_v$  = flowing density of steam at inlet to condenser, lb/ft<sup>3</sup>

**Type 16.** Liquid at its bubble point to a control valve or steam trap

Criteria:  $\Delta P/100'$  (PSI) = 0.5 to 1.5 max.

Velocity (FPM) = 700 max.

Remarks: Consider elevations of liquid surface and control valve. Consider length of line. The pressure drop due to friction should be well below the static head increase in pressure due to lower elevation of the control valve in order to avoid vaporization before valve.

**Type 17.** Steam condensate after a control valve or steam trap

Criteria and Remarks: There are many situations possible in the operation of condensate removal piping. Consideration should be given to the points discussed below.

1. With control valve located in steam line:

The control valve may be placed in the steam if the condensate will still have sufficient pressure to flow to its destination. This would be the case when the condensate is at a temperature whose saturation pressure is sufficiently above the condensate destination pressure to permit flow. Low condensate temperatures can be tolerated when flow is to a condensate pot operating under a vacuum.

To size the condensate line, one must first obtain the destination pressure. Then an initial condensate temperature (and pressure) must be determined. This will depend on the process-side temperatures of the exchanger, on whether the flow is countercurrent or co-current, and

on the condensate temperature approach to process-side temperature. Lower condensate temperatures will be governing for condensate line sizing.

If the length of the condensate line is known, this length (equivalent feet) should be used in the pressure drop calculation. If the length is now known, as is generally the case, 300 equivalent feet may be used as being the distance to a condensate header or pot. Pipe friction pressure drop should not be more than  $\frac{1}{2}$  of the total pressure drop. It may be necessary to consider the line in sections for calculation purposes in order to account for the increased flashing as pressure falls. PD 395A may be used to find the piping two-phase pressure drop as a function of a fictitious all-liquid  $\Delta P$ .

2. With control valve in condensate line:

The control valve is often placed in the condensate line when process-side temperatures are low, resulting in low condensate temperatures. The pressure before the control valve in this case will be full steam pressure, less a small amount for exchanger pressure drop. The temperature of the condensate before the control valve can be anything from saturation temperature down to the process side temperature at the condensate outlet. For condensate line sizing, higher temperature will be governing, since more flashing will result. Condensate temperature equal to steam temperature should, therefore, be assumed unless there is reason to believe it to be lower.

3. General Remarks, applicable to all cases.

Use a unit pressure drop  $1\frac{1}{2}$  times the value for clean commercial steel pipe to allow for roughening of the pipe walls due to the corrosive effects of condensate.

Pressure drop per length of pipe will be greatest at the downstream end of the pipe where the pressure level is the lowest. More liquid will have flashed to vapor and the vapor density is the lowest. There should be a limitation on instantaneous pressure drop as follows:

$$\Delta P/100' \text{ (PSI)} = 7.5 \text{ max.}$$

This should be calculated using  $1\frac{1}{2}$  times the values for clean commercial steel pipe as mentioned above. Often this limitation will be governing, with the result that the steam trap or control valve will be able to operate with much more than  $\frac{1}{2}$  of the total pressure drop.

**Type 18.** Make-up gas to a hydrogen consuming process

Criteria:  $\Delta P/100' \text{ (PSI)} = 1.0 \text{ max.}$

$$\text{Velocity (FPM)} = 6000/\sqrt{\rho_v} \text{ max.}$$

Remarks: Consider length of line. Take smaller  $\Delta P/100'$  for long lines.

**Type 19. Fuel Gas to Heaters**

**Criteria:**

1. Before control valve:

$$\Delta P/100' \text{ (PSI)} = 0.05 p \text{ max.}$$

p = gauge pressure before valve

2. After control valve:

$$\Delta P/100' \text{ (PSI)} = 0.1 p \text{ max.}$$

p = gauge pressure after valve

If pressure is not known, the following standard values may be used:

For gas with gross heating value of 500 BTU/SCF or more: 10 psig

For gas with gross heating value less than 500 BTU/SCF: 20 psig

3. Header:

$$\Delta P/100' \text{ (PSI)} = 0.05 p \text{ max.}$$

Comments of Item 2 apply, except that p refers to gauge pressure in header.

**Remarks:** Quantity of gas can be calculated from process specification heater duty using an appropriate heater efficiency and fuel gas heating value.

If more than one process stream is to be heated in the same heater box, careful determination should be made for the amount of heat to be released from each set of burners.

**Type 20. Fuel Oil to Heaters**

Criteria:

| <u>GPM</u> | <u>Size</u>   |
|------------|---------------|
| 0 - 5.9    | 1" - Sch. 80  |
| 6 - 19.9   | 1½" - Sch. 80 |
| 20 - 34.9  | 2" - Sch. 80  |
| 35 - 100   | 3" - Sch. 40  |
| 101 - 300  | 4" - Sch. 40  |

Remarks: Use 3 volumes recirculated for 1 volume burned. Use flowing temperature such as to give a viscosity of 50 centistokes. Specific gravity is about 0.9. Size lines as above.

Note that this is laminar flow.

Use same criteria for return lines to surge, storage, or refinery fuel oil system.

**Type 21. Atomizing Steam to Heaters**

Criteria: Usual steam criteria

Remarks: Use 3-4 lbs. of steam per gallon of fuel oil burned. Use pressure of 75 psig maximum after valve if there is a valve.

**Type 22. Instrument Air Piping**

Criteria: Main air supply header shall be 1½" or larger.

Branch Header line size:

|                    |     |      |       |       |
|--------------------|-----|------|-------|-------|
| Number of taps     | 1-5 | 6-10 | 11-15 | 16-20 |
| Branch header size | ½"  | ¾"   | 1"    | 1-½"  |

**Type 23. Cooling Water**

Criteria:

|                |                      |   |         |
|----------------|----------------------|---|---------|
| 0-650 GPM:     | Max. $\Delta P/100'$ | = | 1.3 PSI |
| 651-2800 GPM:  | Max. Velocity        | = | 500 FPM |
| 2801-7000 GPM: | Max. Velocity        | = | 600 FPM |
| Over 7001 GPM: | Max. Velocity        | = | 700 FPM |

Remarks: The 1.3 PSI/100' criterion is based on  $\Delta P/100'$  obtained by using PD 435-C. Pressure drop after a long period of usage may be twice as high as this. If film type corrosion protection is used, maximum velocity should be reduced to 350-500 FPM.

**Type 24.**      Static Electricity Consideration

Criteria:      Velocity (FPM) = 400 max.

Remarks:      When the flowing hydrocarbon is a material whose vapor pressure is such as to form an explosive mixture with air, the flowing velocity must be limited in order to minimize the buildup of static electricity. This consideration is particularly important when handling materials such as kerosene and jet fuel to storage tanks.

## **GENERAL COMMENTS - HYDRAULICS**

Line sizing is only a part of the overall subject of hydraulics. Other areas of hydraulics affect the sizing of lines, particularly insofar as the determination of available pressure drop is concerned. The following presents a discussion of some of the more important hydraulic systems and considerations with which the line sizing engineer should be familiar.

### **A. NPSH**

Every centrifugal pump has a minimum positive pressure requirement at its suction flange to prevent vaporization of the pumped liquid, which will result in cavitation. This pressure requirement is called "net positive suction head" (NPSH). NPSH is usually expressed as the feet of liquid head, in excess of the fluid vapor pressure, required at the suction flange of a specific pump in order to overcome the internal pressure drop in the pump suction nozzle and passages to the eye of the impeller. The NPSH required is determined by the manufacturer as a characteristic of the pump and will set the elevations of many of the vessels in a process unit.

#### **NPSH - Calculations**

Pump NPSH calculations can be approached from two different view points. A contractor's calculation is basically a check of the system to determine if the specified suction vessel elevation is great enough to overcome the friction loss of the actual suction piping arrangement and still provide the pump NPSH requirement as defined by the supplier. All details of the system and equipment are usually known at the time the contractor makes his check.

**Schedule (Thickness) of Steel Pipe Used in Obtaining Resistance  
of Valves and Fittings of Various Pressure Classes by Test\***

| Valve or Fitting<br>ASA Pressure Classification |                                      | Schedule No.<br>of Pipe<br>Thickness                               |
|-------------------------------------------------|--------------------------------------|--------------------------------------------------------------------|
| Steam Rating                                    | Cold Rating                          |                                                                    |
| 250-Pound and Lower                             | 500 psig                             | Schedule 40                                                        |
| 300-Pound to 600-Pound                          | 1440 psig                            | Schedule 80                                                        |
| 900-Pound                                       | 2160 psig                            | Schedule 120                                                       |
| 1500-Pound                                      | 3600 psig                            | Schedule 160                                                       |
| 2500-Pound                                      | $\frac{1}{2}$ to 6"<br>8" and larger | 6000 psig<br>3600 psig<br>xx (Double Extra Strong)<br>Schedule 160 |

\*These schedule numbers have been arbitrarily selected only for the purpose of identifying the various pressure classes of valves and fittings with specific pipe dimensions for the interpretation of flow test data; they should not be construed as a recommendation for installation purposes.

**Representative Equivalent Length in Pipe Diameters (L/D)  
of Various Valves and Fittings**

| Description of Product                                     |                                                |                                                                                                                                                   |                                                                                       | Equivalent Length<br>in Pipe Diameters<br>(L/D)                        |                         |            |     |
|------------------------------------------------------------|------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|------------------------------------------------------------------------|-------------------------|------------|-----|
| Globe<br>Valves                                            | Stem Perpendicular<br>to Run                   | With no obstruction in flat, bevel, or plug type seat)<br>With wing or pin guided disc                                                            | Fully open<br>Fully open                                                              | 340<br>450                                                             |                         |            |     |
|                                                            | Y-Pattern                                      | (No obstruction in flat, bevel, or plug type seat<br>- With stem 60 degrees from run of pipe line<br>- With stem 45 degrees from run of pipe line | Fully open<br>Fully open                                                              | 175<br>145                                                             |                         |            |     |
|                                                            |                                                | Angle Valves                                                                                                                                      | With no obstruction in flat, bevel, or plug type seat<br>With wing or pin guided disc | Fully open<br>Fully open                                               | 145<br>200              |            |     |
| Gate<br>Valves                                             | Wedge, Disc,<br>Double Disc,<br>or Plug Disc   |                                                                                                                                                   | Fully open<br>Three-quarters open<br>One-half open<br>One-quarter open                | 13<br>35<br>160<br>900                                                 |                         |            |     |
|                                                            |                                                | Pulp Stock                                                                                                                                        |                                                                                       | Fully open<br>Three-quarters open<br>One-half open<br>One-quarter open | 17<br>50<br>260<br>1200 |            |     |
|                                                            |                                                |                                                                                                                                                   | Conduit Pipe Line Gate, Ball, and Plug Valves                                         |                                                                        |                         | Fully open | 3** |
|                                                            |                                                |                                                                                                                                                   | Check<br>Valves                                                                       | Conventional Swing                                                     | 0.5'...Fully open       | 135        |     |
|                                                            | Clearway Swing                                 |                                                                                                                                                   |                                                                                       | 0.5'...Fully open                                                      | 50                      |            |     |
| Globe Lift or Stop; Stem Perpendicular to Run or Y-Pattern | 2.0'...Fully open                              | Same as Globe                                                                                                                                     |                                                                                       |                                                                        |                         |            |     |
| Angle Lift or Stop                                         | 2.0'...Fully open                              | Same as Angle                                                                                                                                     |                                                                                       |                                                                        |                         |            |     |
| In-Line Ball                                               | 2.5 vertical and 0.25 horizontal'...Fully open | 150                                                                                                                                               |                                                                                       |                                                                        |                         |            |     |
| Foot Valves with Strainer                                  |                                                | With poppet lift-type disc<br>With leather-hinged disc                                                                                            | 0.3'...Fully open<br>0.4'...Fully open                                                | 420<br>75                                                              |                         |            |     |
| Butterfly Valves (8-inch and larger)                       |                                                |                                                                                                                                                   | Fully open                                                                            | 40                                                                     |                         |            |     |
| Cocks                                                      | Straight-Through                               | Rectangular plug port area equal to 100% of pipe area                                                                                             | Fully open                                                                            | 18                                                                     |                         |            |     |
|                                                            | Three-Way                                      | Rectangular plug port area equal to<br>80% of pipe area (fully open)                                                                              | Flow straight through<br>Flow through branch                                          | 44<br>140                                                              |                         |            |     |
| Fittings                                                   | 90 Degree Standard Elbow                       |                                                                                                                                                   |                                                                                       | 30                                                                     |                         |            |     |
|                                                            | 45 Degree Standard Elbow                       |                                                                                                                                                   |                                                                                       | 16                                                                     |                         |            |     |
|                                                            | 90 degree Long Radius Elbow                    |                                                                                                                                                   |                                                                                       | 20                                                                     |                         |            |     |
|                                                            | 90 Degree Street Elbow                         |                                                                                                                                                   |                                                                                       | 50                                                                     |                         |            |     |
|                                                            | 45 Degree Street Elbow                         |                                                                                                                                                   |                                                                                       | 26                                                                     |                         |            |     |
|                                                            | Square Corner Elbow                            |                                                                                                                                                   |                                                                                       | 57                                                                     |                         |            |     |
|                                                            | Standard Tee                                   | With flow through run<br>With flow through branch                                                                                                 |                                                                                       | 20<br>60                                                               |                         |            |     |
|                                                            |                                                | Close Pattern Return Bend                                                                                                                         |                                                                                       |                                                                        | 50                      |            |     |
| Pipe                                                       | 90 Degree Pipe Bends                           |                                                                                                                                                   |                                                                                       | See Page A-27                                                          |                         |            |     |
|                                                            | Miter Bends                                    |                                                                                                                                                   |                                                                                       | See Page A-27                                                          |                         |            |     |
|                                                            | Sudden Enlargements and Contractions           |                                                                                                                                                   |                                                                                       | See Page A-26                                                          |                         |            |     |
|                                                            | Entrance and Exit Losses                       |                                                                                                                                                   |                                                                                       | See Page A-26                                                          |                         |            |     |

\*\*Exact equivalent length is equal to the length between flange faces or welding ends.

\*Minimum calculated pressure drop (psi) across valve to provide sufficient flow to lift disc fully.

## Resistance of Bends

### Resistance of 90 Degree Bends<sup>21</sup>

The chart at the right shows the resistance of 90 degree bends to the flow of fluids in terms of equivalent lengths of straight pipe.

Resistance of bends greater than 90 degrees is found using the formula:

$$\frac{L}{D} = R_1 + (n - 1) \left( R_1 + \frac{R_2}{2} \right)$$

$n$  = total number of 90° bends in coil  
 $R_1$  = total resistance due to one 90° bend, in  $L/D$   
 $R_2$  = resistance due to length of one 90° bend, in  $L/D$   
 $R_3$  = bend resistance due to one 90° bend, in  $L/D$

**Problem:** Determine the equivalent lengths in pipe diameters of a 90 degree bend and a 270 degree bend having a relative radius of 12.

**Solution:** Referring to the "Total Resistance" curve, the equivalent length for a 90 degree bend is 34.5 pipe diameters.

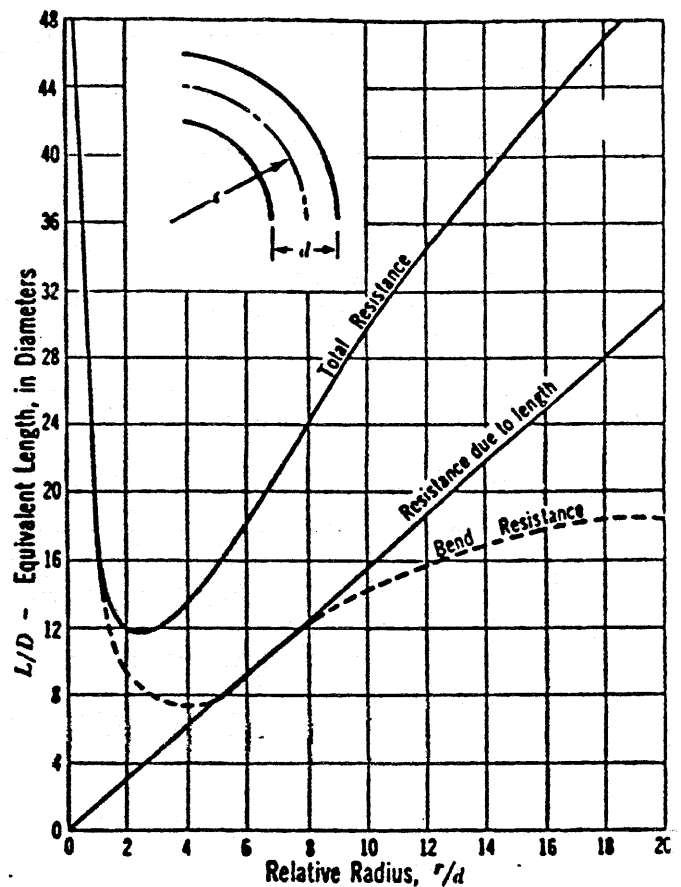
The equivalent length of a 270 degree bend is:

$$L/D = 34.5 + (3 - 1) [18.7 + (15.8 + 2)]$$

$$L/D = 87.7 \text{ pipe diameters}$$

**Note:** This loss is less than the sum of losses through three 90 degree bends separated by tangents. For "resistance of bends theory", see page 2-12.

**Chart for Resistance of 90 Degree Bends**  
 From *Pressure Losses for Fluid Flow in 90 Degree Pipe Bends* by K. H. Bcij. Courtesy of *Journal of Research of National Bureau of Standards*, Vol. 21, July, 1938.



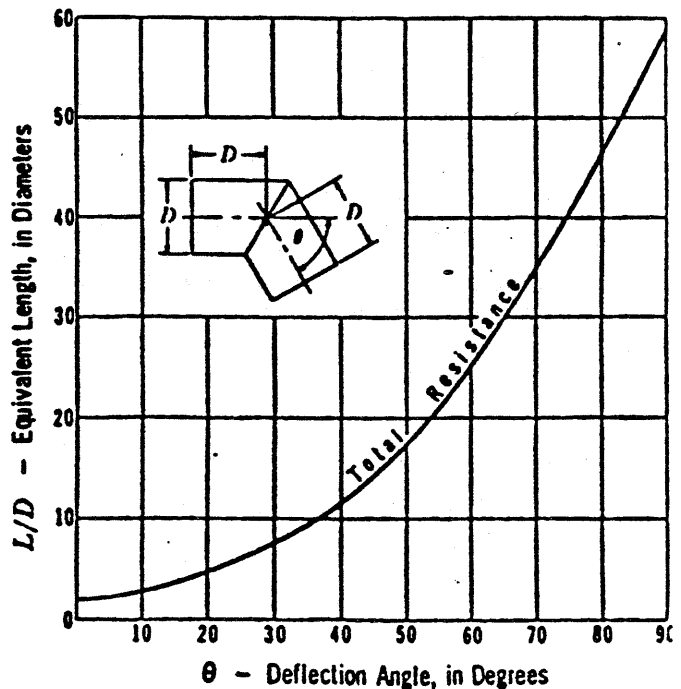
### Resistance of Miter Bends<sup>4</sup>

The chart at the lower right shows the resistance of miter bends to the flow of fluids. The chart is based on data published by the American Society of Mechanical Engineers (ASME).

**Problem:** Determine the equivalent length in pipe diameters of a 40 degree miter bend.

**Solution:** Referring to the "Total Resistance" curve in the chart, the equivalent length is 12 pipe diameters.

**Chart for Resistance of Miter Bends**



Crane Co. "Flow of Fluids through Valves, Fittings, and Pipe",  
 Technical Paper 410, page A-27.

PD 904

## PIPE DATA

### Carbon and Alloy Steel — Stainless Steel

(also see next three pages)

| Nom-<br>inal<br>Pipe<br>Size<br><br>Inches | Outside<br>Diam.<br><br>Inches | Identification       |                 |                                          | Wall<br>Thick-<br>ness<br>(t)<br><br>Inches | Inside<br>Diam-<br>eter<br>(d)<br><br>Inches | Area<br>of<br>Metal<br><br>Square<br>Inches | Transverse<br>Internal Area |                            | Moment<br>of<br>Inertia<br>(I)<br><br>Inches <sup>4</sup> | Weight<br>Pipe<br><br>Pounds<br>per<br>foot | Weight<br>Water<br><br>Pounds<br>per foot<br>of pipe | External<br>Surface<br><br>Sq. Ft.<br>per foot<br>of pipe | Section<br>Modulus<br><br>( $\frac{I}{C}$ ) |
|--------------------------------------------|--------------------------------|----------------------|-----------------|------------------------------------------|---------------------------------------------|----------------------------------------------|---------------------------------------------|-----------------------------|----------------------------|-----------------------------------------------------------|---------------------------------------------|------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------|
|                                            |                                | Steel                |                 | Stain-<br>less<br>Steel<br>Sched.<br>No. |                                             |                                              |                                             | (a)<br><br>Square<br>Inches | (A)<br><br>Square<br>Feet  |                                                           |                                             |                                                      |                                                           |                                             |
|                                            |                                | Iron<br>Pipe<br>Size | Sched.<br>No.   |                                          |                                             |                                              |                                             |                             |                            |                                                           |                                             |                                                      |                                                           |                                             |
| 1/8                                        | 0.405                          | STD<br>XS            | ...<br>40<br>80 | 10S<br>40S<br>80S                        | .049<br>.068<br>.095                        | .307<br>.269<br>.215                         | .0548<br>.0720<br>.0925                     | .0740<br>.0568<br>.0364     | .00051<br>.00040<br>.00025 | .00088<br>.00106<br>.00122                                | .19<br>.24<br>.31                           | .032<br>.025<br>.016                                 | .106<br>.106<br>.106                                      | .00437<br>.00523<br>.00602                  |
| 1/4                                        | 0.540                          | STD<br>XS            | ...<br>40<br>80 | 10S<br>40S<br>80S                        | .065<br>.088<br>.119                        | .410<br>.364<br>.302                         | .0970<br>.1250<br>.1574                     | .1320<br>.1041<br>.0716     | .00091<br>.00072<br>.00050 | .00279<br>.00331<br>.00377                                | .33<br>.42<br>.54                           | .057<br>.045<br>.031                                 | .141<br>.141<br>.141                                      | .01032<br>.01227<br>.01395                  |
| 3/8                                        | 0.675                          | STD<br>XS            | ...<br>40<br>80 | 10S<br>40S<br>80S                        | .065<br>.091<br>.126                        | .545<br>.493<br>.423                         | .1246<br>.1670<br>.2173                     | .2333<br>.1910<br>.1405     | .00162<br>.00133<br>.00098 | .00586<br>.00729<br>.00862                                | .42<br>.57<br>.74                           | .101<br>.083<br>.061                                 | .178<br>.178<br>.178                                      | .01736<br>.02160<br>.02554                  |
| 1/2                                        | 0.840                          | ...                  | ...             | 5S                                       | .065                                        | .710                                         | .1583                                       | .3959                       | .00275                     | .01197                                                    | .54                                         | .172                                                 | .220                                                      | .02849                                      |
|                                            |                                | ...                  | ...             | 10S                                      | .083                                        | .674                                         | .1974                                       | .3568                       | .00248                     | .01431                                                    | .67                                         | .155                                                 | .220                                                      | .03407                                      |
|                                            |                                | STD                  | 40              | 40S                                      | .109                                        | .622                                         | .2503                                       | .3040                       | .00211                     | .01709                                                    | .85                                         | .132                                                 | .220                                                      | .04069                                      |
|                                            |                                | XS                   | 80              | 80S                                      | .147                                        | .546                                         | .3200                                       | .2340                       | .00163                     | .02008                                                    | 1.09                                        | .102                                                 | .220                                                      | .04780                                      |
|                                            |                                | ...                  | 160             | ...                                      | .187                                        | .466                                         | .3836                                       | .1706                       | .00118                     | .02212                                                    | 1.31                                        | .074                                                 | .220                                                      | .05267                                      |
| 3/4                                        | 1.050                          | XXS                  | ...             | ...                                      | .294                                        | .252                                         | .5043                                       | .050                        | .00035                     | .02424                                                    | 1.71                                        | .022                                                 | .220                                                      | .05772                                      |
|                                            |                                | ...                  | ...             | 5S                                       | .065                                        | .920                                         | .2011                                       | .6648                       | .00462                     | .02450                                                    | .69                                         | .288                                                 | .275                                                      | .04667                                      |
|                                            |                                | ...                  | ...             | 10S                                      | .083                                        | .884                                         | .2521                                       | .6138                       | .00426                     | .02969                                                    | .86                                         | .266                                                 | .275                                                      | .05655                                      |
|                                            |                                | STD                  | 40              | 40S                                      | .113                                        | .824                                         | .3326                                       | .5330                       | .00371                     | .03704                                                    | 1.13                                        | .231                                                 | .275                                                      | .07055                                      |
|                                            |                                | XS                   | 80              | 80S                                      | .154                                        | .742                                         | .4335                                       | .4330                       | .00300                     | .04479                                                    | 1.47                                        | .188                                                 | .275                                                      | .08531                                      |
| 1                                          | 1.315                          | ...                  | ...             | ...                                      | .219                                        | .612                                         | .5698                                       | .2961                       | .00206                     | .05269                                                    | 1.94                                        | .128                                                 | .275                                                      | .10036                                      |
|                                            |                                | ...                  | 160             | ...                                      | .308                                        | .434                                         | .7180                                       | .148                        | .00103                     | .05792                                                    | 2.44                                        | .064                                                 | .275                                                      | .11032                                      |
|                                            |                                | ...                  | ...             | 5S                                       | .065                                        | 1.185                                        | .2553                                       | 1.1029                      | .00766                     | .04999                                                    | .87                                         | .478                                                 | .344                                                      | .07603                                      |
|                                            |                                | ...                  | ...             | 10S                                      | .109                                        | 1.097                                        | .4130                                       | .9452                       | .00656                     | .07569                                                    | 1.40                                        | .409                                                 | .344                                                      | .11512                                      |
|                                            |                                | STD                  | 40              | 40S                                      | .133                                        | 1.049                                        | .4939                                       | .8640                       | .00600                     | .08734                                                    | 1.68                                        | .375                                                 | .344                                                      | .1328                                       |
| 1 1/4                                      | 1.660                          | XS                   | 80              | 80S                                      | .179                                        | .957                                         | .6388                                       | .7190                       | .00499                     | .1056                                                     | 2.17                                        | .312                                                 | .344                                                      | .1606                                       |
|                                            |                                | ...                  | 160             | ...                                      | .250                                        | .815                                         | .8365                                       | .5217                       | .00362                     | .1251                                                     | 2.84                                        | .230                                                 | .344                                                      | .1903                                       |
|                                            |                                | XXS                  | ...             | ...                                      | .358                                        | .599                                         | 1.0760                                      | .282                        | .00196                     | .1405                                                     | 3.66                                        | .122                                                 | .344                                                      | .2136                                       |
|                                            |                                | ...                  | ...             | 5S                                       | .065                                        | 1.530                                        | .3257                                       | 1.839                       | .01277                     | .1038                                                     | 1.11                                        | .797                                                 | .435                                                      | .1250                                       |
|                                            |                                | ...                  | ...             | 10S                                      | .109                                        | 1.442                                        | .4717                                       | 1.633                       | .01134                     | .1605                                                     | 1.81                                        | .708                                                 | .435                                                      | .1934                                       |
| 1 1/2                                      | 1.900                          | STD                  | 40              | 40S                                      | .140                                        | 1.380                                        | .6685                                       | 1.495                       | .01040                     | .1947                                                     | 2.27                                        | .649                                                 | .435                                                      | .2346                                       |
|                                            |                                | XS                   | 80              | 80S                                      | .191                                        | 1.278                                        | .8815                                       | 1.283                       | .00891                     | .2418                                                     | 3.00                                        | .555                                                 | .435                                                      | .2913                                       |
|                                            |                                | ...                  | 160             | ...                                      | .250                                        | 1.160                                        | 1.1070                                      | 1.057                       | .00734                     | .2839                                                     | 3.76                                        | .458                                                 | .435                                                      | .3421                                       |
|                                            |                                | XXS                  | ...             | ...                                      | .382                                        | .896                                         | 1.534                                       | .630                        | .00438                     | .3411                                                     | 5.21                                        | .273                                                 | .435                                                      | .4110                                       |
|                                            |                                | ...                  | ...             | 5S                                       | .065                                        | 1.770                                        | .3747                                       | 2.461                       | .01709                     | .1579                                                     | 1.28                                        | 1.066                                                | .497                                                      | .1662                                       |
| 2                                          | 2.375                          | ...                  | ...             | ...                                      | .109                                        | 1.682                                        | .6133                                       | 2.222                       | .01543                     | .2468                                                     | 2.09                                        | .963                                                 | .497                                                      | .2598                                       |
|                                            |                                | ...                  | ...             | 10S                                      | .109                                        | 1.682                                        | .6133                                       | 2.222                       | .01543                     | .2468                                                     | 2.09                                        | .963                                                 | .497                                                      | .2598                                       |
|                                            |                                | STD                  | 40              | 40S                                      | .145                                        | 1.610                                        | .7995                                       | 2.036                       | .01414                     | .3099                                                     | 2.72                                        | .882                                                 | .497                                                      | .3262                                       |
|                                            |                                | XS                   | 80              | 80S                                      | .200                                        | 1.500                                        | 1.068                                       | 1.767                       | .01225                     | .3912                                                     | 3.63                                        | .765                                                 | .497                                                      | .4118                                       |
|                                            |                                | ...                  | 160             | ...                                      | .281                                        | 1.338                                        | 1.429                                       | 1.406                       | .00976                     | .4824                                                     | 4.86                                        | .608                                                 | .497                                                      | .5078                                       |
| 2 1/2                                      | 2.875                          | XXS                  | ...             | ...                                      | .400                                        | 1.100                                        | 1.885                                       | .950                        | .00660                     | .5678                                                     | 6.41                                        | .42                                                  | .497                                                      | .5977                                       |
|                                            |                                | ...                  | ...             | 5S                                       | .065                                        | 2.245                                        | .4717                                       | 3.958                       | .02749                     | .3149                                                     | 1.61                                        | 1.72                                                 | .622                                                      | .2652                                       |
|                                            |                                | ...                  | ...             | 10S                                      | .109                                        | 2.157                                        | .7760                                       | 3.654                       | .02538                     | .4992                                                     | 2.64                                        | 1.58                                                 | .622                                                      | .4204                                       |
|                                            |                                | STD                  | 40              | 40S                                      | .154                                        | 2.067                                        | 1.075                                       | 3.355                       | .02330                     | .6657                                                     | 3.65                                        | 1.45                                                 | .622                                                      | .5606                                       |
|                                            |                                | XS                   | 80              | 80S                                      | .218                                        | 1.939                                        | 1.477                                       | 2.953                       | .02050                     | .8679                                                     | 5.02                                        | 1.28                                                 | .622                                                      | .7309                                       |
| 3                                          | 3.500                          | ...                  | 160             | ...                                      | .344                                        | 1.687                                        | 2.190                                       | 2.241                       | .01556                     | 1.162                                                     | 7.46                                        | .97                                                  | .622                                                      | .979                                        |
|                                            |                                | XXS                  | ...             | ...                                      | .436                                        | 1.503                                        | 2.656                                       | 1.774                       | .01232                     | 1.311                                                     | 9.03                                        | .77                                                  | .622                                                      | 1.104                                       |
|                                            |                                | ...                  | ...             | 5S                                       | .083                                        | 2.709                                        | .7280                                       | 5.764                       | .04002                     | .7100                                                     | 2.48                                        | 2.50                                                 | .753                                                      | .4939                                       |
|                                            |                                | ...                  | ...             | 10S                                      | .120                                        | 2.635                                        | 1.039                                       | 5.453                       | .03787                     | .9873                                                     | 3.53                                        | 2.36                                                 | .753                                                      | .6868                                       |
|                                            |                                | STD                  | 40              | 40S                                      | .203                                        | 2.469                                        | 1.704                                       | 4.788                       | .03322                     | 1.530                                                     | 5.79                                        | 2.07                                                 | .753                                                      | 1.064                                       |
| 3 1/2                                      | 3.500                          | XS                   | 80              | 80S                                      | .276                                        | 2.323                                        | 2.254                                       | 4.238                       | .02942                     | 1.924                                                     | 7.66                                        | 1.87                                                 | .753                                                      | 1.339                                       |
|                                            |                                | ...                  | 160             | ...                                      | .375                                        | 2.125                                        | 2.945                                       | 3.546                       | .02463                     | 2.353                                                     | 10.01                                       | 1.54                                                 | .753                                                      | 1.638                                       |
|                                            |                                | XXS                  | ...             | ...                                      | .552                                        | 1.771                                        | 4.028                                       | 2.464                       | .01710                     | 2.871                                                     | 13.69                                       | 1.07                                                 | .753                                                      | 1.997                                       |
|                                            |                                | ...                  | ...             | 5S                                       | .083                                        | 3.334                                        | .8910                                       | 8.730                       | .06063                     | 1.301                                                     | 3.03                                        | 3.78                                                 | .916                                                      | .7435                                       |
|                                            |                                | ...                  | ...             | 10S                                      | .120                                        | 3.260                                        | 1.274                                       | 8.347                       | .05796                     | 1.822                                                     | 4.33                                        | 3.62                                                 | .916                                                      | 1.041                                       |
| 4                                          | 3.500                          | STD                  | 40              | 40S                                      | .216                                        | 3.068                                        | 2.228                                       | 7.393                       | .05130                     | 3.017                                                     | 7.58                                        | 3.20                                                 | .916                                                      | 1.724                                       |
|                                            |                                | XS                   | 80              | 80S                                      | .300                                        | 2.900                                        | 3.016                                       | 6.605                       | .04587                     | 3.894                                                     | 10.25                                       | 2.86                                                 | .916                                                      | 2.225                                       |
|                                            |                                | ...                  | 160             | ...                                      | .438                                        | 2.624                                        | 4.205                                       | 5.408                       | .03755                     | 5.032                                                     | 14.32                                       | 2.35                                                 | .916                                                      | 2.876                                       |
|                                            |                                | XXS                  | ...             | ...                                      | .600                                        | 2.300                                        | 5.466                                       | 4.155                       | .02885                     | 5.993                                                     | 18.58                                       | 1.80                                                 | .916                                                      | 3.424                                       |
|                                            |                                | ...                  | ...             | 5S                                       | .083                                        | 3.334                                        | .8910                                       | 8.730                       | .06063                     | 1.301                                                     | 3.03                                        | 3.78                                                 | .916                                                      | .7435                                       |

Identification, wall thickness and weights are extracted from ANSI B36.10 and B36.19. The notations STD, XS, and XXS indicate Standard, Extra Strong, and Double Extra Strong pipe respectively.

Transverse internal area values listed in "square feet" also represent volume in cubic feet per foot of pipe length.

## PIPE DATA — cont.

| Nom-<br>inal<br>Pipe<br>Size<br><br>Inches | Outside<br>Diam.<br><br>Inches | Identification       |               |                                          | Wall<br>Thick-<br>ness<br>(t)<br><br>Inches | Inside<br>Diam-<br>eter<br>(d)<br><br>Inches | Area<br>of<br>Metal<br><br>Square<br>Inches | Transverse              |                       | Moment<br>of<br>Inertia<br>(I)<br><br>Inches <sup>4</sup> | Weight<br>Pipe<br><br>Pounds<br>per<br>foot | Weight<br>Water<br><br>Pounds<br>per foot<br>of pipe | External<br>Surface<br><br>Sq. Ft.<br>per foot<br>of pipe | Section<br>Modulus<br><br>( $\frac{I}{O.D.}$ ) |
|--------------------------------------------|--------------------------------|----------------------|---------------|------------------------------------------|---------------------------------------------|----------------------------------------------|---------------------------------------------|-------------------------|-----------------------|-----------------------------------------------------------|---------------------------------------------|------------------------------------------------------|-----------------------------------------------------------|------------------------------------------------|
|                                            |                                | Steel                |               | Stain-<br>less<br>Steel<br>Sched.<br>No. |                                             |                                              |                                             | Internal Area           |                       |                                                           |                                             |                                                      |                                                           |                                                |
|                                            |                                | Iron<br>Pipe<br>Size | Sched.<br>No. |                                          |                                             |                                              |                                             | (a)<br>Square<br>Inches | (A)<br>Square<br>Feet |                                                           |                                             |                                                      |                                                           |                                                |
| 3½                                         | 4.000                          | ...                  | ...           | 5S                                       | .083                                        | 3.834                                        | 1.021                                       | 11.545                  | .08017                | 1.960                                                     | 3.48                                        | 5.00                                                 | 1.047                                                     | .9799                                          |
|                                            |                                | ...                  | ...           | 10S                                      | .120                                        | 3.760                                        | 1.463                                       | 11.104                  | .07711                | 2.755                                                     | 4.97                                        | 4.81                                                 | 1.047                                                     | 1.378                                          |
|                                            |                                | STD                  | 40            | 40S                                      | .226                                        | 3.548                                        | 2.680                                       | 9.886                   | .06870                | 4.788                                                     | 9.11                                        | 4.29                                                 | 1.047                                                     | 2.394                                          |
|                                            |                                | XS                   | 80            | 80S                                      | .318                                        | 3.364                                        | 3.678                                       | 8.888                   | .06170                | 6.280                                                     | 12.50                                       | 3.84                                                 | 1.047                                                     | 3.140                                          |
|                                            |                                | ...                  | ...           | ...                                      | ...                                         | ...                                          | ...                                         | ...                     | ...                   | ...                                                       | ...                                         | ...                                                  | ...                                                       | ...                                            |
| 4                                          | 4.500                          | ...                  | ...           | 5S                                       | .083                                        | 4.334                                        | 1.152                                       | 14.75                   | .10245                | 2.810                                                     | 3.92                                        | 6.39                                                 | 1.178                                                     | 1.249                                          |
|                                            |                                | ...                  | ...           | 10S                                      | .120                                        | 4.260                                        | 1.651                                       | 14.25                   | .09898                | 3.963                                                     | 5.61                                        | 6.18                                                 | 1.178                                                     | 1.761                                          |
|                                            |                                | STD                  | 40            | 40S                                      | .237                                        | 4.026                                        | 3.174                                       | 12.73                   | .08840                | 7.233                                                     | 10.79                                       | 5.50                                                 | 1.178                                                     | 3.214                                          |
|                                            |                                | XS                   | 80            | 80S                                      | .337                                        | 3.826                                        | 4.407                                       | 11.50                   | .07986                | 9.610                                                     | 14.98                                       | 4.98                                                 | 1.178                                                     | 4.271                                          |
|                                            |                                | ...                  | 120           | ...                                      | .438                                        | 3.624                                        | 5.595                                       | 10.31                   | .0716                 | 11.65                                                     | 19.00                                       | 4.47                                                 | 1.178                                                     | 5.178                                          |
| ...                                        | 160                            | ...                  | .531          | 3.438                                    | 6.621                                       | 9.28                                         | .0645                                       | 13.27                   | 22.51                 | 4.02                                                      | 1.178                                       | 5.898                                                |                                                           |                                                |
| ...                                        | ...                            | ...                  | .674          | 3.152                                    | 8.101                                       | 7.80                                         | .0542                                       | 15.28                   | 27.54                 | 3.38                                                      | 1.178                                       | 6.791                                                |                                                           |                                                |
| 5                                          | 5.563                          | ...                  | ...           | 5S                                       | .109                                        | 5.345                                        | 1.868                                       | 22.44                   | .1558                 | 6.947                                                     | 6.36                                        | 9.72                                                 | 1.456                                                     | 2.498                                          |
|                                            |                                | ...                  | ...           | 10S                                      | .134                                        | 5.295                                        | 2.285                                       | 22.02                   | .1529                 | 8.425                                                     | 7.77                                        | 9.54                                                 | 1.456                                                     | 3.029                                          |
|                                            |                                | STD                  | 40            | 40S                                      | .258                                        | 5.047                                        | 4.300                                       | 20.01                   | .1390                 | 15.16                                                     | 14.62                                       | 8.67                                                 | 1.456                                                     | 5.451                                          |
|                                            |                                | XS                   | 80            | 80S                                      | .375                                        | 4.813                                        | 6.112                                       | 18.19                   | .1263                 | 20.67                                                     | 20.78                                       | 7.88                                                 | 1.456                                                     | 7.431                                          |
|                                            |                                | ...                  | 120           | ...                                      | .500                                        | 4.563                                        | 7.953                                       | 16.35                   | .1136                 | 25.73                                                     | 27.04                                       | 7.09                                                 | 1.456                                                     | 9.250                                          |
| ...                                        | 160                            | ...                  | .625          | 4.313                                    | 9.696                                       | 14.61                                        | .1015                                       | 30.03                   | 32.96                 | 6.33                                                      | 1.456                                       | 10.796                                               |                                                           |                                                |
| ...                                        | ...                            | ...                  | .750          | 4.063                                    | 11.340                                      | 12.97                                        | .0901                                       | 33.63                   | 38.55                 | 5.61                                                      | 1.456                                       | 12.090                                               |                                                           |                                                |
| 6                                          | 6.625                          | ...                  | ...           | 5S                                       | .109                                        | 6.407                                        | 2.231                                       | 32.24                   | .2239                 | 11.85                                                     | 7.60                                        | 13.97                                                | 1.734                                                     | 3.576                                          |
|                                            |                                | ...                  | ...           | 10S                                      | .134                                        | 6.357                                        | 2.733                                       | 31.74                   | .2204                 | 14.40                                                     | 9.29                                        | 13.75                                                | 1.734                                                     | 4.346                                          |
|                                            |                                | STD                  | 40            | 40S                                      | .280                                        | 6.065                                        | 5.581                                       | 28.89                   | .2006                 | 28.14                                                     | 18.97                                       | 12.51                                                | 1.734                                                     | 8.496                                          |
|                                            |                                | XS                   | 80            | 80S                                      | .432                                        | 5.761                                        | 8.405                                       | 26.07                   | .1810                 | 40.49                                                     | 28.57                                       | 11.29                                                | 1.734                                                     | 12.22                                          |
|                                            |                                | ...                  | 120           | ...                                      | .562                                        | 5.501                                        | 10.70                                       | 23.77                   | .1650                 | 49.61                                                     | 36.39                                       | 10.30                                                | 1.734                                                     | 14.98                                          |
| ...                                        | 160                            | ...                  | .719          | 5.187                                    | 13.32                                       | 21.15                                        | .1469                                       | 58.97                   | 45.35                 | 9.16                                                      | 1.734                                       | 17.81                                                |                                                           |                                                |
| ...                                        | ...                            | ...                  | .864          | 4.897                                    | 15.64                                       | 18.84                                        | .1308                                       | 66.33                   | 53.16                 | 8.16                                                      | 1.734                                       | 20.02                                                |                                                           |                                                |
| 8                                          | 8.625                          | ...                  | ...           | 5S                                       | .109                                        | 8.407                                        | 2.916                                       | 55.51                   | .3855                 | 26.44                                                     | 9.93                                        | 24.06                                                | 2.258                                                     | 6.131                                          |
|                                            |                                | ...                  | ...           | 10S                                      | .148                                        | 8.329                                        | 3.941                                       | 54.48                   | .3784                 | 35.41                                                     | 13.40                                       | 23.61                                                | 2.258                                                     | 8.212                                          |
|                                            |                                | ...                  | 20            | ...                                      | .250                                        | 8.125                                        | 6.57                                        | 51.85                   | .3601                 | 57.72                                                     | 22.36                                       | 22.47                                                | 2.258                                                     | 13.39                                          |
|                                            |                                | ...                  | 30            | ...                                      | .277                                        | 8.071                                        | 7.26                                        | 51.16                   | .3553                 | 63.35                                                     | 24.70                                       | 22.17                                                | 2.258                                                     | 14.69                                          |
|                                            |                                | STD                  | 40            | 40S                                      | .322                                        | 7.981                                        | 8.40                                        | 50.03                   | .3474                 | 72.49                                                     | 28.55                                       | 21.70                                                | 2.258                                                     | 16.81                                          |
|                                            |                                | ...                  | 60            | ...                                      | .406                                        | 7.813                                        | 10.48                                       | 47.94                   | .3329                 | 88.73                                                     | 35.64                                       | 20.77                                                | 2.258                                                     | 20.58                                          |
|                                            |                                | XS                   | 80            | 80S                                      | .500                                        | 7.625                                        | 12.76                                       | 45.66                   | .3171                 | 105.7                                                     | 43.39                                       | 19.78                                                | 2.258                                                     | 24.51                                          |
|                                            |                                | ...                  | 100           | ...                                      | .594                                        | 7.437                                        | 14.96                                       | 43.46                   | .3018                 | 121.3                                                     | 50.95                                       | 18.83                                                | 2.258                                                     | 28.14                                          |
|                                            |                                | ...                  | 120           | ...                                      | .719                                        | 7.187                                        | 17.84                                       | 40.59                   | .2819                 | 140.5                                                     | 60.71                                       | 17.59                                                | 2.258                                                     | 32.58                                          |
|                                            |                                | ...                  | 140           | ...                                      | .812                                        | 7.001                                        | 19.93                                       | 38.50                   | .2673                 | 153.7                                                     | 67.76                                       | 16.68                                                | 2.258                                                     | 35.65                                          |
|                                            |                                | ...                  | 160           | ...                                      | .875                                        | 6.875                                        | 21.30                                       | 37.12                   | .2578                 | 162.0                                                     | 72.42                                       | 16.10                                                | 2.258                                                     | 37.56                                          |
| ...                                        | ...                            | ...                  | .906          | 6.813                                    | 21.97                                       | 36.46                                        | .2532                                       | 165.9                   | 74.69                 | 15.80                                                     | 2.258                                       | 38.48                                                |                                                           |                                                |
| 10                                         | 10.750                         | ...                  | ...           | 5S                                       | .134                                        | 10.482                                       | 4.36                                        | 86.29                   | .5992                 | 63.0                                                      | 15.19                                       | 37.39                                                | 2.814                                                     | 11.71                                          |
|                                            |                                | ...                  | ...           | 10S                                      | .165                                        | 10.420                                       | 5.49                                        | 85.28                   | .5922                 | 76.9                                                      | 18.65                                       | 36.95                                                | 2.814                                                     | 14.30                                          |
|                                            |                                | ...                  | 20            | ...                                      | .250                                        | 10.250                                       | 8.24                                        | 82.52                   | .5731                 | 113.7                                                     | 28.04                                       | 35.76                                                | 2.814                                                     | 21.15                                          |
|                                            |                                | ...                  | 30            | ...                                      | .307                                        | 10.136                                       | 10.07                                       | 80.69                   | .5603                 | 137.4                                                     | 34.24                                       | 34.96                                                | 2.814                                                     | 25.57                                          |
|                                            |                                | STD                  | 40            | 40S                                      | .365                                        | 10.020                                       | 11.90                                       | 78.86                   | .5475                 | 160.7                                                     | 40.48                                       | 34.20                                                | 2.814                                                     | 29.90                                          |
|                                            |                                | XS                   | 60            | 80S                                      | .500                                        | 9.750                                        | 16.10                                       | 74.66                   | .5185                 | 212.0                                                     | 54.74                                       | 32.35                                                | 2.814                                                     | 39.43                                          |
|                                            |                                | ...                  | 80            | ...                                      | .594                                        | 9.562                                        | 18.92                                       | 71.84                   | .4989                 | 244.8                                                     | 64.43                                       | 31.13                                                | 2.814                                                     | 45.54                                          |
|                                            |                                | ...                  | 100           | ...                                      | .719                                        | 9.312                                        | 22.63                                       | 68.13                   | .4732                 | 286.1                                                     | 77.03                                       | 29.53                                                | 2.814                                                     | 53.22                                          |
|                                            |                                | ...                  | 120           | ...                                      | .844                                        | 9.062                                        | 26.24                                       | 64.53                   | .4481                 | 324.2                                                     | 89.29                                       | 27.96                                                | 2.814                                                     | 60.32                                          |
|                                            |                                | ...                  | 140           | ...                                      | 1.000                                       | 8.750                                        | 30.63                                       | 60.13                   | .4176                 | 367.8                                                     | 104.13                                      | 26.06                                                | 2.814                                                     | 68.43                                          |
|                                            |                                | ...                  | 160           | ...                                      | 1.125                                       | 8.500                                        | 34.02                                       | 56.75                   | .3941                 | 399.3                                                     | 115.64                                      | 24.59                                                | 2.814                                                     | 74.29                                          |
| 12                                         | 12.75                          | ...                  | ...           | 5S                                       | .156                                        | 12.438                                       | 6.17                                        | 121.50                  | .8438                 | 122.4                                                     | 20.98                                       | 52.65                                                | 3.338                                                     | 19.2                                           |
|                                            |                                | ...                  | ...           | 10S                                      | .180                                        | 12.390                                       | 7.11                                        | 120.57                  | .8373                 | 140.4                                                     | 24.17                                       | 52.25                                                | 3.338                                                     | 22.0                                           |
|                                            |                                | ...                  | 20            | ...                                      | .250                                        | 12.250                                       | 9.82                                        | 117.86                  | .8185                 | 191.8                                                     | 33.38                                       | 51.07                                                | 3.338                                                     | 30.2                                           |
|                                            |                                | ...                  | 30            | ...                                      | .330                                        | 12.090                                       | 12.87                                       | 114.80                  | .7972                 | 248.4                                                     | 43.77                                       | 49.74                                                | 3.338                                                     | 39.0                                           |
|                                            |                                | STD                  | 40            | 40S                                      | .375                                        | 12.000                                       | 14.58                                       | 113.10                  | .7854                 | 279.3                                                     | 49.56                                       | 49.00                                                | 3.338                                                     | 43.8                                           |
|                                            |                                | ...                  | 60            | ...                                      | .406                                        | 11.938                                       | 15.77                                       | 111.93                  | .7773                 | 300.3                                                     | 53.52                                       | 48.50                                                | 3.338                                                     | 47.1                                           |
|                                            |                                | XS                   | 80            | 80S                                      | .500                                        | 11.750                                       | 19.24                                       | 108.43                  | .7528                 | 361.5                                                     | 65.42                                       | 46.92                                                | 3.338                                                     | 56.7                                           |
|                                            |                                | ...                  | 100           | ...                                      | .562                                        | 11.626                                       | 21.52                                       | 106.16                  | .7372                 | 400.4                                                     | 73.15                                       | 46.00                                                | 3.338                                                     | 62.8                                           |
|                                            |                                | ...                  | 120           | ...                                      | .688                                        | 11.374                                       | 26.03                                       | 101.64                  | .7058                 | 475.1                                                     | 88.63                                       | 44.04                                                | 3.338                                                     | 74.6                                           |
|                                            |                                | ...                  | 140           | ...                                      | .844                                        | 11.062                                       | 1.53                                        | 96.14                   | .6677                 | 561.6                                                     | 107.32                                      | 41.66                                                | 3.338                                                     | 88.1                                           |
|                                            |                                | ...                  | 160           | ...                                      | 1.000                                       | 10.750                                       | 36.91                                       | 90.76                   | .6303                 | 641.6                                                     | 125.49                                      | 39.33                                                | 3.338                                                     | 100.7                                          |
| ...                                        | ...                            | ...                  | 1.125         | 10.500                                   | 41.08                                       | 86.59                                        | .6013                                       | 700.5                   | 139.67                | 37.52                                                     | 3.338                                       | 109.9                                                |                                                           |                                                |
| ...                                        | ...                            | ...                  | 1.312         | 10.126                                   | 47.14                                       | 80.53                                        | .5592                                       | 781.1                   | 160.27                | 34.89                                                     | 3.338                                       | 122.6                                                |                                                           |                                                |

## PIPE DATA—cont.

| Nom-<br>inal<br>Pipe<br>Size<br><br>Inches | Outside<br>Diam.<br><br>Inches | Identification       |               |                                          | Wall<br>Thick-<br>ness<br>(t)<br><br>Inches | Inside<br>Diam-<br>eter<br>(d)<br><br>Inches | Area<br>of<br>Metal<br><br>Square<br>Inches | Transverse<br>Internal Area |                           | Moment<br>of<br>Inertia<br>(I)<br><br>Inches <sup>4</sup> | Weight<br>Pipe<br><br>Pounds<br>per<br>foot | Weight<br>Water<br><br>Pounds<br>per foot<br>of pipe | External<br>Surface<br><br>Sq. Ft.<br>per foot<br>of pipe | Section<br>Modulus<br><br>( $\frac{2I}{O.D.}$ ) |
|--------------------------------------------|--------------------------------|----------------------|---------------|------------------------------------------|---------------------------------------------|----------------------------------------------|---------------------------------------------|-----------------------------|---------------------------|-----------------------------------------------------------|---------------------------------------------|------------------------------------------------------|-----------------------------------------------------------|-------------------------------------------------|
|                                            |                                | Steel                |               | Stain-<br>less<br>Steel<br>Sched.<br>No. |                                             |                                              |                                             | (a)<br><br>Square<br>Inches | (A)<br><br>Square<br>Feet |                                                           |                                             |                                                      |                                                           |                                                 |
|                                            |                                | Iron<br>Pipe<br>Size | Sched.<br>No. |                                          |                                             |                                              |                                             |                             |                           |                                                           |                                             |                                                      |                                                           |                                                 |
| 14                                         | 14.00                          | ...                  | ...           | 5S                                       | .156                                        | 13.688                                       | 6.78                                        | 147.15                      | 1.0219                    | 162.6                                                     | 23.07                                       | 63.77                                                | 3.665                                                     | 23.2                                            |
|                                            |                                | ...                  | ...           | 10S                                      | .188                                        | 13.624                                       | 8.16                                        | 145.78                      | 1.0124                    | 194.6                                                     | 27.73                                       | 63.17                                                | 3.665                                                     | 27.8                                            |
|                                            |                                | ...                  | 10            | ...                                      | .250                                        | 13.500                                       | 10.80                                       | 143.14                      | .9940                     | 255.3                                                     | 36.71                                       | 62.03                                                | 3.665                                                     | 36.6                                            |
|                                            |                                | ...                  | 20            | ...                                      | .312                                        | 13.376                                       | 13.42                                       | 140.52                      | .9758                     | 314.4                                                     | 45.61                                       | 60.89                                                | 3.665                                                     | 45.0                                            |
|                                            |                                | STD                  | 30            | ...                                      | .375                                        | 13.250                                       | 16.05                                       | 137.88                      | .9575                     | 372.8                                                     | 54.57                                       | 59.75                                                | 3.665                                                     | 53.2                                            |
|                                            |                                | ...                  | 40            | ...                                      | .438                                        | 13.124                                       | 18.66                                       | 135.28                      | .9394                     | 429.1                                                     | 63.44                                       | 58.64                                                | 3.665                                                     | 61.3                                            |
|                                            |                                | XS                   | ...           | ...                                      | .500                                        | 13.000                                       | 21.21                                       | 132.73                      | .9217                     | 483.8                                                     | 72.09                                       | 57.46                                                | 3.665                                                     | 69.1                                            |
|                                            |                                | ...                  | 60            | ...                                      | .594                                        | 12.812                                       | 24.98                                       | 128.96                      | .8956                     | 562.3                                                     | 85.05                                       | 55.86                                                | 3.665                                                     | 80.3                                            |
|                                            |                                | ...                  | 80            | ...                                      | .750                                        | 12.500                                       | 31.22                                       | 122.72                      | .8522                     | 678.3                                                     | 106.13                                      | 53.18                                                | 3.665                                                     | 98.2                                            |
|                                            |                                | ...                  | 100           | ...                                      | .938                                        | 12.124                                       | 38.45                                       | 115.49                      | .8020                     | 824.4                                                     | 130.85                                      | 50.04                                                | 3.665                                                     | 117.8                                           |
|                                            |                                | ...                  | 120           | ...                                      | 1.094                                       | 11.812                                       | 44.32                                       | 109.62                      | .7612                     | 929.6                                                     | 150.79                                      | 47.45                                                | 3.665                                                     | 132.8                                           |
|                                            |                                | ...                  | 140           | ...                                      | 1.250                                       | 11.500                                       | 50.07                                       | 103.87                      | .7213                     | 1027.0                                                    | 170.28                                      | 45.01                                                | 3.665                                                     | 146.8                                           |
|                                            |                                | ...                  | 160           | ...                                      | 1.406                                       | 11.188                                       | 55.63                                       | 98.31                       | .6827                     | 1117.0                                                    | 189.11                                      | 42.60                                                | 3.665                                                     | 159.6                                           |
| 16                                         | 16.00                          | ...                  | ...           | 5S                                       | .165                                        | 15.670                                       | 8.21                                        | 192.85                      | 1.3393                    | 257.3                                                     | 27.90                                       | 83.57                                                | 4.189                                                     | 32.2                                            |
|                                            |                                | ...                  | ...           | 10S                                      | .188                                        | 15.624                                       | 9.34                                        | 191.72                      | 1.3314                    | 291.9                                                     | 31.75                                       | 83.08                                                | 4.189                                                     | 36.5                                            |
|                                            |                                | ...                  | 10            | ...                                      | .250                                        | 15.500                                       | 12.37                                       | 188.69                      | 1.3103                    | 383.7                                                     | 42.05                                       | 81.74                                                | 4.189                                                     | 48.0                                            |
|                                            |                                | ...                  | 20            | ...                                      | .312                                        | 15.376                                       | 15.38                                       | 185.69                      | 1.2895                    | 473.2                                                     | 52.27                                       | 80.50                                                | 4.189                                                     | 59.2                                            |
|                                            |                                | STD                  | 30            | ...                                      | .375                                        | 15.250                                       | 18.41                                       | 182.65                      | 1.2684                    | 562.1                                                     | 62.58                                       | 79.12                                                | 4.189                                                     | 70.3                                            |
|                                            |                                | XS                   | 40            | ...                                      | .500                                        | 15.000                                       | 24.35                                       | 176.72                      | 1.2272                    | 731.9                                                     | 82.77                                       | 76.58                                                | 4.189                                                     | 91.5                                            |
|                                            |                                | ...                  | 60            | ...                                      | .656                                        | 14.688                                       | 31.62                                       | 169.44                      | 1.1766                    | 932.4                                                     | 107.50                                      | 73.42                                                | 4.189                                                     | 116.6                                           |
|                                            |                                | ...                  | 80            | ...                                      | .844                                        | 14.312                                       | 40.14                                       | 160.92                      | 1.1175                    | 1155.8                                                    | 136.61                                      | 69.73                                                | 4.189                                                     | 144.5                                           |
|                                            |                                | ...                  | 100           | ...                                      | 1.031                                       | 13.938                                       | 48.48                                       | 152.58                      | 1.0596                    | 1364.5                                                    | 164.82                                      | 66.12                                                | 4.189                                                     | 170.5                                           |
|                                            |                                | ...                  | 120           | ...                                      | 1.219                                       | 13.562                                       | 56.56                                       | 144.50                      | 1.0035                    | 1555.8                                                    | 192.43                                      | 62.62                                                | 4.189                                                     | 194.5                                           |
|                                            |                                | ...                  | 140           | ...                                      | 1.438                                       | 13.124                                       | 65.78                                       | 135.28                      | .9394                     | 1760.3                                                    | 223.64                                      | 58.64                                                | 4.189                                                     | 220.0                                           |
|                                            |                                | ...                  | 160           | ...                                      | 1.594                                       | 12.812                                       | 72.10                                       | 128.96                      | .8956                     | 1893.5                                                    | 245.25                                      | 55.83                                                | 4.189                                                     | 236.7                                           |
|                                            |                                | 18                   | 18.00         | ...                                      | ...                                         | 5S                                           | .165                                        | 17.670                      | 9.25                      | 245.22                                                    | 1.7029                                      | 367.6                                                | 31.43                                                     | 106.26                                          |
| ...                                        | ...                            |                      |               | 10S                                      | .188                                        | 17.624                                       | 10.52                                       | 243.95                      | 1.6941                    | 417.3                                                     | 35.76                                       | 105.71                                               | 4.712                                                     | 46.4                                            |
| ...                                        | 10                             |                      |               | ...                                      | .250                                        | 17.500                                       | 13.94                                       | 240.53                      | 1.6703                    | 549.1                                                     | 47.39                                       | 104.21                                               | 4.712                                                     | 61.1                                            |
| ...                                        | 20                             |                      |               | ...                                      | .312                                        | 17.376                                       | 17.34                                       | 237.13                      | 1.6467                    | 678.2                                                     | 58.94                                       | 102.77                                               | 4.712                                                     | 75.5                                            |
| STD                                        | ...                            |                      |               | ...                                      | .375                                        | 17.250                                       | 20.76                                       | 233.71                      | 1.6230                    | 806.7                                                     | 70.59                                       | 101.18                                               | 4.712                                                     | 89.6                                            |
| ...                                        | 30                             |                      |               | ...                                      | .438                                        | 17.124                                       | 24.17                                       | 230.30                      | 1.5990                    | 930.3                                                     | 82.15                                       | 99.84                                                | 4.712                                                     | 103.4                                           |
| XS                                         | ...                            |                      |               | ...                                      | .500                                        | 17.000                                       | 27.49                                       | 226.98                      | 1.5763                    | 1053.2                                                    | 93.45                                       | 98.27                                                | 4.712                                                     | 117.0                                           |
| ...                                        | 40                             |                      |               | ...                                      | .562                                        | 16.876                                       | 30.79                                       | 223.68                      | 1.5533                    | 1171.5                                                    | 104.67                                      | 96.93                                                | 4.712                                                     | 130.1                                           |
| ...                                        | 60                             |                      |               | ...                                      | .750                                        | 16.500                                       | 40.64                                       | 213.83                      | 1.4849                    | 1514.7                                                    | 138.17                                      | 92.57                                                | 4.712                                                     | 168.3                                           |
| ...                                        | 80                             |                      |               | ...                                      | .938                                        | 16.124                                       | 50.23                                       | 204.24                      | 1.4183                    | 1833.0                                                    | 170.92                                      | 88.50                                                | 4.712                                                     | 203.8                                           |
| ...                                        | 100                            |                      |               | ...                                      | 1.156                                       | 15.688                                       | 61.17                                       | 193.30                      | 1.3423                    | 2180.0                                                    | 207.96                                      | 83.76                                                | 4.712                                                     | 242.3                                           |
| ...                                        | 120                            |                      |               | ...                                      | 1.375                                       | 15.250                                       | 71.81                                       | 182.66                      | 1.2684                    | 2498.1                                                    | 244.14                                      | 79.07                                                | 4.712                                                     | 277.6                                           |
| ...                                        | 140                            |                      |               | ...                                      | 1.562                                       | 14.876                                       | 80.66                                       | 173.80                      | 1.2070                    | 2749.0                                                    | 274.22                                      | 75.32                                                | 4.712                                                     | 305.5                                           |
| ...                                        | 160                            | ...                  | 1.781         | 14.438                                   | 90.75                                       | 163.72                                       | 1.1369                                      | 3020.0                      | 308.50                    | 70.88                                                     | 4.712                                       | 335.6                                                |                                                           |                                                 |
| 20                                         | 20.00                          | ...                  | ...           | 5S                                       | .188                                        | 19.624                                       | 11.70                                       | 302.46                      | 2.1004                    | 574.2                                                     | 39.78                                       | 131.06                                               | 5.236                                                     | 57.4                                            |
|                                            |                                | ...                  | ...           | 10S                                      | .218                                        | 19.564                                       | 13.55                                       | 300.61                      | 2.0876                    | 662.8                                                     | 46.06                                       | 130.27                                               | 5.236                                                     | 66.3                                            |
|                                            |                                | ...                  | 10            | ...                                      | .250                                        | 19.500                                       | 15.51                                       | 298.65                      | 2.0740                    | 765.4                                                     | 52.73                                       | 129.42                                               | 5.236                                                     | 75.6                                            |
|                                            |                                | ...                  | 20            | ...                                      | .375                                        | 19.250                                       | 23.12                                       | 290.04                      | 2.0142                    | 1113.0                                                    | 78.60                                       | 125.67                                               | 5.236                                                     | 111.3                                           |
|                                            |                                | STD                  | ...           | ...                                      | .500                                        | 19.000                                       | 30.63                                       | 283.53                      | 1.9690                    | 1457.0                                                    | 104.13                                      | 122.87                                               | 5.236                                                     | 145.7                                           |
|                                            |                                | XS                   | 30            | ...                                      | .594                                        | 18.812                                       | 36.15                                       | 278.00                      | 1.9305                    | 1703.0                                                    | 123.11                                      | 120.46                                               | 5.236                                                     | 170.4                                           |
|                                            |                                | ...                  | 40            | ...                                      | .812                                        | 18.376                                       | 48.95                                       | 265.21                      | 1.8417                    | 2257.0                                                    | 166.40                                      | 114.92                                               | 5.236                                                     | 225.7                                           |
|                                            |                                | ...                  | 60            | ...                                      | 1.031                                       | 17.938                                       | 61.44                                       | 252.72                      | 1.7550                    | 2772.0                                                    | 208.87                                      | 109.51                                               | 5.236                                                     | 277.1                                           |
|                                            |                                | ...                  | 80            | ...                                      | 1.281                                       | 17.438                                       | 75.33                                       | 238.83                      | 1.6585                    | 3315.2                                                    | 256.10                                      | 103.39                                               | 5.236                                                     | 331.5                                           |
|                                            |                                | ...                  | 100           | ...                                      | 1.500                                       | 17.000                                       | 87.18                                       | 226.98                      | 1.5762                    | 3754.0                                                    | 296.37                                      | 98.35                                                | 5.236                                                     | 375.5                                           |
|                                            |                                | ...                  | 120           | ...                                      | 1.750                                       | 16.500                                       | 100.33                                      | 213.82                      | 1.4849                    | 4216.0                                                    | 341.09                                      | 92.66                                                | 5.236                                                     | 421.7                                           |
|                                            |                                | ...                  | 140           | ...                                      | 1.969                                       | 16.062                                       | 111.49                                      | 202.67                      | 1.4074                    | 4585.5                                                    | 379.17                                      | 87.74                                                | 5.236                                                     | 458.5                                           |
|                                            |                                | 22                   | 22.00         | ...                                      | ...                                         | 5S                                           | .188                                        | 21.624                      | 12.88                     | 367.25                                                    | 2.5503                                      | 766.2                                                | 43.80                                                     | 159.14                                          |
| ...                                        | ...                            |                      |               | 10S                                      | .218                                        | 21.564                                       | 14.92                                       | 365.21                      | 2.5362                    | 884.8                                                     | 50.71                                       | 158.26                                               | 5.760                                                     | 80.4                                            |
| ...                                        | 10                             |                      |               | ...                                      | .250                                        | 21.500                                       | 17.08                                       | 363.05                      | 2.5212                    | 1010.3                                                    | 58.07                                       | 157.32                                               | 5.760                                                     | 91.8                                            |
| ...                                        | 20                             |                      |               | ...                                      | .375                                        | 21.250                                       | 25.48                                       | 354.66                      | 2.4629                    | 1489.7                                                    | 86.61                                       | 153.68                                               | 5.760                                                     | 135.4                                           |
| STD                                        | ...                            |                      |               | ...                                      | .500                                        | 21.000                                       | 33.77                                       | 346.36                      | 2.4053                    | 1952.5                                                    | 114.81                                      | 150.09                                               | 5.760                                                     | 171.5                                           |
| XS                                         | 30                             |                      |               | ...                                      | .875                                        | 20.250                                       | 58.07                                       | 322.06                      | 2.2365                    | 3244.9                                                    | 197.41                                      | 139.56                                               | 5.760                                                     | 295.0                                           |
| ...                                        | 60                             |                      |               | ...                                      | 1.125                                       | 19.75                                        | 73.78                                       | 306.35                      | 2.1275                    | 4030.4                                                    | 250.81                                      | 132.76                                               | 5.760                                                     | 366.4                                           |
| ...                                        | 80                             |                      |               | ...                                      | 1.375                                       | 19.25                                        | 89.09                                       | 291.04                      | 2.0211                    | 4758.5                                                    | 302.88                                      | 126.12                                               | 5.760                                                     | 432.6                                           |
| ...                                        | 100                            |                      |               | ...                                      | 1.625                                       | 18.75                                        | 104.02                                      | 276.12                      | 1.9175                    | 5432.0                                                    | 353.61                                      | 119.65                                               | 5.760                                                     | 493.8                                           |
| ...                                        | 120                            |                      |               | ...                                      | 1.875                                       | 18.25                                        | 118.55                                      | 261.59                      | 1.8166                    | 6053.7                                                    | 403.00                                      | 113.36                                               | 5.760                                                     | 550.3                                           |
| ...                                        | 140                            |                      |               | ...                                      | 2.125                                       | 17.75                                        | 132.68                                      | 247.45                      | 1.7184                    | 6626.4                                                    | 451.06                                      | 107.23                                               | 5.760                                                     | 602.4                                           |
| ...                                        | 160                            |                      |               | ...                                      |                                             |                                              |                                             |                             |                           |                                                           |                                             |                                                      |                                                           |                                                 |

Identification, wall thickness and weights are extracted from ANSI B36.10 and B36.19. The notations STD, XS, and XXS indicate Standard, Extra Strong, and Double Extra Strong pipe respectively.

Transverse internal area values listed in "square feet" also represent volume in cubic feet per foot of pipe length.

## PIPE DATA—cont.

| Nom-<br>inal<br>Pipe<br>Size<br><br>Inches | Outside<br>Diam.<br><br>Inches | Identification       |               |                                          | Wall<br>Thick-<br>ness<br>(t)<br><br>Inches | Inside<br>Diam-<br>eter<br>(d)<br><br>Inches | Area<br>of<br>Metal<br><br>Square<br>Inches | Transverse                  |                           | Moment<br>of<br>Inertia<br>(I)<br><br>Inches <sup>4</sup> | Weight<br>Pipe<br><br>Pounds<br>per<br>foot | Weight<br>Water<br><br>Pounds<br>per foot<br>of pipe | External<br>Surface<br><br>Sq. Ft.<br>per foot<br>of pipe | Section<br>Modulus<br><br>$\left(\frac{I}{O.D.}\right)$ |
|--------------------------------------------|--------------------------------|----------------------|---------------|------------------------------------------|---------------------------------------------|----------------------------------------------|---------------------------------------------|-----------------------------|---------------------------|-----------------------------------------------------------|---------------------------------------------|------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------------------|
|                                            |                                | Steel                |               | Stain-<br>less<br>Steel<br>Sched.<br>No. |                                             |                                              |                                             | Internal Area               |                           |                                                           |                                             |                                                      |                                                           |                                                         |
|                                            |                                | Iron<br>Pipe<br>Size | Sched.<br>No. |                                          |                                             |                                              |                                             | (a)<br><br>Square<br>Inches | (A)<br><br>Square<br>Feet |                                                           |                                             |                                                      |                                                           |                                                         |
| 24                                         | 24.00                          | ...                  | ...           | 5S                                       | .218                                        | 23.564                                       | 16.29                                       | 436.10                      | 3.0285                    | 1151.6                                                    | 55.37                                       | 188.98                                               | 6.283                                                     | 96.0                                                    |
|                                            |                                | ...                  | 10            | 10S                                      | .250                                        | 23.500                                       | 18.65                                       | 433.74                      | 3.0121                    | 1315.4                                                    | 63.41                                       | 187.95                                               | 6.283                                                     | 109.6                                                   |
|                                            |                                | STD                  | 20            | ...                                      | .375                                        | 23.250                                       | 27.83                                       | 424.56                      | 2.9483                    | 1942.0                                                    | 94.62                                       | 183.95                                               | 6.283                                                     | 161.9                                                   |
|                                            |                                | XS                   | ...           | ...                                      | .500                                        | 23.000                                       | 36.91                                       | 415.48                      | 2.8853                    | 2549.5                                                    | 125.49                                      | 179.87                                               | 6.283                                                     | 212.5                                                   |
|                                            |                                | ...                  | 30            | ...                                      | .562                                        | 22.876                                       | 41.39                                       | 411.00                      | 2.8542                    | 2843.0                                                    | 140.68                                      | 178.09                                               | 6.283                                                     | 237.0                                                   |
|                                            |                                | ...                  | 40            | ...                                      | .688                                        | 22.624                                       | 50.31                                       | 402.07                      | 2.7921                    | 3421.3                                                    | 171.29                                      | 174.23                                               | 6.283                                                     | 285.1                                                   |
|                                            |                                | ...                  | 60            | ...                                      | .969                                        | 22.062                                       | 70.04                                       | 382.35                      | 2.6552                    | 4652.8                                                    | 238.35                                      | 165.52                                               | 6.283                                                     | 387.7                                                   |
|                                            |                                | ...                  | 80            | ...                                      | 1.219                                       | 21.562                                       | 87.17                                       | 365.22                      | 2.5362                    | 5672.0                                                    | 296.58                                      | 158.26                                               | 6.283                                                     | 472.8                                                   |
|                                            |                                | ...                  | 100           | ...                                      | 1.531                                       | 20.938                                       | 108.07                                      | 344.32                      | 2.3911                    | 6849.9                                                    | 367.39                                      | 149.06                                               | 6.283                                                     | 570.8                                                   |
|                                            |                                | ...                  | 120           | ...                                      | 1.812                                       | 20.376                                       | 126.31                                      | 326.08                      | 2.2645                    | 7825.0                                                    | 429.39                                      | 141.17                                               | 6.283                                                     | 652.1                                                   |
|                                            |                                | ...                  | 140           | ...                                      | 2.062                                       | 19.876                                       | 142.11                                      | 310.28                      | 2.1547                    | 8625.0                                                    | 483.12                                      | 134.45                                               | 6.283                                                     | 718.9                                                   |
|                                            |                                | ...                  | 160           | ...                                      | 2.344                                       | 19.312                                       | 159.41                                      | 292.98                      | 2.0346                    | 9455.9                                                    | 542.13                                      | 126.84                                               | 6.283                                                     | 787.9                                                   |
| 26                                         | 26.00                          | ...                  | 10            | ...                                      | .312                                        | 25.376                                       | 25.18                                       | 505.75                      | 3.5122                    | 2077.2                                                    | 85.60                                       | 219.16                                               | 6.806                                                     | 159.8                                                   |
|                                            |                                | STD                  | ...           | ...                                      | .375                                        | 25.250                                       | 30.19                                       | 500.74                      | 3.4774                    | 2478.4                                                    | 102.63                                      | 216.99                                               | 6.806                                                     | 190.6                                                   |
|                                            |                                | XS                   | 20            | ...                                      | .500                                        | 25.000                                       | 40.06                                       | 490.87                      | 3.4088                    | 3257.0                                                    | 136.17                                      | 212.71                                               | 6.806                                                     | 250.5                                                   |
| 28                                         | 28.00                          | ...                  | 10            | ...                                      | .312                                        | 27.376                                       | 27.14                                       | 588.61                      | 4.0876                    | 2601.0                                                    | 92.26                                       | 255.07                                               | 7.330                                                     | 185.8                                                   |
|                                            |                                | STD                  | ...           | ...                                      | .375                                        | 27.250                                       | 32.54                                       | 583.21                      | 4.0501                    | 3105.1                                                    | 110.64                                      | 252.73                                               | 7.330                                                     | 221.8                                                   |
|                                            |                                | XS                   | 20            | ...                                      | .500                                        | 27.000                                       | 43.20                                       | 572.56                      | 3.9761                    | 4084.8                                                    | 146.85                                      | 248.11                                               | 7.330                                                     | 291.8                                                   |
|                                            |                                | ...                  | 30            | ...                                      | .625                                        | 26.750                                       | 53.75                                       | 562.00                      | 3.9028                    | 5037.7                                                    | 182.73                                      | 243.53                                               | 7.330                                                     | 359.8                                                   |
| 30                                         | 30.00                          | ...                  | ...           | 5S                                       | .250                                        | 29.500                                       | 23.37                                       | 683.49                      | 4.7465                    | 2585.2                                                    | 79.43                                       | 296.18                                               | 7.854                                                     | 172.3                                                   |
|                                            |                                | ...                  | 10            | 10S                                      | .312                                        | 29.376                                       | 29.10                                       | 677.76                      | 4.7067                    | 3206.3                                                    | 98.93                                       | 293.70                                               | 7.854                                                     | 213.8                                                   |
|                                            |                                | STD                  | ...           | ...                                      | .375                                        | 29.250                                       | 34.90                                       | 671.96                      | 4.6664                    | 3829.4                                                    | 118.65                                      | 291.18                                               | 7.854                                                     | 255.3                                                   |
|                                            |                                | XS                   | 20            | ...                                      | .500                                        | 29.000                                       | 46.34                                       | 660.52                      | 4.5869                    | 5042.2                                                    | 157.53                                      | 286.22                                               | 7.854                                                     | 336.1                                                   |
|                                            |                                | ...                  | 30            | ...                                      | .625                                        | 28.750                                       | 57.68                                       | 649.18                      | 4.5082                    | 6224.0                                                    | 196.08                                      | 281.31                                               | 7.854                                                     | 414.9                                                   |
| 32                                         | 32.00                          | ...                  | 10            | ...                                      | .312                                        | 31.376                                       | 31.06                                       | 773.19                      | 5.3694                    | 3898.9                                                    | 105.59                                      | 335.05                                               | 8.378                                                     | 243.7                                                   |
|                                            |                                | STD                  | ...           | ...                                      | .375                                        | 31.250                                       | 37.26                                       | 766.99                      | 5.3263                    | 4658.5                                                    | 126.66                                      | 332.36                                               | 8.378                                                     | 291.2                                                   |
|                                            |                                | XS                   | 20            | ...                                      | .500                                        | 31.000                                       | 49.48                                       | 754.77                      | 5.2414                    | 6138.6                                                    | 168.21                                      | 327.06                                               | 8.378                                                     | 383.7                                                   |
|                                            |                                | ...                  | 30            | ...                                      | .625                                        | 30.750                                       | 61.60                                       | 742.64                      | 5.1572                    | 7583.4                                                    | 209.43                                      | 321.81                                               | 8.378                                                     | 474.0                                                   |
|                                            |                                | ...                  | 40            | ...                                      | .688                                        | 30.624                                       | 67.68                                       | 736.57                      | 5.1151                    | 8298.3                                                    | 230.08                                      | 319.18                                               | 8.378                                                     | 518.6                                                   |
| 34                                         | 34.00                          | ...                  | 10            | ...                                      | .344                                        | 33.312                                       | 36.37                                       | 871.55                      | 6.0524                    | 5150.5                                                    | 123.65                                      | 377.67                                               | 8.901                                                     | 303.0                                                   |
|                                            |                                | STD                  | ...           | ...                                      | .375                                        | 33.250                                       | 39.61                                       | 868.31                      | 6.0299                    | 5599.3                                                    | 134.67                                      | 376.27                                               | 8.901                                                     | 329.4                                                   |
|                                            |                                | XS                   | 20            | ...                                      | .500                                        | 33.000                                       | 52.62                                       | 855.30                      | 5.9396                    | 7383.5                                                    | 178.89                                      | 370.63                                               | 8.901                                                     | 434.3                                                   |
|                                            |                                | ...                  | 30            | ...                                      | .625                                        | 32.750                                       | 65.53                                       | 842.39                      | 5.8499                    | 9127.6                                                    | 222.78                                      | 365.03                                               | 8.901                                                     | 536.9                                                   |
|                                            |                                | ...                  | 40            | ...                                      | .688                                        | 32.624                                       | 72.00                                       | 835.92                      | 5.8050                    | 9991.6                                                    | 244.77                                      | 362.23                                               | 8.901                                                     | 587.7                                                   |
| 36                                         | 36.00                          | ...                  | 10            | ...                                      | .312                                        | 35.376                                       | 34.98                                       | 982.90                      | 6.8257                    | 5569.5                                                    | 118.92                                      | 425.92                                               | 9.425                                                     | 309.4                                                   |
|                                            |                                | STD                  | ...           | ...                                      | .375                                        | 35.250                                       | 41.97                                       | 975.91                      | 6.7771                    | 6658.9                                                    | 142.68                                      | 422.89                                               | 9.425                                                     | 369.9                                                   |
|                                            |                                | XS                   | 20            | ...                                      | .500                                        | 35.000                                       | 55.76                                       | 962.11                      | 6.6813                    | 8786.2                                                    | 189.57                                      | 416.91                                               | 9.425                                                     | 488.1                                                   |
|                                            |                                | ...                  | 30            | ...                                      | .625                                        | 34.750                                       | 69.46                                       | 948.42                      | 6.5862                    | 10868.4                                                   | 236.13                                      | 417.22                                               | 9.425                                                     | 603.8                                                   |
|                                            |                                | ...                  | 40            | ...                                      | .750                                        | 34.500                                       | 83.06                                       | 934.82                      | 6.4918                    | 12906.1                                                   | 282.35                                      | 405.09                                               | 9.425                                                     | 717.0                                                   |

Identification, wall thickness and weights are extracted from ANSI B36.10 and B36.19. The notations STD, XS, and XXS indicate Standard, Extra Strong, and Double Extra Strong pipe respectively.

Transverse internal area values listed in "square feet" also represent volume in cubic feet per foot of pipe length.

**LINE SIZING CRITERIA**  
**INDEX OF TYPE NUMBERS**

| <b><u>Type</u></b> | <b><u>Description</u></b>                                                   |
|--------------------|-----------------------------------------------------------------------------|
| 1.                 | Gravity flow                                                                |
| 2.                 | Pump suction                                                                |
| 3.                 | Pump discharge                                                              |
| 4.                 | Liquid to non-pumped reboiler                                               |
| 5.                 | Reboiler return to column                                                   |
| 6.                 | Column overhead vapor                                                       |
| 7.                 | Column hot vapor bypass                                                     |
| 8.                 | Column overhead condenser rundown                                           |
| 9.                 | Compressor suction                                                          |
| 10.                | Compressor discharge                                                        |
| 11.                | High available pressure drop (25 psi or more available for piping friction) |
| 12.                | Feed to a column                                                            |
| 13.                | Vacuum unit heater transfer                                                 |
| 14.                | Steam                                                                       |
| 15.                | Condensing steam turbine exhaust                                            |
| 16.                | Liquid at its bubble point to a control valve or steam trap                 |
| 17.                | Steam condensate after a control valve or steam trap                        |
| 18.                | Makeup gas to a hydrogen consuming process                                  |
| 19.                | Fuel gas to heaters                                                         |
| 20.                | Fuel oil to heaters                                                         |
| 21.                | Atomizing steam to heaters                                                  |
| 22.                | Instrument air piping                                                       |
| 23.                | Cooling water                                                               |
| 24.                | Static electricity consideration                                            |

**Type 1. Gravity Flow**

Criteria:  $\Delta P/100' \text{ (PSI)} = 0.20 \text{ max.}$

Remarks: Can be tighter if line is mostly vertical.

**Type 2. Pump Suction**

- a. Liquid at bubble point or less than 50°F below it.

Criteria: If not FCC main column bottoms or similar solids - carrying stream,  $\Delta P/100' \text{ (PSI)} = 0.20 \text{ max.}$

If FCC main column bottom or similar stream, velocity should be 180 FPM to avoid settling of solids. If  $\Delta P$  of 0.20 PSI/100' has been exceeded, use the largest size that will still give 180 FPM.

Remarks: For lines 3" and smaller, 180 FPM will result in  $\Delta P/100'$  in excess of 0.20 PSI which should be allowed for in determining NPSH availability.

- b. Liquid 50°F or more below bubble point.

Criteria:  $\Delta P/100' \text{ (PSI)} = 0.35 \text{ max.}$

Remarks: Watch viscosity for heavy cool liquids. Consider viscosity when it is 2.0 centistokes or more, at which point the actual pressure drop could be as much as 27% higher than that calculated using viscosity of 0.6 centistokes.

On the other hand, the goal of the design engineer's calculation is the determination of the suction vessel elevation before details of the system and equipment are known. The following considerations and estimates should be taken into account in the engineer's calculation:

1. Estimate the minimum pump NPSH requirements, in feet of liquid, by means of the attached chart (Page 9-61). This chart is based upon the approximate NPSH requirement that would permit a range of pump suppliers to be able to quote pumps that are economical in both first cost and efficiency. The estimated NPSH requirement should be based on the pump design capacity. The chart is limited to single stage pumps with maximum differential heads of 1400 feet at 60 HZ and 1000 feet at 50 HZ. A pump vendor should be consulted for the NPSH requirements of pumps to suit unusual cases or services beyond the range of the attached chart.

The equation used to produce the curves on the attached chart includes an additional 2 feet which will minimize cases where NPSH suppression testing is required. The suppression test is a shop NPSH performance test which incurs additional cost and adds to delivery time. For low design capacities, chart values for NPSHR should be used instead of equation values.

2. Estimate the elevation of the pump centerline above the base line. The attached chart (Page 9-61) presents average values for this distance based on pump capacity.
3. Estimate the friction loss, in feet of flowing liquid, in the suction piping between the vessel and the pump suction flange. The piping friction loss should be based on the pump design flow rate and on clean pipe friction factors. The calculated friction loss per hundred feet must be multiplied by

On the other hand, the goal of the design engineer's calculation is the determination of the suction vessel elevation before details of the system and equipment are known. The following considerations and estimates should be taken into account in the engineer's calculation:

1. Estimate the minimum pump NPSH requirements, in feet of liquid, by means of the attached chart (Page 9-61). This chart is based upon the approximate NPSH requirement that would permit a range of pump suppliers to be able to quote pumps that are economical in both first cost and efficiency. The estimated NPSH requirement should be based on the pump design capacity. The chart is limited to single stage pumps with maximum differential heads of 1400 feet at 60 HZ and 1000 feet at 50 HZ. A pump vendor should be consulted for the NPSH requirements of pumps to suit unusual cases or services beyond the range of the attached chart.

The equation used to produce the curves on the attached chart includes an additional 2 feet which will minimize cases where NPSH suppression testing is required. The suppression test is a shop NPSH performance test which incurs additional cost and adds to delivery time. For low design capacities, chart values for NPSHR should be used instead of equation values.

2. Estimate the elevation of the pump centerline above the base line. The attached chart (Page 9-61) presents average values for this distance based on pump capacity.
3. Estimate the friction loss, in feet of flowing liquid, in the suction piping between the vessel and the pump suction flange. The piping friction loss should be based on the pump design flow rate and on clean pipe friction factors. The calculated friction loss per hundred feet must be multiplied by

the estimated suction pipe equivalent length in hundreds of feet. For normal suction piping arrangements from process vessels, the equivalent length may be estimated by means of the following equations:

- a. For a single pump (with spare) service:

$$L = 50 + 500 D + 50 D^{1/2}$$

- b. For multiple pump services (with spares) with common suction piping or for a pump service with a piping split to a reboiler or other service:

From the suction vessel to the piping split:

$$L = 10 + 150 D + 20 D^{1/2}$$

From the piping split to pump suction:

$$L = 40 + 400 D + 40 D^{1/2}$$

D = pipe I.D. in ft.

L = estimated equivalent feet of suction pipe

The equations include an estimated length of straight piping and a term expressed as pipe diameters which accounts for a reasonable number of fittings, a full line size block valve, a full line size suction strainer in a clean condition and a split to a spare pump in each pump service. Also included is a size adjustment factor ( $D^{1/2}$ ) which will provide additional equivalent feet for larger pipe sizes. Keep in mind that the pump suction valve may be one size smaller than the suction line where the suction connection on the pump is two or three sizes smaller than the line. Since the pump suction connection

size is not known during the engineering work, the engineer must use judgment to decide if the smaller valve will add a significant additional pressure drop.

4. Investigate the system absolute pressure on the liquid in the suction vessel to determine if the minimum pressure under all operating conditions exceeds the vapor pressure of the liquid at pump suction temperature. Any additional system pressure above the vapor pressure can be considered as NPSH available. This situation is most likely to exist in liquid full systems or at pumps handling sub-cooled materials such as from storage tanks or surge drums or in systems containing a cooler in the pump suction piping.
5. Next, consider the elevation of the minimum liquid level above the bottom of a horizontal vessel or above the bottom tangent line of a vertical vessel. The minimum controlled liquid level should be used to set NPSH availability. The engineer should consider if it is ever likely to have an operation at full pumping rate with the liquid level below the minimum controlled level. In such cases, the NPSH availability should be taken from the lowest liquid level at which the pump will be expected to operate at full rate. It is not uncommon for the minimum controlled level to be at least one foot above the bottom tangent line.
6. Finally, the need for and amount of contingency must be evaluated. Consider the following conditions and rules when determining the amount of NPSH contingency to be provided:
  - a. A standard contingency factor of fifteen percent of the estimated pump NPSH requirement, with a minimum of two feet, should be added to the vessel elevation.

- b. Consider if accelerated clogging of the pump suction strainer will occur in normally dirty services where coke or other materials may accumulate. If accelerated clogging of the pump suction strainer is anticipated, an additional contingency equal to the head required to compensate for the pressure drop resulting from the equivalent of 250 pipe diameters of additional piping should be added.
- c. Consider additional piping loss if the suction piping has a tendency to become dirty or fouled in operation.
- d. Consider the possibility of greater pump capacity due to a larger impeller or motor.

The engineer's calculations should clearly record the amount and reasons for any contingency provided.

- 7. The suction vessel elevation necessary to satisfy the estimated pump NPSH requirements can now be determined by adding the feet of flowing liquid from items 1, 2, 3 and 6. From this total, deduct the feet of flowing liquid from items 4 and 5. The net result is then the minimum elevation above base line for the bottom of a horizontal suction vessel or the bottom tangent line of a vertical suction vessel to suit NPSH requirements. Mechanical and physical requirements, as indicated on Page 9-62, should also be considered before setting the final vessel elevation. See example problem on pages 9-63 through 9-65.

## B. Thermosyphon Reboiler Systems

The hydraulic design of a thermosyphon reboiler system requires very careful consideration since the driving force is derived only from the difference in densities between the inlet liquid and the mixed phase outlet. For a maximum vaporization of 30%, the engineer may use the following approximate method to arrive at a first trial line size:

For inlet piping:

$$12 < \frac{d^2}{Q} < 15, \text{ or } d = \sqrt{Q (12 \text{ to } 15)}$$

For outlet piping:

$$24 < \frac{d^2}{Q} < 30, \text{ or } d = \sqrt{Q (24 \text{ to } 30)}$$

Where:

$d$  = nominal pipe size in inches

$Q$  = reboiler duty in millions of BTU per hour

With these trial line sizes, the engineer can now proceed to a more accurate analysis of the system. The following pressure drops are all additive in determining the liquid driving head required.

$$1. \quad \text{Entrance loss (psi)} = \frac{0.5 V^2}{2g} \times \frac{\text{S.G.}}{2.31}$$

$V$  = velocity ft./sec.

S.G. = liquid specific gravity

$$2. \quad \text{Line loss to exchanger} = \frac{\text{psi}}{100 \text{ ft.}} \times \frac{\text{equivalent length}}{100}$$

$$3. \quad \text{Line loss to column} = \frac{\text{psi}}{100 \text{ ft.}} \times \frac{\text{equivalent length}}{100}$$

$$4. \quad \text{Exchanger loss} = \text{specified loss in psi}$$

$$5. \quad \text{Exit loss (psi)} = \frac{V^2}{2g} \times \frac{\text{S.G.}}{2.31}$$

$V$  = velocity ft./sec.

S.G. = composite specific gravity

6.     Static loss to column (psi) =  $H \times \frac{S.G.}{2.31}$

H = estimated vertical length of return line

S.G. = composite specific gravity

7.     Contingency estimated between ½ and 1 psi or equal to line loss.

The sum of the above pressure drops is now converted to the liquid head required.

$$\text{Head} = \frac{\text{Total psi} \times 2.31}{S.G.}$$

S.G. = liquid specific gravity

This head is now the required driving head in feet as determined from the minimum liquid level in the vessel to the centerline of the reboiler. This procedure can be used for vertical thermosyphon reboilers if the centerline of the exchanger is considered to be at the mid-point of the tube length.

### C. Heater Pressure Drops

Although the final heater pressure drops must be determined by the heater designer or heater vendor, the hydraulic engineer should have some approximation of heater pressure drops in order to proceed with his preliminary hydraulic survey. The following typical heater pressure drops may be used on a preliminary basis, to be confirmed or corrected as heater design information becomes available.

|                          |           |
|--------------------------|-----------|
| Crude Heaters            | 125 psi   |
| Vacuum Heaters           | 75 psi    |
| Hydrotreating Heaters    | 20-60 psi |
| Platforming (per heater) | 3-20 psi  |
| Thermal Crackers         | 200 psi   |
| Coker Heaters            | 300 psi   |
| Visbreakers              | 250 psi   |
| Hot Oil Heaters          | 20-40 psi |
| Fired Reboilers          | 50 psi    |
| Fractionator Charge      | 40 psi    |

#### **D. Heat Exchanger Pressure Drops**

Heat exchanger pressure drops vary from mm. of mercury to as much as 25 psi. Because the pressure drops vary so widely, there is no substitute for the good judgement of the engineer. For normal fluid exchangers, at least 5 psi per shell on each side should be allowed as minimum. Some additional guidelines are as follows:

|                                 |                  |
|---------------------------------|------------------|
| Cooling water side              | 10 psi           |
| Combined feed exchangers        | 2-5 psi per side |
| Condensers                      | 1-5 psi          |
| Reboilers-Kettle & Thermosyphon | 0.2-0.5 psi      |
| Reboilers-forced circulation    | 5-10 psi         |
| Vacuum condensers               | 10-25 mm mercury |

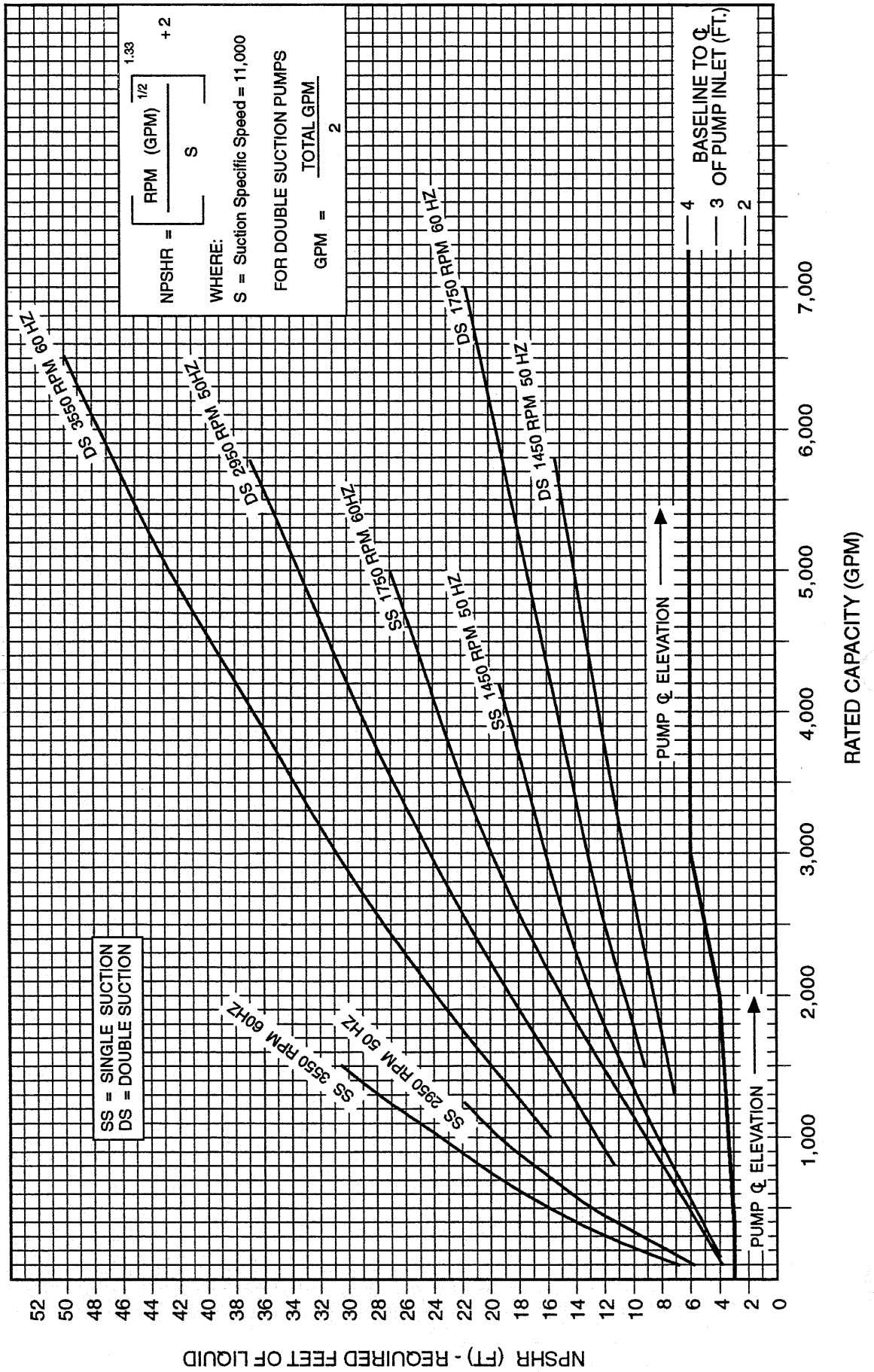
#### **E. Control Valve Pressure Drops**

Control valve pressure drops must be considered during the hydraulic analysis of a system. However, the amount of pressure drop to be considered requires experience and judgement. In order to provide some guidance in this area, consider that control valves in pump discharge circuits should be allowed the maximum of the following pressure drops:

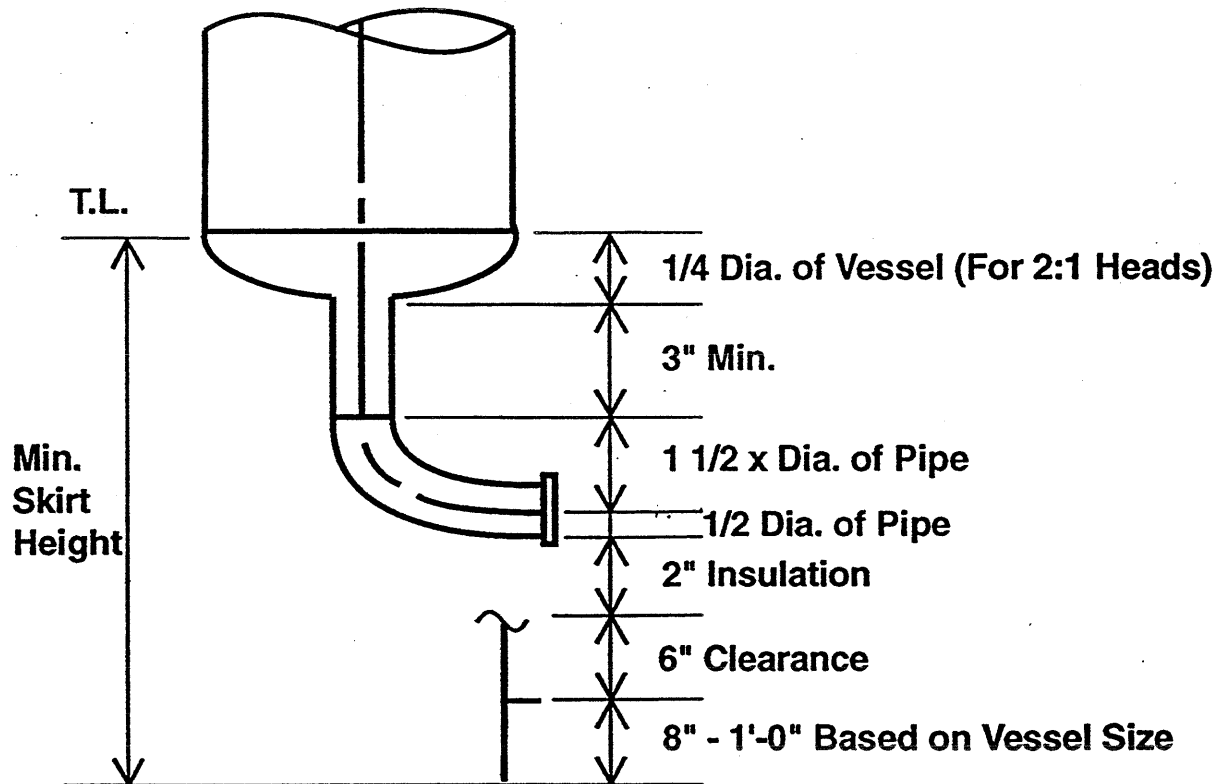
- 25 psi minimum
- 50% of system friction pressure drop
- 7-10% of pump differential

Most other control valves should be allowed pressure drop in accordance with the available pressure. Provision of control valve pressure drop should be sufficient to compensate for changes in operating conditions, fluid properties and system aging.

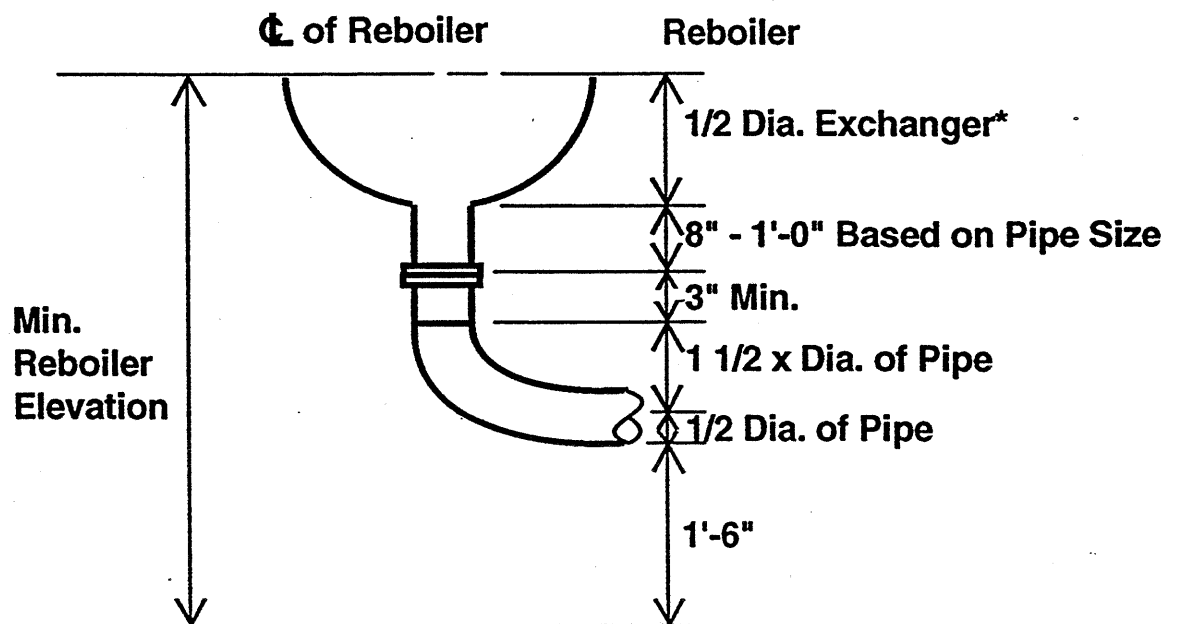
# SINGLE STAGE CENTRIFUGAL PUMPS MINIMUM REQUIRED NPSH



## Minimum Column Elevation

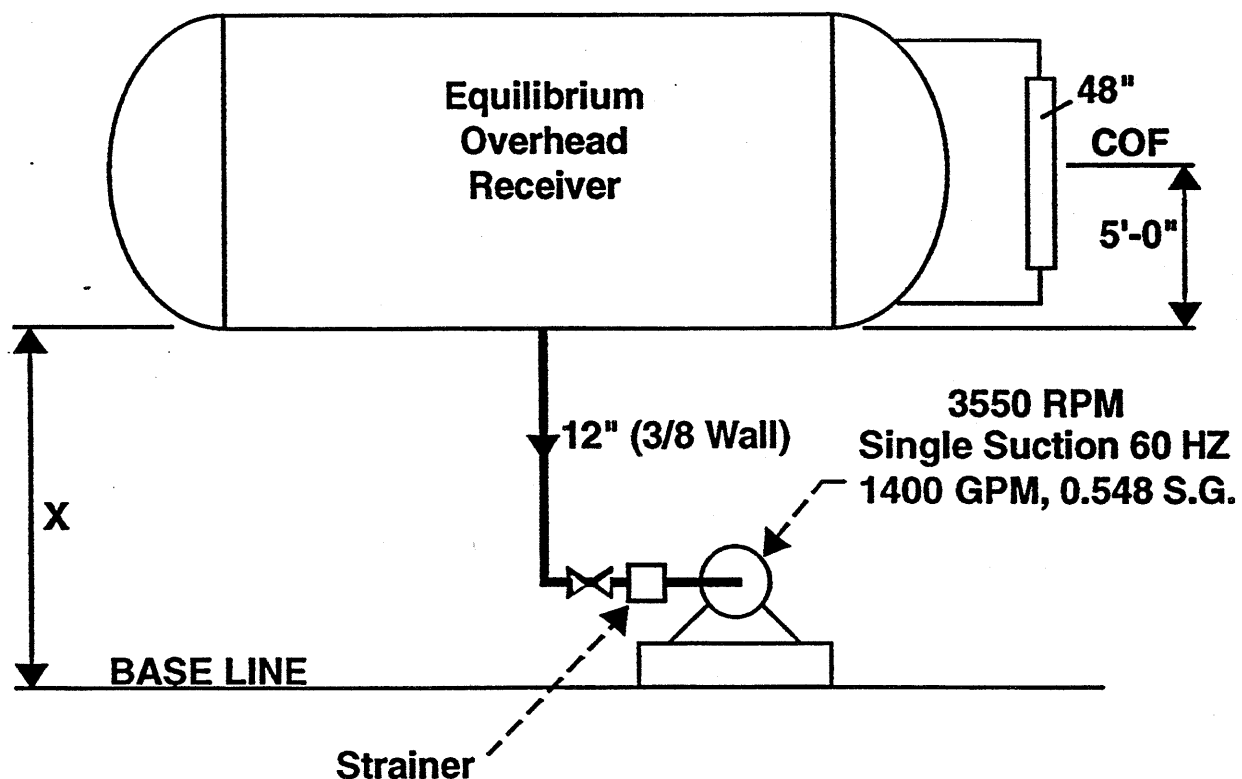


## Minimum Reboiler Elevation



\* For Kettle Type This Dimension Should Be from Top of Wier to Bottom of Reboiler.

# Pump NPSH Calculation



$$X = h_{NPSH} + h_{CL} + h_{PFL} - h_p - h_{MLL} + h_{CONT}$$

**EXAMPLE PROBLEM**  
**PUMP NPSH CALCULATION**

1. Estimate NPSH required

Pump rate 1400 GPM, 0.548 S.G. Head less than 1500 feet

From curve (SS 3550 RPM 60 Hz) minimum required NPSH = (+) 29.5 feet

2. Estimate pump centerline elevation from chart

Centerline elevation above base line = (+) 2.8 feet

3. Estimate piping friction loss

$\Delta P/100'$  for 12"-3/8" wall pipe =  $0.168 \times 0.548 = 0.09$  psi

Estimated equivalent length =  $50 + 500 \left( \frac{12}{12} \right) + 50 \left( \frac{12}{12} \right)^{1/2} = 600$  ft.

Piping friction loss =  $\frac{600}{100} \times 0.09 \times \frac{2.31 \text{ ft. water/psi}}{0.548 \text{ S.G.}} = 2.3$  ft.

Check for smaller suction valve

$\Delta P/100'$  for 10" sch 40 pipe =  $0.4 \times 0.548 = 0.22$  psi

Fully open gate valve is equivalent to 13 pipe diameters

$\Delta P$  (10" valve) =  $\frac{13 \times 10.02}{100 \times 12} \times 0.22 \times \frac{2.31}{0.548} = 0.1$  ft.

Total suction piping system friction loss = (+) 2.4 feet

4. Check system absolute pressure

Equilibrium system absolute pressure equals vapor pressure

Additional equivalent liquid head available = (-) 0.0 feet

5. Consider minimum controlled liquid level

Center of 48" float is 5'-0" above bottom of vessel

Minimum controlled level is 3'-0" above bottom of vessel

Pump will not be operated below control range

Liquid available for NPSH = (-) 3.0 feet

6. Provide for contingency

System is clean, use standard contingency

Total contingency to be provided =  $0.15 \times 29.5 =$  (+) 4.4 feet

Minimum elevation of vessel above base line = 36.1 feet

A DS 3550 RPM, 60 Hz pump would have reduced the required elevation by approximately 10 feet.

## Liquid Line $\Delta P$ Problems

Flowing GPM = 500  
Viscosity (centistokes) = 0.6  
Flowing Sp. Gr. = 0.75

A. Find  $\Delta P/100'$  in 6" Sch 80 Pipe

*0.92 x 0.75 = 0.69 psi/100'*

B. Find  $\Delta P/100'$  in 8" Sch 40 Pipe

C. Find Velocity in 8" Sch 40 Pipe

D. Find Corrected  $\Delta P/100'$  in 6" Sch 80 Pipe if  $\mu = 50$  centistokes

E. What size pipe would result in a  $\Delta P/100' = 0.28$  if flow is 4000 GPM, Sp. Gr. = 0.80 and  $\mu = 0.6$  CTSTK?

## **Vapor Line $\Delta P$ Problems**

**Flowing Quantity = 40,000 Lb/Hr  
Specific Volume = 0.9 Cu.Ft./Lb**

**A. Find  $\Delta P/100'$  in 6" Sch 80 Pipe**

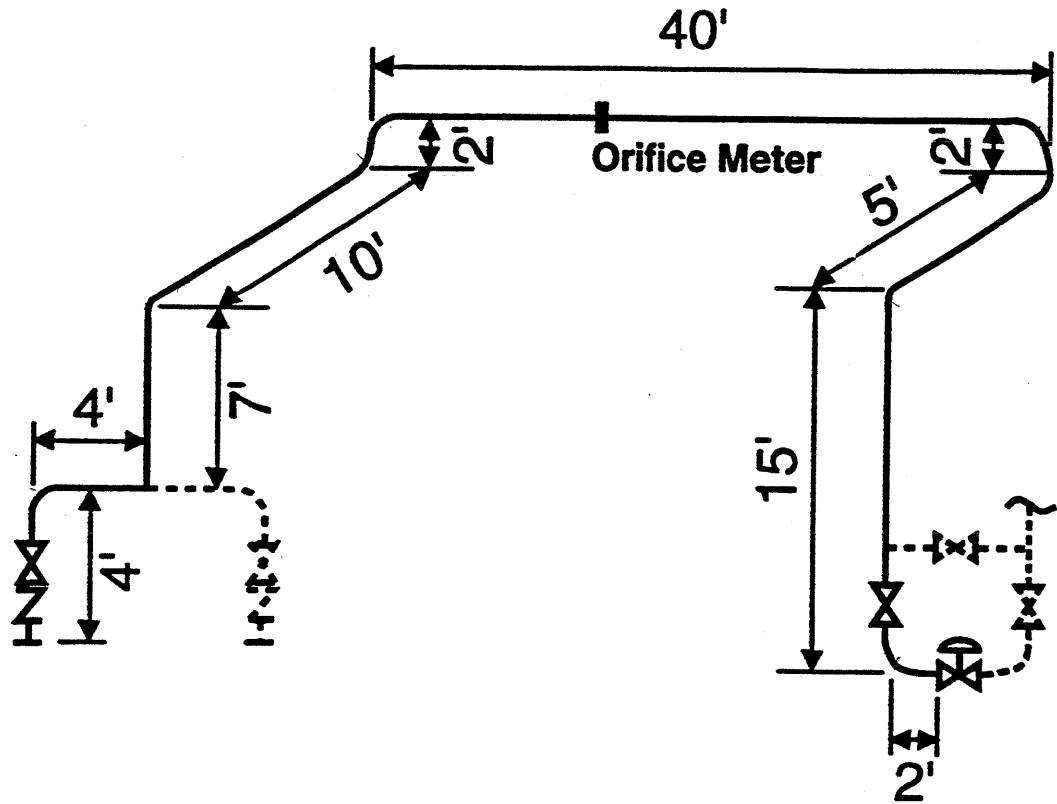
**B. Find  $\Delta P/100'$  in 8" Sch 40 Pipe**

**C. Find Velocity in 8" Sch 40 Pipe**

**D. What size pipe would result in a  $\Delta P/100'$  equal to or less than 0.4 PSI if flow is 100,000 Lb/Hr and density is 2 Lb/Cu.Ft.?**

**What is Velocity in line?**

# Typical Calculation Of Piping Equivalent Length. 8" Pump Discharge Line



## **Two Phase Line Sizing**

**Find the Schedule 80 pipe size that will result in a pressure drop of approximately 0.5 PSI/100' as a result of a two phase flow having the following components:**

**Liquid flow:**

**500 GPM**

**Sp. Gr. 0.75**

**Vapor flow:**

**40,000 Lb/Hr**

**Sp. Vol. 0.9 Ft<sup>3</sup>/Lb**

## HYDRAULICS

### E. EXAMPLES

#### FRACTIONATOR

##### BASIS:

##### SET NORMAL OPERATING PROFILE

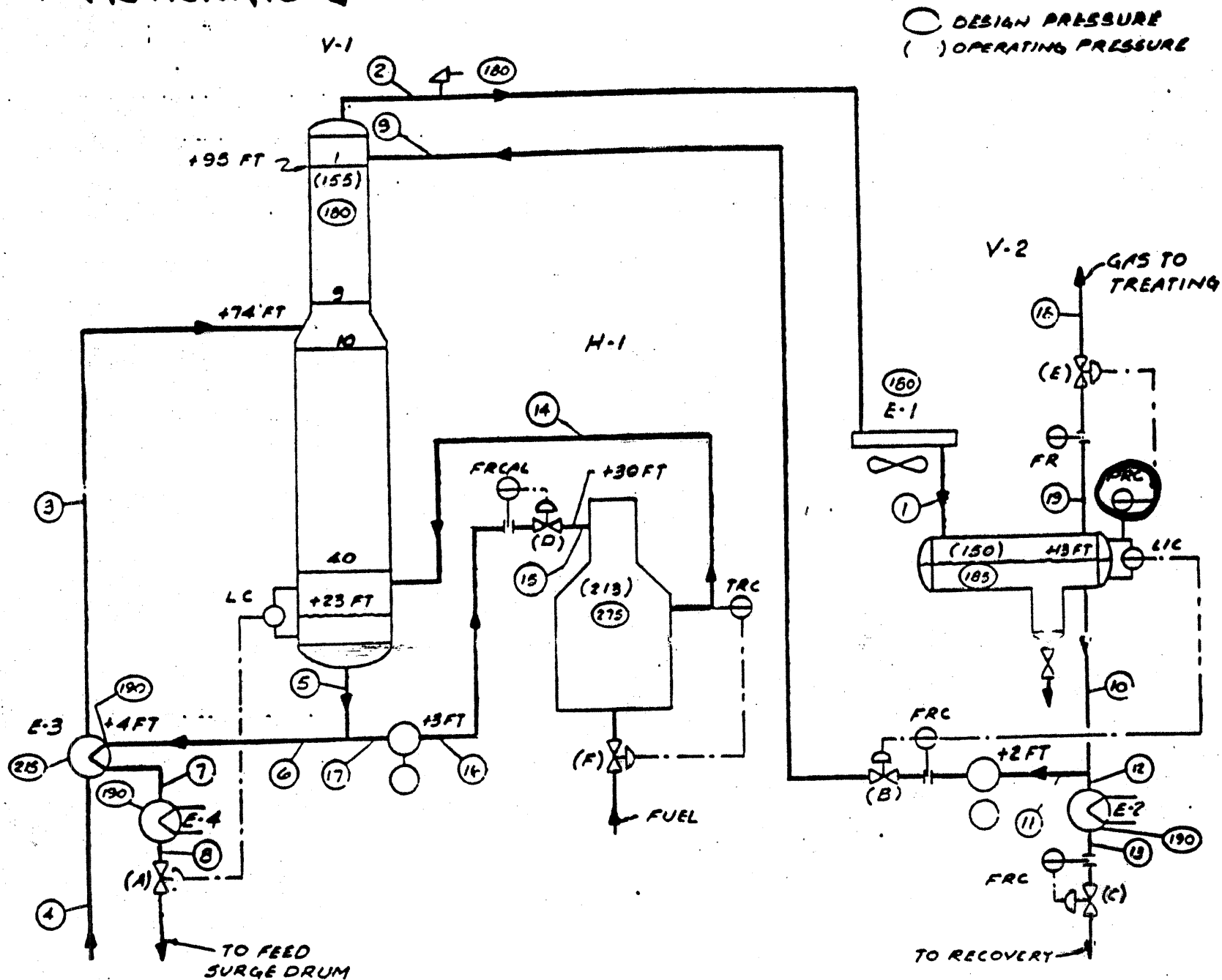
- DETERMINE FIXED PRESSURE POINTS
- ESTABLISH LINE SIZE /  $\Delta P$  EACH SEGMENT
- ESTABLISH EQUIP  $\Delta P$  (SAME AS PROT SPEC)

##### DETERMINE RELIEVING/DESIGN PROFILE

- DETERMINE RV LOCATION
- ESTABLISH RV SET PSI
- DETERMINE EQUIP P AT RV SET PSI
- SET DESIGN P

CHECK ANY OVERCAPACITY OF EQUIPMENT  
OR ALTERNATE

# FRACTIONATOR



# FRACTIONATOR

五

# HYDRAULICS

## FRACTIONATOR

| LINE NO.<br>(C.V. NO.) | SIZE IN. | SCHEDULE | $\Delta P/100$ FT.<br>PSI | ESTIM. EQ.<br>FT. x 100 | DESCRIPTION                  | NORMAL            |                         | $\Delta P$<br>PSI | INLET<br>PRESS.<br>PSIG | $\Delta P$<br>PSI | INLET<br>PRESS.<br>PSIG | $\Delta P$<br>PSI | INLET<br>PRESS.<br>PSIG | DESIGN<br>PRESS.<br>PSIG |
|------------------------|----------|----------|---------------------------|-------------------------|------------------------------|-------------------|-------------------------|-------------------|-------------------------|-------------------|-------------------------|-------------------|-------------------------|--------------------------|
|                        |          |          |                           |                         |                              | $\Delta P$<br>PSI | INLET<br>PRESS.<br>PSIG |                   |                         |                   |                         |                   |                         |                          |
|                        |          |          |                           |                         | AT NORM. L-L Bott V-1        |                   | 158.8                   |                   |                         |                   |                         |                   |                         |                          |
| ②                      | 10       | 40       | .15                       | 1.3                     |                              | 0.2               | 158.8                   |                   |                         |                   |                         |                   |                         |                          |
|                        |          |          |                           |                         | STATIC HD. (19 x .433 x 0.69 | 5.7               | 158.6                   |                   |                         |                   |                         |                   |                         |                          |
| ⑥                      | 4        | 40       | 1.0                       | 2                       |                              | 2                 | 164.3                   |                   |                         |                   |                         |                   |                         |                          |
|                        |          |          |                           |                         | EXCH. E-3 (HOT SIDE)         | 10.0              | 162.3                   |                   |                         |                   |                         |                   |                         | 190                      |
| ⑦                      | 4        | 40       | 0.9                       | 2                       |                              | 1.8               | 152.3                   |                   |                         |                   |                         |                   |                         |                          |
|                        |          |          |                           |                         | EXCH E-4 (HOT SIDE)          | 5.0               | 150.5                   |                   |                         |                   |                         |                   |                         | 190                      |
| ⑧                      | 4        | 40       | 0.9                       | 2                       |                              | 1.8               | 145.5                   |                   |                         |                   |                         |                   |                         |                          |
| (A)                    |          |          |                           |                         | CONTROL VALVE                | 23.7              | 143.7                   |                   |                         |                   |                         |                   |                         |                          |
|                        |          |          |                           |                         | NET BOTS. V-1 Bott. LIMITS   |                   | 110.0                   |                   |                         |                   |                         |                   |                         |                          |
|                        |          |          |                           |                         |                              |                   |                         |                   |                         |                   |                         |                   |                         |                          |
|                        |          |          |                           |                         |                              |                   |                         |                   |                         |                   |                         |                   |                         |                          |

## GENERAL LINE SIZING COMMENTS

When faced with the time limitations of production engineering, the design engineer must have available to him various guidelines and rules of thumb to reduce the time consumed in line sizing. Although optimization of line sizing should not be ignored, the available increments of pipe size normally encountered make the expenditure of an extensive amount of time involved in line size optimization very questionable. UOP employs a computer program with built-in optimization procedures to assist the design engineer in the performance of his line sizing job. However, for this discussion, we will approach line sizing without the aid of the computer and rely upon good judgement and experience to reduce the time required and still provide a reasonable approach to optimization.

Following are some general comments to keep in mind as we proceed through this discussion:

- A. Line sizing will be based on "normal" flow rates and "normal" pressures as developed by the process design. However, the engineer should keep in mind the effect of "design" flow rates, maximum flow rates and start-up, shutdown and upset conditions that may have a significant influence on the plant pressure profile. It is generally helpful to develop a simple sketch of the plant or system piping arrangement to indicate the normal pressure profile and to record the results of investigations of alternate considerations. The sketch also provides a good means to visualize the possible effect of static head on pressure considerations used in line sizing.
- B. The principle criterion for line size selection will be pressure drop, expressed as pounds per square inch (PSI) per 100 equivalent feet of pipe. Velocity, expressed in feet per minute, will also be an important factor.

- C. Additional properties used in our line sizing procedures will be specific gravity, vapor density and vapor specific volume. Specific gravity will normally refer to a liquid and is a dimensionless number determined as the ratio of the density of the liquid at flowing temperature to the density of water at the temperature of its maximum density. Vapor density will be expressed in pounds per cubic foot. Vapor specific volume will be expressed as cubic feet per pound.
- D. In certain line sizing problems, such as vacuum heater transfer lines and pressure relief piping, limitations due to sonic velocity must be observed. In a pipe of constant diameter, a compressible fluid cannot move faster than the speed of sound in that fluid. This speed, for a typical  $C_p/C_v$  of 1.1, is equal to:

$$14,000 \sqrt{\frac{\text{Temperature } ^\circ\text{R}}{\text{Molecular Weight}}}$$

Sonic velocity is expressed in feet per minute and is proportional to  $\sqrt{C_p/C_v}$ . The sonic velocity limitation can be easily overlooked, resulting in a calculated pressure drop lower than that which actually exists. When sonic velocity is exceeded in a pipe, the downstream pressure in the pipe will build up until the increased density permits the flow to be exactly at sonic velocity. This built-up downstream pressure would then be used in a total pressure drop calculation rather than some lower pressure in a vessel connected to the pipe.

- E. If the specific volume of the vapor in a line changes significantly due to line pressure drop, certain corrections should be made in the pressure drop calculation. As a general rule, if the pressure drop for a known length of line is less than 10% of the upstream absolute pressure, either the upstream or downstream specific volume can be used in the pressure drop calculation. If the total pressure drop is between 10

and 40% of the upstream pressure, use the average specific volume. If the total pressure drop is greater than 40% of the upstream pressure, divide the line into sections for calculation purposes.

- F. For strength considerations, good practice limits the minimum permissible line size to 1" nominal for pipe rack runs and pipe spans between supports. In order to reduce purchasing and detailing problems and to minimize inventory requirements, pipe sizes such as 1¼, 2½, 3½ and 5 inch will normally be avoided. Schedule 80 minimum is recommended for 2 inch and smaller pipe size.
- G. Pipe sizes have a constant outside diameter. Therefore, as the wall thickness increases, the flowing area will be reduced. The engineer should keep this point in mind when working in piping systems at high pressure or when high corrosion allowances are required.
- H. When considering the wall thickness for pressure requirements or corrosion allowance, remember that the wall thickness tolerance is  $\pm 12\frac{1}{2}\%$  thru 24" seamless pipe size. The wall thickness tolerance is normally reduced to  $\pm 0.01$  inch for welded pipe and sizes greater than 24" when fabricated from rolled plate.
- I. Although most of the information contained in this discussion is directed toward new piping, the engineer should keep in mind that the economics and decision factors involved in revamps are different. Consequently, smaller line sizes can often be used on revamps compared to new construction.

- J. Chart PD 435-C (Page 9-6) is used to determine the sizing of lines for liquid flow. The engineer enters the chart with the appropriate flowing GPM at the bottom and proceeds upward, selecting the proper line size to suit the pressure drop or velocity criteria which will be discussed later. Note that for the smaller line sizes, this chart indicates separate lines for different pipe schedules or wall thicknesses. The indicated chart  $\Delta P$  should be multiplied by the flowing specific gravity to determine actual  $\Delta P$ . Chart PD 435-C is based on a liquid having a kinematic viscosity of 0.6 centistoke. For more viscous materials, the chart  $\Delta P$  should be multiplied by the

correction factor  $\left( \frac{\mu}{0.6} \right)^{0.2}$  where  $\mu$  is in centistokes.

For example, a flowing liquid having a viscosity of 20 centistokes will have a line pressure drop approximately twice as great as would be indicated by the chart. This factor applies for turbulent flow (Reynolds number greater than 2000) only. See example problem on page 9-21.

- K. Charts PD 436, PD 437 and PD 438 ( Pages 9-7, 9-8 and 9-9) are used to determine the sizing of lines for vapor flow. These charts are used in much the same manner as PD 435-C above. The chart  $\Delta P$  should be multiplied by the specific volume to determine actual  $\Delta P$  and the chart velocity should be multiplied by specific volume to determine actual velocity. See example problem on page 9-22.
- L. For pressure drop calculations involving two-phase flow, chart PD 395A (Page 9-10) is used. This chart is based on a method developed for horizontal flow. However, practically all of the two-phase flow applications encountered in process piping for refinery units are in the relatively high velocity flow regimes of annular, spray or froth flow. Therefore, it is felt that frictional pressure drops and type of flow regime are not much affected by pipe orientation at these velocities. See example problem on pages 9-23 and 9-24.

M. When designing two phase upflow lines, such as column feeds, reboiler returns and condenser rundowns, the flowing velocity should be kept high enough to prevent slug flow. Annular or mist flow is usually assured if the velocity in ft/sec is approximately equal to 60 divided by the square root of the mixed phase density in lbs/ft<sup>3</sup>. The chart "Approximate Two-Phase Flow Patterns" (Page 9-11) may also be used to determine the approximate flow condition.

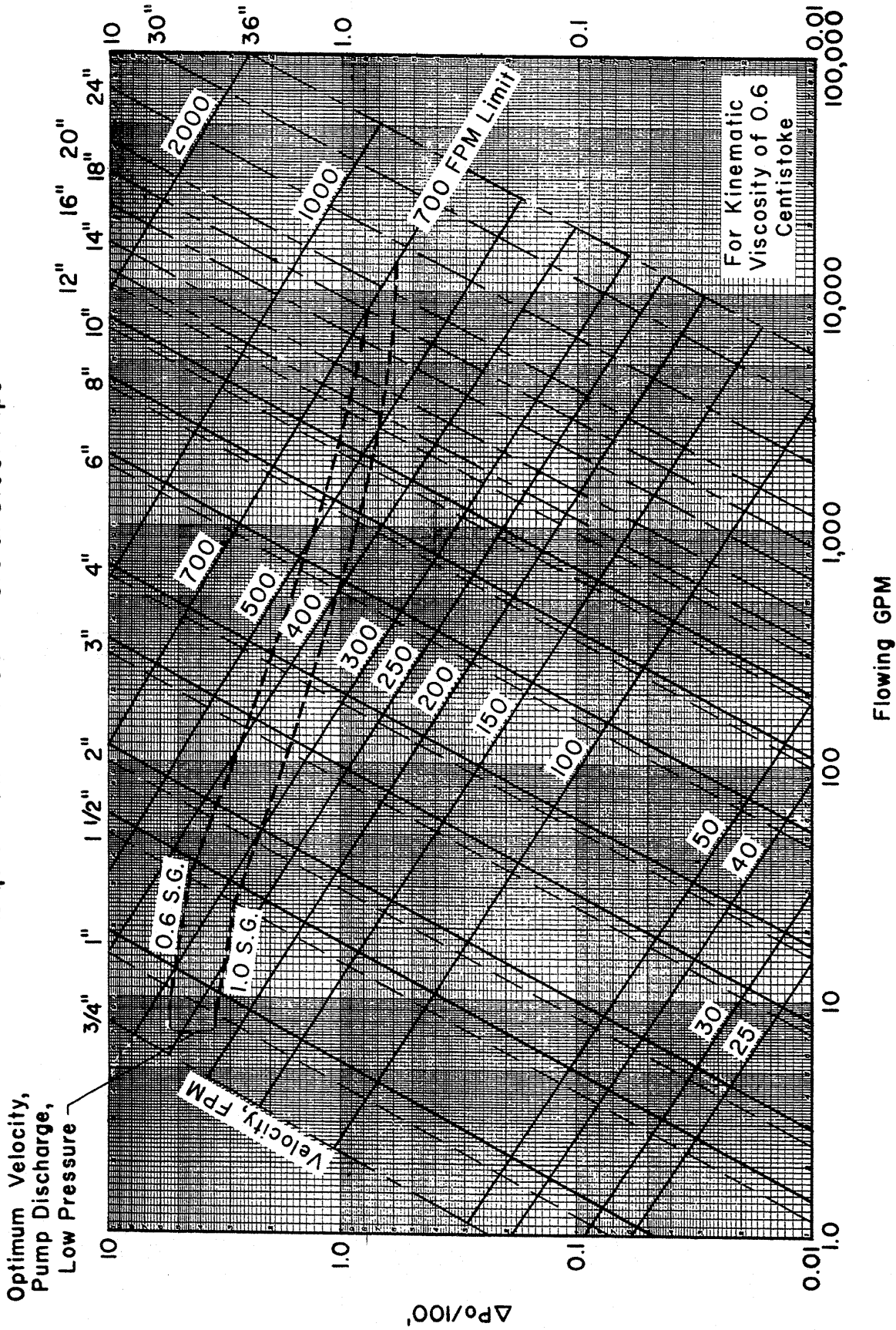
N. At UOP, the engineers use hydraulic tabulation forms to assist in their line sizing work. These forms simplify the work of the engineer and provide a convenient means to communicate the hydraulic information to specialty equipment engineers. Three examples are as follows:

1. Page 9-12 is a form used for single phase line sizing, vapor or liquid, and for pump and control valve information. The form is used in conjunction with charts PD 435-C, PD 436, PD 437 and PD 438.
2. Page 9-13 is a form used for two phase line sizing and is used in conjunction with chart PD 395-A. This form provides a convenient means for tabulating the two phase flow line sizing data.
3. Page 9-14 is an additional form which defines the two phase sizing procedure in equation form. Some engineers may prefer to use this method to record their line sizing calculations.

$$V_c = \frac{60}{\sqrt{\rho_{mix}}}$$
  
$$V_{mix} = \frac{60}{\sqrt{\rho_{mix}}} = 27.3 \text{ ft/sec}$$
  
$$V_{10} = \frac{60}{\sqrt{\rho_{mix}}} = 27.3 \text{ ft/sec}$$

9-5

# Liquid Flow Thru Commercial Steel Pipe



- Sch. 80
- Sch. 40
- 3/8" Wall

Note:

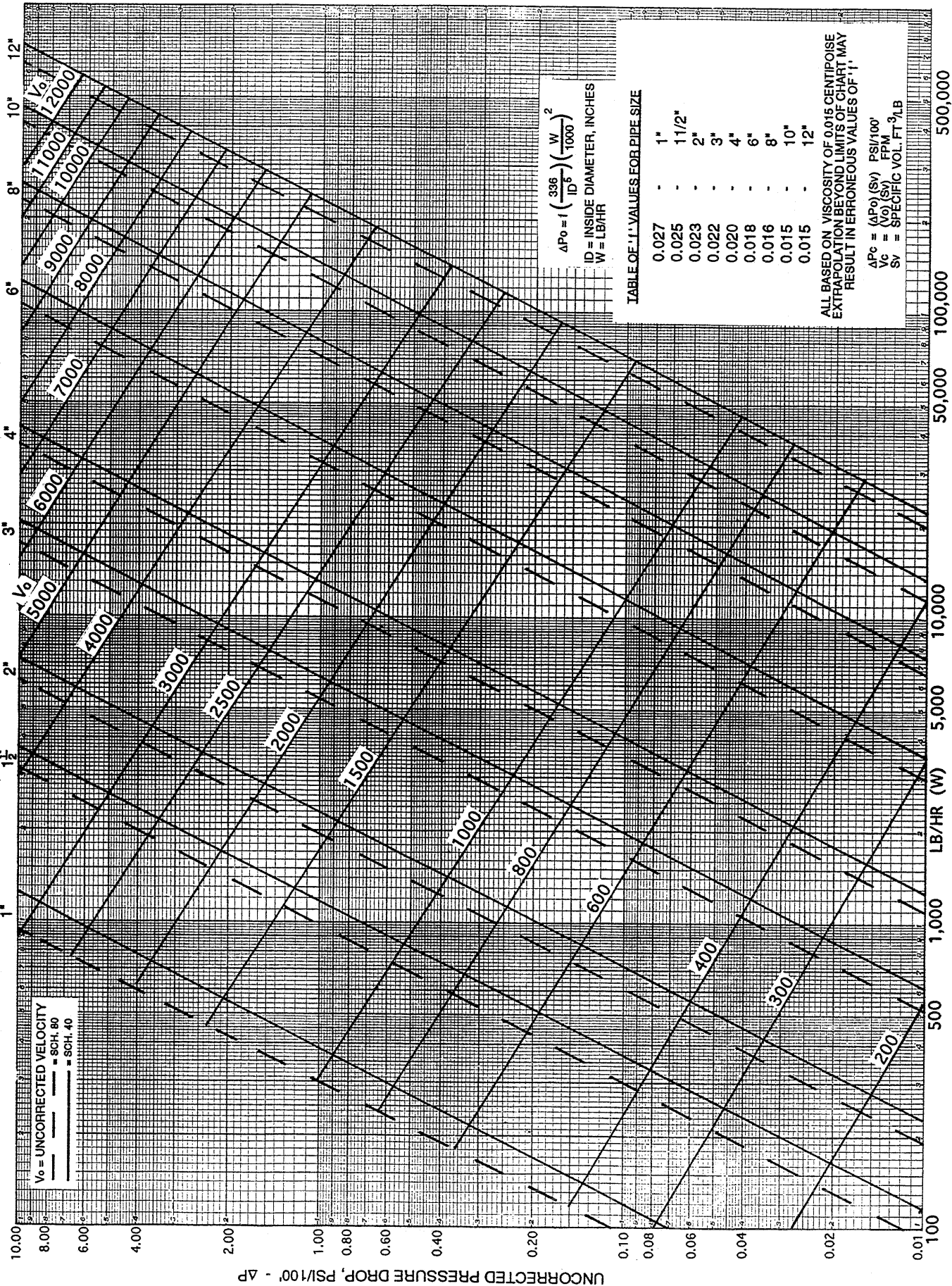
To Find ΔP in PSI per 100 ft. of Pipe,  
Multiply ΔPo/100' by Specific Gravity.

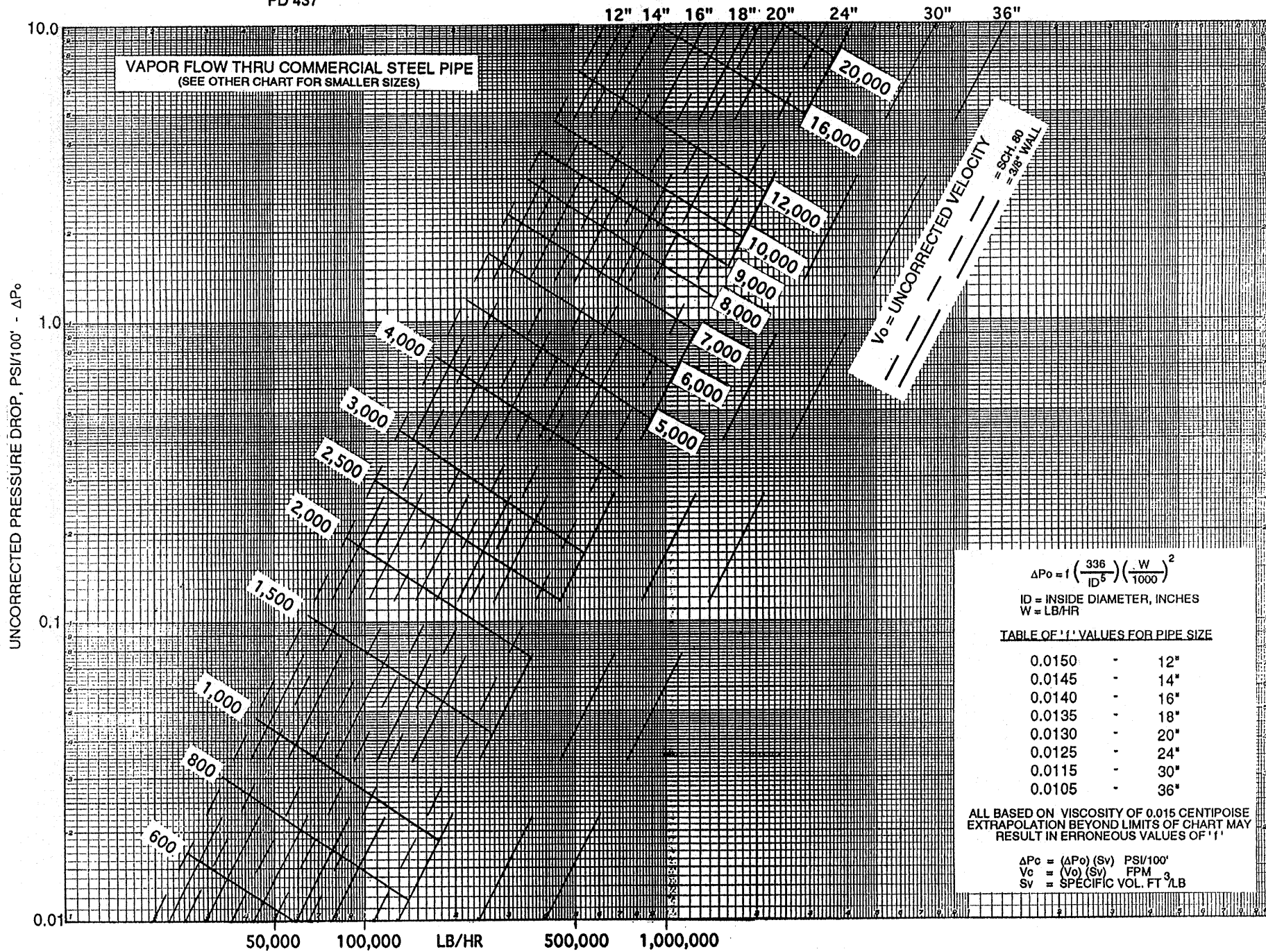
5-3-78 REJ

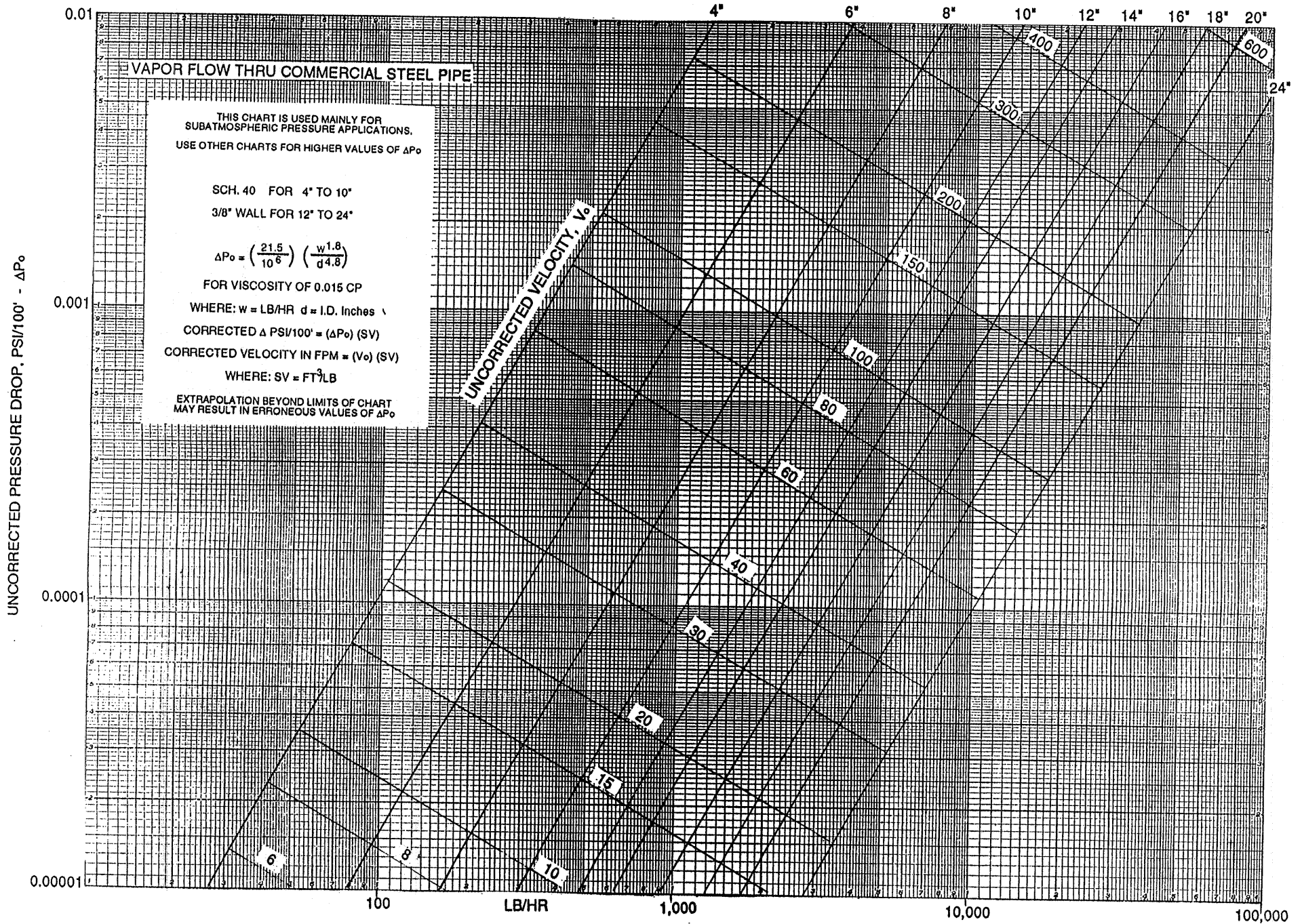
PD 435-C  
(Supersedes PD 435-B)

# VAPOR FLOW THRU COMMERCIAL STEEL PIPE

PD 436

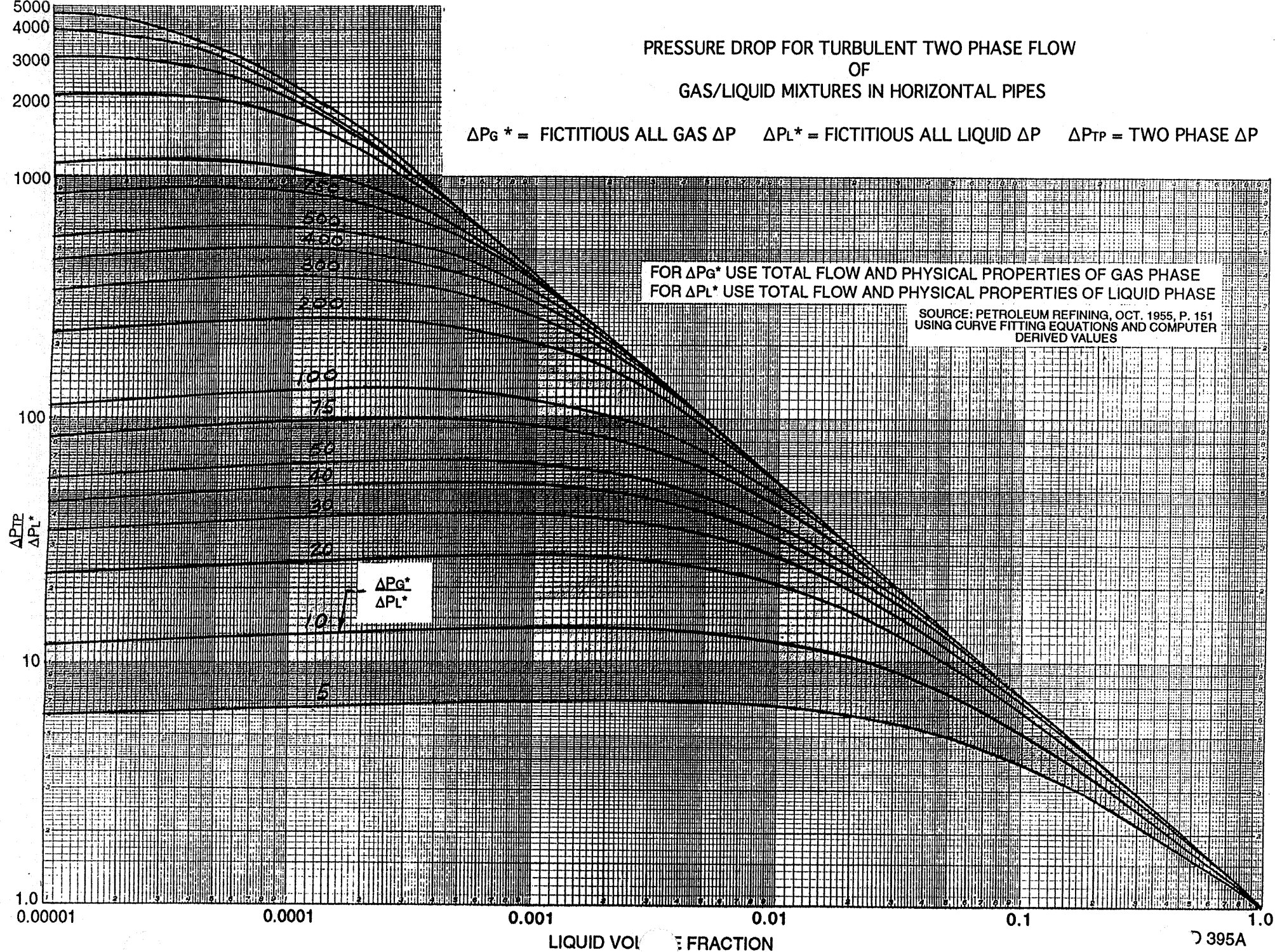




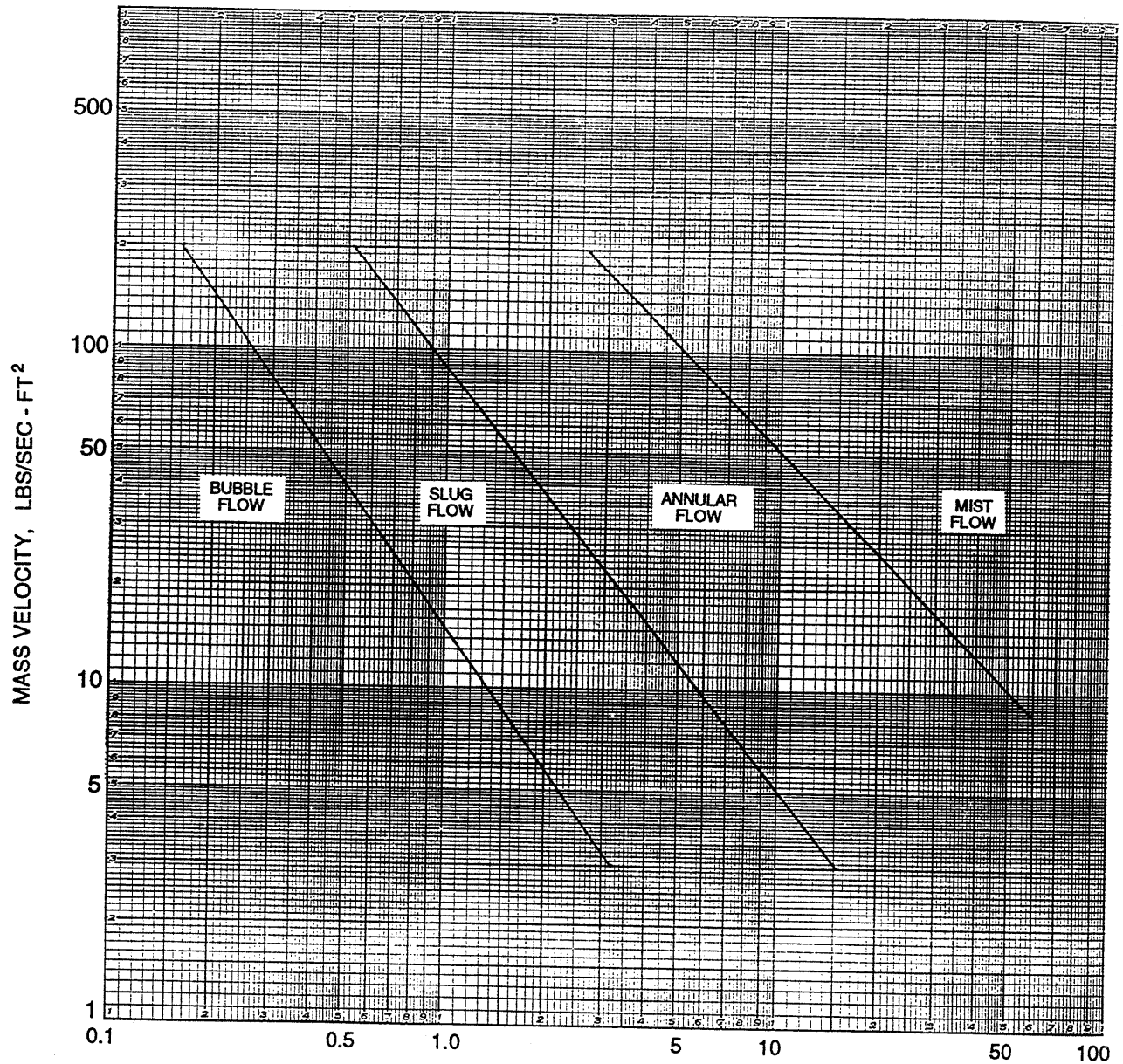


# PRESSURE DROP FOR TURBULENT TWO PHASE FLOW OF GAS/LIQUID MIXTURES IN HORIZONTAL PIPES

$\Delta P_G^* =$  FICTITIOUS ALL GAS  $\Delta P$      $\Delta P_L^* =$  FICTITIOUS ALL LIQUID  $\Delta P$      $\Delta P_{TP} =$  TWO PHASE  $\Delta P$

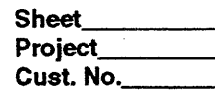


# APPROXIMATE TWO - PHASE FLOW PATTERNS (VERTICAL UPFLOW)



$$\frac{1}{\left(\frac{W_L}{W_g}\right)^{0.9} \left(\frac{\rho_g}{\rho_L}\right)^{0.5} \left(\frac{\mu_L}{\mu_g}\right)^{0.1}}$$

W = Lbs./Sec.  
 ρ = Lbs./Ft.<sup>3</sup>  
 μ = Centipoise



Sheet \_\_\_\_\_  
Project \_\_\_\_\_  
Cust. No. \_\_\_\_\_

[illegible]

| uop                                                               |  |                                                       |  | WORKSHEET                                                           |  |
|-------------------------------------------------------------------|--|-------------------------------------------------------|--|---------------------------------------------------------------------|--|
| HYDRAULIC TABULATION                                              |  |                                                       |  | PROJECT NO. _____<br>SHEET _____ OF _____<br>BY _____<br>DATE _____ |  |
| VAPOR AND LIQUID<br>LINE<br>(TWO PHASE FLOW)                      |  |                                                       |  |                                                                     |  |
| ① LIQUID FLOW USGPM                                               |  |                                                       |  |                                                                     |  |
| ② LIQUID FLOW SP. GR.                                             |  |                                                       |  |                                                                     |  |
| ③ LIQUID FLOW LB./HR. x 10 <sup>3</sup>                           |  |                                                       |  |                                                                     |  |
| ④ VAPOR FLOW LB./HR. x 10 <sup>3</sup>                            |  |                                                       |  |                                                                     |  |
| ⑤ TOTAL LB./HR. x 10 <sup>3</sup>                                 |  |                                                       |  |                                                                     |  |
| ⑥ VAPOR SP. VOL. CU. FT./LB.                                      |  |                                                       |  |                                                                     |  |
| ⑦ LIQUID VOLUME CFS = $\frac{\text{GPM}}{448}$                    |  |                                                       |  |                                                                     |  |
| ⑧ VAPOR VOLUME CFS                                                |  |                                                       |  |                                                                     |  |
| ⑨ TOTAL VOLUME CFS                                                |  |                                                       |  |                                                                     |  |
| ⑩ VOL. L/TOTAL VOL. = LVF                                         |  |                                                       |  |                                                                     |  |
| ⑪                                                                 |  |                                                       |  |                                                                     |  |
| ⑫ LINE SIZE, INCHES                                               |  |                                                       |  |                                                                     |  |
| ⑬ PIPE SCHEDULE                                                   |  |                                                       |  |                                                                     |  |
| ⑭ IF ALL LIQUID USGPM                                             |  | ① x ⑤ / ③                                             |  |                                                                     |  |
| ⑮ FRICTION PSI/100 FT. (UNCOR.)                                   |  |                                                       |  |                                                                     |  |
| ⑯ $\Delta P_L^\circ$ (CORR.)                                      |  | ⑮ x ②                                                 |  |                                                                     |  |
| ⑰ IF ALL GAS LB./HR. x 10 <sup>3</sup>                            |  | ⑤                                                     |  |                                                                     |  |
| ⑱ FRICTION PSI/100 FT. (UNCOR.)                                   |  |                                                       |  |                                                                     |  |
| ⑲ $\Delta P_G^\circ$ (CORR.)                                      |  | ⑱ x ⑥                                                 |  |                                                                     |  |
| ⑳                                                                 |  |                                                       |  |                                                                     |  |
| ㉑ $\Delta P_G^\circ / \Delta P_L^\circ$                           |  | ⑲ / ⑯                                                 |  |                                                                     |  |
| ㉒                                                                 |  |                                                       |  |                                                                     |  |
| ㉓ $\Delta P_{TP} / \Delta P_L^\circ =$ (FACTOR FROM PD-395A)      |  |                                                       |  |                                                                     |  |
| ㉔                                                                 |  |                                                       |  |                                                                     |  |
| ㉕ $\Delta P_L^\circ \times$ (FACTOR)<br>= $\Delta P_{TP}$ (CORR.) |  | ⑯ x ㉓                                                 |  |                                                                     |  |
| ㉖                                                                 |  |                                                       |  |                                                                     |  |
| ㉗ VELOCITIES FPM (CORR.)                                          |  |                                                       |  |                                                                     |  |
| $\Delta P_L^\circ \sim$ FICTITIOUS ALL LIQUID $\Delta P$          |  | $\Delta P_G^\circ \sim$ FICTITIOUS ALL GAS $\Delta P$ |  |                                                                     |  |

# MIXED PHASE LINE SIZING

$$\text{Liquid Volume Fraction} = \frac{V_L}{V_L + V_G} = \frac{\frac{W_L}{\text{S.G.} \times 62.5}}{\frac{W_L}{\text{S.G.} \times 62.5} + \frac{W_G}{\text{\#/Ft}^3}}$$

$$= \frac{\frac{4000 \times 0.85}{0.85 \times 62.5}}{\frac{4000 \times 0.85}{0.85 \times 62.5} + \frac{40000}{1.09}}$$

$$= \frac{4000}{4000 + 36000} = \frac{4000}{40000} = 0.1$$

$$\text{Total Flow Gas} = W_L + W_G = 4000 + 40000 = 44000 \text{ \#/HR}$$

$$\text{Total Flow Liquid} = \frac{W_L + W_G}{\text{S.G.} \times 500} = \frac{44000}{0.85 \times 500} = 104 \text{ GPM}$$

Try \_\_\_\_ " LINE

$$\frac{\text{Total Flow } \Delta P_G}{\text{Total Flow } \Delta P_L} = \frac{\Delta P_{G0} \times \frac{1}{\text{\#/FT}^3}}{\Delta P_{L0} \times \text{S.G.}} = \frac{x \times \frac{1}{x}}{x} = \frac{1}{x} = \frac{1}{104} = 0.0096$$

$$\Delta P_{G0} = f \times \frac{336}{d^5} \times \left( \frac{W}{1000} \right)^2 = \frac{x \times 336 \times 44000^2}{x \times 10^6} = 6.34 \times 10^{-4}$$

$$\Delta P_{TP} = \text{Total Flow } \Delta P_L \times \text{Factor} = 0.0096 \times 6.34 \times 10^{-4} = 6.08 \times 10^{-6}$$

Try \_\_\_\_ " LINE

$$\frac{\text{Total Flow } \Delta P_G}{\text{Total Flow } \Delta P_L} = \frac{\Delta P_{G0} \times \frac{1}{\text{\#/FT}^3}}{\Delta P_{L0} \times \text{S.G.}} = \frac{x \times \frac{1}{x}}{x} = \frac{1}{x} = \frac{1}{104} = 0.0096$$

$$\Delta P_{G0} = f \times \frac{336}{d^5} \times \left( \frac{W}{1000} \right)^2 = \frac{x \times 336 \times 44000^2}{x \times 10^6} = 6.34 \times 10^{-4}$$

$$\Delta P_{TP} = \text{Total Flow } \Delta P_L \times \text{Factor} = 0.0096 \times 6.34 \times 10^{-4} = 6.08 \times 10^{-6}$$

Use \_\_\_\_ " LINE