# Engineering Information

## SPECIFYING SPRAY NOZZLES

Spray nozzles have three basic functions:

- meter flow
- distribute liquid
- break up a liquid stream into droplets

The process of choosing a nozzle includes specifying:

a.) its flow-rate-versus-pressure characteristics (see catalog flow rate tables)
b.) how the droplets will be distributed after leaving the nozzle (see spray pattern, pp. 2, 3)
c.) the size of the droplets that will be produced (contact BETE Applications Engineering if droplet size is critical)
d.) the nozzle connection to the feed pipe (see dimension tables)
e.) the material of construction (see page 12 for complete list)

## FLOW RATE

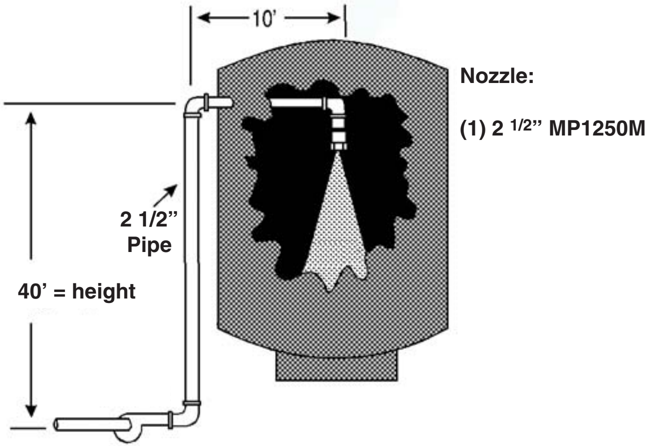
The volume of liquid flowing through a nozzle depends primarily on the difference in fluid pressure upstream of its orifice and the pressure into which the nozzle discharges (normally that of the atmosphere). Pressures that are listed in the flow rate tables of each nozzle series are *gauge pressures.*

Flow rates for pressures not tabulated may be calculated using the equation given at the bottom of each table. The factor "K" is listed for each nozzle and has units of gpm ÷ $PSI^x$.

A nozzle may discharge into a vessel where the pressure is not atmospheric. Since the nozzle flow rate is determined by the *differential* pressure across it, the flow rate may be calculated by subtracting the gauge pressure inside the vessel from the gauge pressure at the nozzle inlet as shown:

$$GPM = K\,(PSI_{Inlet} - PSI_{Vessel})^{x}$$

### System Design Example




**Calculate Total Water Flow and Pressure at Pump for Nozzles Operating at 7 PSI**

Total Flow *(pp. 38, 39)* = (1 nozzle)(99 GPM/nozzle) = **99 GPM**

**Pump Pressure Formula:**

$$P_{pump} = P_{nozzle} + P_{pipe\ losses} + \rho h/144$$

Pipe Friction: (50')(3.09 PSI/100') = 1.6 PSI
Fitting Loss: (3 elbows)(5'/elbow) = 15'
(15')(3.09 PSI/100') = 0.5 PSI
Total Piping Losses: 1.6 PSI + 0.5 PSI = **2.1 PSI**
Elevation Losses: (62.4)(40')/ 144 = **17.3 PSI**

$P_{pump}$ = 7 PSI + 2.1 PSI + 17.3 PSI = 26.4 PSI

**Pump must be sized to provide 99 GPM at 26.4 PSI**

## FLUID PROPERTIES

Specific gravity primarily affects nozzle flow. Flow rates of liquids denser than water are lower than flow rates of water at the same pressure because more energy is required to accelerate denser fluids. The following relationship exists between flow rates (Q) of fluids with different specific gravities:

$$\frac{Q_2}{Q_1} = \sqrt{\frac{SG_1}{SG_2}}$$

Viscosity also affects nozzle performance. High viscosities inhibit atomization. In general, fluids with viscosities greater than 100 cP are difficult to atomize except with air atomizing nozzles.

**FLUID PROPERTIES (at room temperature)**

| Fluid | Viscosity | Specific Gravity |
|---|---|---|
| Water | 1cP | SG=1 |
| 10W-30 Oil | 110 cP | SG=0.88 |
| Honey | 1500 cP | SG=1.05 |

## SYSTEM DESIGN

The piping system that supplies the nozzles must be designed to deliver the correct pressure at the nozzle inlet.

The following formula is useful in estimating the pressure a pump will have to supply to a nozzle system:

$$P_{Pump} = P_{Nozzle} + P_{Pipe\ Losses} + \frac{\rho h}{144}$$

*where:*
*$\rho$ = density of fluid (lbm/ft$^3$)*
*[water = 62.4 lbm/ft$^3$]*
*h = height of nozzle above pump (ft) - negative if the nozzle is below the pump*
*P = pressure (PSI)*

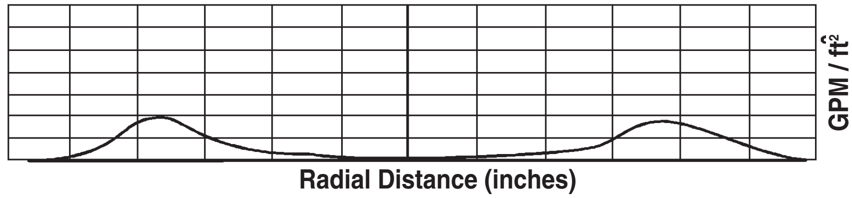
A chart of pipe friction losses is presented on page 121. In using the chart be sure to look at the *total* system flow if there are multiple nozzles to be supplied by one pipe. Elbows, tees and other pipe fittings (p. 121) also contribute to pressure loss and can be significant, especially in short, convoluted runs.

**SPRAY ANGLE**
The spray angle chosen for a particular application depends on the coverage required.

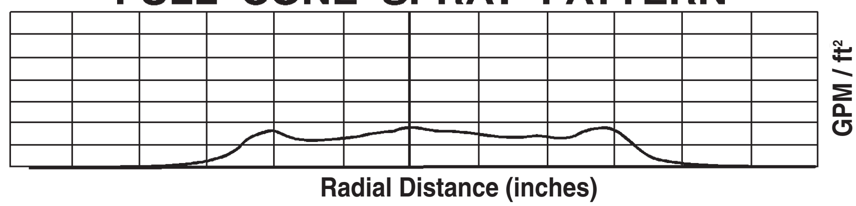
The spray angle for spiral nozzles is relatively stable over a wide range of pressures, while the spray angle for whirl nozzles tends to decrease as the pressure is increased. For additional information see page 120.

**NOZZLE SPRAY PATTERN**
The term "Spray Pattern" describes the location and spray density of the liquid emitted from a nozzle.

**HOLLOW CONE SPRAY PATTERN**




**FULL CONE SPRAY PATTERN**




Two examples of pattern measurement are shown above. The height of the curve at any point is the spray density in units of GPM/ft$^2$.

**DROPLET SIZE**
Droplet size is often critical. Many processes such as gas scrubbing depend on exposing the maximum possible amount of liquid surface to a gas stream. Other applications require that the droplets be as large as possible, such as when the spray must project into a fast moving gas stream.

Exposing the maximum surface area requires breaking the liquid into droplets as small as possible. To get an idea of how this works, imagine a cube of water with a volume of 1gallon. This cube has a surface area of 1.6 ft$^2$. If we now split it in two, we expose some of the inner surface and increase the total surface area to 2.1 ft$^2$. Atomizing the liquid into spheres 1 mm (1,000 microns) in diameter would increase the surface area of this gallon of liquid to 244 ft$^2$.

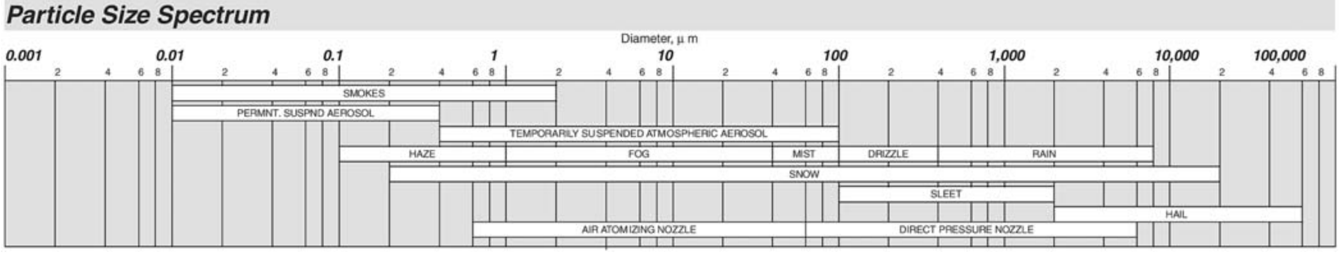
A nozzle actually produces a range of droplet sizes from the solid liquid stream. Since it is inconvenient to list all the sizes produced, droplet size (in microns) is usually expressed by a mean or median diameter. An understanding of diameter terms is essential.

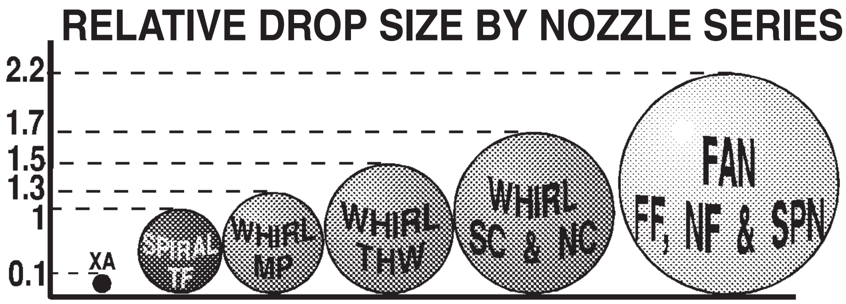
The following definitions are given for the most frequently used mean and median diameters:

**Arithmetic Mean Diameter ($D_{10}$):**
- The average of the diameters of all the droplets in the spray sample.

**Volume Mean Diameter ($D_{30}$):**
- The diameter of a droplet whose volume, if multiplied by the total number of droplets, will equal the total volume of the sample.

**Particle Size Spectrum**






**Sauter Mean Diameter ($D_{32}$):**

- The diameter of a droplet whose ratio of volume to surface area is equal to that of the complete spray sample.

**Mass (Volume) Median Diameter ($DV_{05}$):**

- The diameter which divides the mass (or volume) of the spray into two equal halves. Thus 1/2 of the total mass is made up of droplets with diameters smaller than this number and the other half with diameters that are larger.

The Sauter Mean Diameter is one of the most useful ways to characterize a spray. The ratio of volume to surface area for the Sauter Mean is the same as that ratio for the entire spray volume. For this reason, the use of the Sauter Mean is preferred for process calculations.

Whirl nozzles generally produce larger droplets than spiral nozzles, and air-atomizing nozzles such as the XA or SpiralAir Series typically produce the smallest droplets of all.

It is sometimes useful to predict the effect a change in pressure will have on the droplet size produced by the nozzle. For single fluid nozzles the following equation may be used for modest changes in pressure:

$$\frac{D_2}{D_1} = \left(\frac{P_2}{P_1}\right)^{-0.3}$$

**TROUBLESHOOTING BASICS**

The following are some of the things to look for when a system is not performing as intended:

**Nozzle Wear or Corrosion**

- may cause excessive flow rate due to enlarged passages
- may increase droplet size
- degrades spray pattern

**Nozzle Clogging**

- low flow rates
- poor spray pattern

**Inadequate Pipe Size**

- excessive pipe pressure losses leading to low nozzle pressures
- high velocities in headers that disrupt fluid entering the nozzle

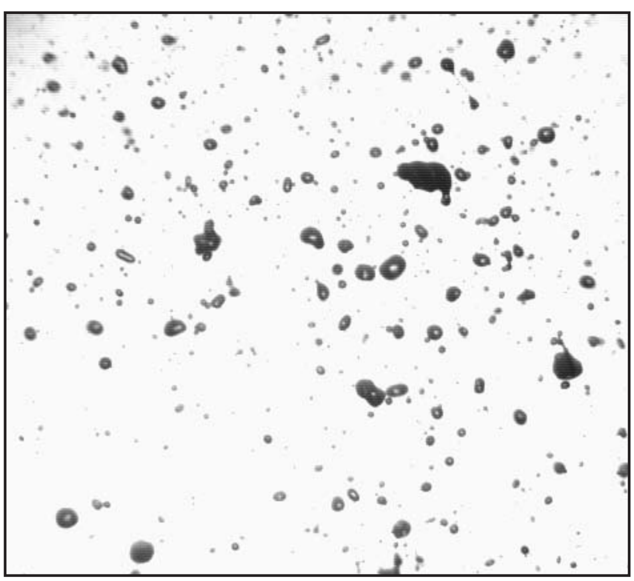
**Incorrect Nozzle Location**

- poor gas/liquid contact in scrubbers and quenchers
- poor area coverage

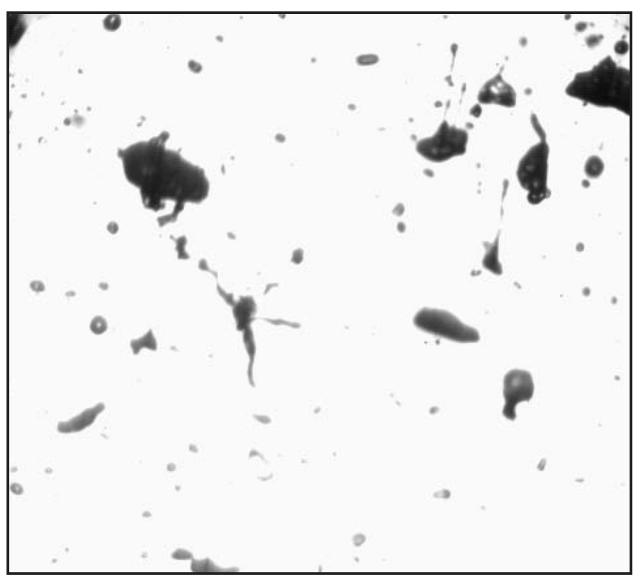
**Incorrect Nozzle for Application**

- drop size too small or too large
- incorrect pattern type

Careful system design and selection of the proper BETE nozzle will minimize spray problems.



**Actual droplet images captured using the BETE Model 700 Spray Analysis System.**



**The BETE Droplet Analyzer is capable of characterizing non-spherical droplets like those seen in this actual image.**

**RESEARCH & DEVELOPMENT**
BETE's state-of-the-art **Spray Laboratory** plays a key role in supporting both product R&D and our customer service network.

Equipped with sophisticated video-image processing and digital analysis technology, the Spray Lab makes possible rapid nozzle development and evaluation.

The Spray Lab is also available on a contract basis to provide confidential, quantitative evaluation of nozzle performance. Industrial applications for contract testing range from comparative nozzle performance testing to development of proprietary designs. These capabilities allow our customers to optimize process performance while minimizing capital and operating costs—a winning combination in today's competitive global marketplace.

**Spray Laboratory Capabilities**

- Flow rate (water) measurements from 0.01 to 2000 gpm
- Flow rate (air) measurements to 3000 scfm
- Pressure measurements to 10,000 psi
- Automated drop size distribution measurement from less than 2 to greater than 15,000 microns
- Computerized spray distribution analysis
- Two-fluid capabilities up to 3000 scfm air / 2000 gpm water
- 30′ x 50′ x 22′ high test area

**DROPLET ANALYSIS**
Frustrated by the limited capabilities of laser-based instruments, BETE developed the Model 700 Video Particle Analyzer. This flexible system allows BETE to characterize the difficult sprays containing significant numbers of large and non-spherical drops often encountered in industrial applications. The Model 700 is a video-imaging system combining a CCD video camera, microscope lens, fast strobed xenon light source, and image processing hardware and software running on a host PC-compatible computer.

**PATTERN DISTRIBUTION ANALYSIS**
The BETE Patternator is a unique digital video system for accurately analyzing the volumetric distribution of liquid emitted from a nozzle. The system uses a standard tube patternator combined with BETE's custom shape recognition and timing software. From this digitized information, spray density and effective spray angles are calculated.

Because data collection and analyses are handled by computer, the device is very well-suited for handling the large amount of data required for nozzle development and assessment programs.

Consistently and accurately selecting appropriate sampling positions is extremely important when performing drop size analysis. The challenge lies in sampling the spray in such a way that the number and locations of the individual tests chosen present a reasonable representation of the entire spray. Recognizing this, BETE has integrated the patternator with the Model 700 analyzer on a calibrated X-Y-Z positioner and developed a number of sampling protocols for droplet size analysis. These protocols ensure that the reported drop size distributions most accurately reflect the overall spray performance, thus allowing a high degree of repeatability and confidence.

**COMPUTER MODELING AND SIMULATION**
There are instances when duplicating the operating environment in the spray lab is impossible. When the nozzle is to be used in a high-temperature or pressure environment or sprayed in a high velocity gas stream, BETE Applications Engineers use computer modeling and simulation software developed in-house to assist in specifying the proper nozzle.

Spray-modeling has also been used to predict spray behavior in HF mitigation systems and to specify nozzles and layouts on offshore drilling platforms. Other applications include predicting spray drift from cooling ponds and dust suppression systems and estimating evaporation rates from disposal ponds.

Working with engineering companies and consulting groups, BETE Engineering taps this modeling and simulation technology to offer customized spray nozzle solutions to some of the most vexing problems facing industry today.

**INDUSTRY COOPERATIVE DEVELOPMENT PROGRAMS**
BETE has worked closely with major industries in research and development programs addressing personnel safety and environmental protection issues.

BETE has provided technical expertise, computer simulation, testing, and nozzle prototypes in a variety of projects, including:

- fire control aboard offshore drilling platforms
- toxic gas control
- oil spill cleanup
- reducing CFC use in the semiconductor industry



Research & Development. Research & Development. Research

# Spray Coverage

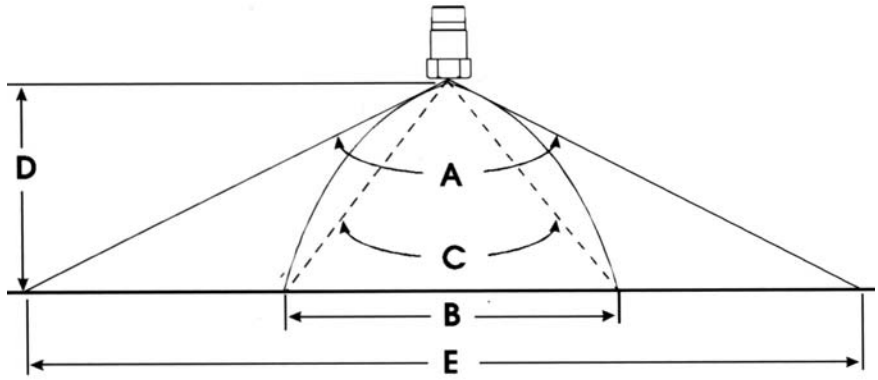
**SPRAY ANGLE TERMS**
Four terms are commonly used to describe spray coverage:

**Spray Angle:**
**(A)** The included angle of the spray as measured close to the nozzle orifice. Since the droplets are immediately acted upon by external forces (gravity and moving gases, for example), this measurement is useful only for determining spray coverage close to the nozzle. The spray angles listed for nozzles in this catalog are angles at the nozzle, measured at the nozzle's design pressure, which is highlighted in each chart of flow rate vs. pressure.
**Actual Spray Coverage:**
**(B)** The actual coverage at a specified distance **(D)** from the nozzle.
**Effective Spray Angle:**
**(C)** The angle calculated from the actual coverage **(B)** at a distance **(D)**.
**Theoretical Spray Coverage:**
**(E)** The coverage at distance **(D)** if the spray moved in a straight line.

**EXAMPLES:**
**Problem:** To achieve a 10″ diameter spray coverage from a nozzle mounted 15″ from the target, what spray angle would be required?
**Solution:** 40° Spray Angle

**Problem:** How far from the target should a nozzle with a 110° spray angle be mounted in order to achieve a 36″ diameter spray?
**Solution:** Approximately 15″. (Actual coverage will be less than theoretical coverage listed in the table.)

***NOTE:*** *For applications where coverage is critical, contact BETE Applications Engineering using the Application Intake Form on page 124.*




***THEORETICAL SPRAY COVERAGE (E) IN INCHES***

| Included Spray Angle (A) | Distance From Nozzle Orifice (D) (inches) 2 | 4 | 6 | 8 | 10 | 12 | 15 | 18 | 24 | 30 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10° | 0.4 | 0.7 | 1.1 | 1.4 | 1.8 | 2.1 | 2.6 | 3.1 | 4.2 | 5.2 | 6.3 |
| 20° | 0.7 | 1.4 | 2.1 | 2.8 | 3.5 | 4.2 | 5.3 | 6.4 | 8.5 | 10.6 | 12.7 |
| 30° | 1.1 | 2.1 | 3.2 | 4.3 | 5.4 | 6.4 | 8.1 | 9.7 | 12.8 | 16.1 | 19.3 |
| 40° | 1.5 | 2.9 | 4.4 | 5.8 | 7.3 | 8.7 | 10.9 | 13.1 | 17.5 | 21.8 | 26.2 |
| 50° | 1.9 | 3.7 | 5.6 | 7.5 | 9.3 | 11.2 | 14.0 | 16.8 | 22.4 | 28.0 | 33.6 |
| 60° | 2.3 | 4.6 | 6.9 | 9.2 | 11.5 | 13.8 | 17.3 | 20.6 | 27.7 | | |
| 70° | 2.8 | 5.6 | 8.4 | 11.2 | 14.0 | 16.8 | 21.0 | 25.2 | 33.6 | | |
| 80° | 3.4 | 6.7 | 10.1 | 13.4 | 16.8 | 20.2 | 25.2 | 30.3 | 40.3 | | |
| 90° | 4.0 | 8.0 | 12.0 | 16.0 | 20.0 | 24.0 | 30.0 | 36.0 | 48.0 | | |
| 100° | 4.8 | 9.5 | 14.3 | 19.1 | 23.8 | 28.6 | 35.8 | 43.0 | | | |
| 110° | 5.7 | 11.4 | 17.1 | 22.8 | 28.5 | 34.3 | 42.8 | 51.4 | | | |
| 120° | 6.9 | 13.9 | 20.8 | 27.7 | 34.6 | 41.6 | 52.0 | 62.4 | | | |
| 130° | 8.6 | 17.2 | 25.7 | 34.3 | 42.9 | 51.5 | 64.4 | | | | |
| 140° | 10.9 | 21.9 | 32.9 | 43.8 | 54.8 | 65.7 | | | | | |
| 150° | 14.9 | 29.8 | 44.7 | 59.6 | 74.5 | | | | | | |
| 170° | 45.8 | 91.6 | | | | | | | | | |

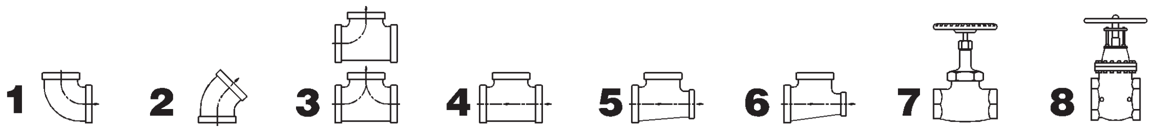
**NOTE: Data shown is theoretical and does not take into consideration the effects of gravity, gas flow, or high pressure operation.**

# Water Flow Data

## FLOW OF WATER THROUGH SCHEDULE 40 STEEL PIPE

Pressure Drop per 100 feet and Velocity in Schedule 40 Pipe for Water at 60° F

| Discharge Gallons per Minute | Discharge Cubic Ft. per Second | Velocity feet per Second | Press. Drop Lbs. per Sq. In. | Velocity feet per Second | Press. Drop Lbs. per Sq. In. | Velocity feet per Second | Press. Drop Lbs. per Sq. In. | Velocity feet per Second | Press. Drop Lbs. per Sq. In. | Velocity feet per Second | Press. Drop Lbs. per Sq. In. | Velocity feet per Second | Press. Drop Lbs. per Sq. In. | Velocity feet per Second | Press. Drop Lbs. per Sq. In. | Velocity feet per Second | Press. Drop Lbs. per Sq. In. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1/8"** | | **1/4"** | | **3/8"** | | **1/2"** | | | | | | | | | |
| 0.2 | 0.000446 | 1.13 | 1.86 | 0.616 | 0.359 | | | | | | | | | | | | |
| 0.3 | 0.000668 | 1.69 | 4.22 | 0.924 | 0.903 | 0.504 | 0.159 | 0.317 | 0.061 | **3/4"** | | | | | | | |
| 0.4 | 0.000891 | 2.26 | 6.98 | 1.23 | 1.61 | 0.672 | 0.345 | 0.422 | 0.086 | | | | | | | | |
| 0.5 | 0.00111 | 2.82 | 10.5 | 1.54 | 2.39 | 0.840 | 0.539 | 0.528 | 0.167 | 0.301 | 0.033 | | | | | | |
| 0.6 | 0.00178 | 3.39 | 14.7 | 1.85 | 3.29 | 1.01 | 0.751 | 0.633 | 0.240 | 0.361 | 0.041 | | | | | | |
| 0.8 | 0.00178 | 4.52 | 25.0 | 2.46 | 5.44 | 1.34 | 1.25 | 0.844 | 0.408 | 0.481 | 0.102 | **1"** | | **1 1/4"** | | | |
| 1 | 0.00223 | 5.65 | 37.2 | 3.08 | 8.28 | 1.68 | 1.85 | 1.06 | 0.600 | 0.602 | 0.155 | 0.371 | 0.048 | | | **1 1/2"** | |
| 2 | 0.00446 | 11.29 | 134.4 | 6.16 | 30.1 | 3.36 | 6.58 | 2.11 | 2.10 | 1.20 | 0.526 | 0.743 | 0.164 | 0.429 | 0.044 | | |
| 3 | 0.00668 | | | 9.25 | 64.1 | 5.04 | 13.9 | 3.17 | 4.33 | 1.81 | 1.09 | 1.114 | 0.336 | 0.644 | 0.09 | 0.473 | 0.043 |
| 4 | 0.00891 | **2"** | | 12.33 | 111.2 | 6.72 | 23.9 | 4.22 | 7.42 | 2.41 | 1.83 | 1.49 | 0.565 | 0.858 | 0.150 | 0.630 | 0.071 |
| 5 | 0.01114 | | | **2 1/2"** | | 8.40 | 36.7 | 5.28 | 11.2 | 3.01 | 2.75 | 1.86 | 0.835 | 1.073 | 0.223 | 0.788 | 0.104 |
| 6 | 0.01337 | 0.574 | 0.044 | | | 10.08 | 51.9 | 6.33 | 15.8 | 3.61 | 3.84 | 2.23 | 1.17 | 1.29 | 0.309 | 0.946 | 0.145 |
| 8 | 0.01782 | 0.765 | 0.073 | | | 13.44 | 91.1 | 8.45 | 27.7 | 4.81 | 6.60 | 2.97 | 1.99 | 1.72 | 0.518 | 1.26 | 0.241 |
| 10 | 0.02228 | 0.956 | 0.108 | 0.670 | 0.046 | | | 10.56 | 42.4 | 6.02 | 9.99 | 3.71 | 2.99 | 2.15 | 0.774 | 1.58 | 0.361 |
| 15 | 0.03342 | 1.43 | 0.224 | 1.01 | 0.094 | **3"** | | | | 9.03 | 21.6 | 5.57 | 6.36 | 3.22 | 1.63 | 2.37 | 0.755 |
| 20 | 0.04456 | 1.91 | 0.375 | 1.34 | 0.158 | 0.868 | 0.056 | **3 1/2"** | | 12.03 | 37.8 | 7.43 | 10.9 | 4.29 | 2.78 | 3.16 | 1.28 |
| 25 | 0.05570 | 2.39 | 0.561 | 1.68 | 0.234 | 0.090 | 0.083 | 0.812 | 0.041 | | | 9.28 | 16.7 | 5.37 | 4.22 | 3.94 | 1.93 |
| 30 | 0.06684 | 2.87 | 0.786 | 2.01 | 0.327 | 1.30 | 0.114 | 0.974 | 0.056 | **4"** | | 11.14 | 23.8 | 6.44 | 5.92 | 4.73 | 2.72 |
| 35 | 0.07798 | 3.35 | 1.05 | 2.35 | 0.436 | 1.52 | 0.151 | 1.14 | 0.074 | 0.882 | 0.041 | 12.99 | 32.2 | 7.51 | 7.90 | 5.52 | 3.64 |
| 40 | 0.08912 | 3.83 | 1.35 | 2.68 | 0.556 | 1.74 | 0.192 | 1.30 | 0.095 | 1.01 | 0.052 | 14.85 | 41.5 | 8.59 | 10.24 | 6.30 | 4.65 |
| 45 | 0.1003 | 4.30 | 1.67 | 3.02 | 0.668 | 1.95 | 0.239 | 1.46 | 0.117 | 1.13 | 0.064 | | | 9.67 | 12.80 | 7.09 | 5.85 |
| 50 | 0.1114 | 4.78 | 2.03 | 3.35 | 0.839 | 2.17 | 0.288 | 1.62 | 0.142 | 1.26 | 0.076 | | | 10.74 | 15.66 | 7.88 | 7.15 |
| 60 | 0.1337 | 5.74 | 2.87 | 4.02 | 1.18 | 2.60 | 0.406 | 1.95 | 0.204 | 1.51 | 0.107 | **5"** | | 12.89 | 22.2 | 9.47 | 10.21 |
| 70 | 0.1560 | 6.70 | 3.84 | 4.69 | 1.59 | 3.04 | 0.540 | 2.27 | 0.261 | 1.76 | 0.143 | 1.12 | 0.047 | | | 11.05 | 13.71 |
| 80 | 0.1782 | 7.65 | 4.97 | 5.36 | 2.03 | 3.47 | 0.687 | 2.60 | 0.334 | 2.02 | 0.180 | 1.28 | 0.060 | | | 12.62 | 17.59 |
| 90 | 0.2005 | 8.60 | 6.20 | 6.03 | 2.53 | 3.91 | 0.861 | 2.92 | 0.416 | 2.27 | 0.224 | 1.44 | 0.074 | **6"** | | 14.20 | 22.0 |
| 100 | 0.2228 | 9.56 | 7.59 | 6.70 | 3.09 | 4.34 | 1.05 | 3.25 | 0.509 | 2.52 | 0.272 | 1.60 | 0.090 | 1.11 | 0.036 | 15.78 | 26.9 |
| 125 | 0.2785 | 11.97 | 11.76 | 8.38 | 4.71 | 5.43 | 1.61 | 4.06 | 0.769 | 3.15 | 0.415 | 2.01 | 0.135 | 1.39 | 0.055 | 19.72 | 41.4 |
| 150 | 0.3342 | 14.36 | 16.70 | 10.05 | 6.69 | 6.51 | 2.24 | 4.87 | 1.08 | 3.78 | 0.580 | 2.41 | 0.190 | 1.67 | 0.077 | | |
| 175 | 0.3899 | 16.75 | 22.3 | 11.73 | 8.97 | 7.60 | 3.00 | 5.68 | 1.44 | 4.41 | 0.774 | 2.81 | 0.253 | 1.94 | 0.102 | **8"** | |
| 200 | 0.4456 | 19.14 | 28.8 | 13.42 | 11.68 | 8.68 | 3.87 | 6.49 | 1.85 | 5.04 | 0.985 | 3.21 | 0.323 | 2.22 | 0.130 | | |
| 225 | 0.5013 | - | - | 15.09 | 14.63 | 9.77 | 4.83 | 7.30 | 2.32 | 5.67 | 1.23 | 3.61 | 0.401 | 2.50 | 0.162 | 1.44 | 0.043 |
| 250 | 0.5570 | - | - | - | - | 10.85 | 5.93 | 8.12 | 2.84 | 6.30 | 1.46 | 4.01 | 0.495 | 2.78 | 0.195 | 1.60 | 0.051 |
| 275 | 0.6127 | - | - | - | - | 11.94 | 7.14 | 8.93 | 3.40 | 6.93 | 1.79 | 4.41 | 0.583 | 3.05 | 0.234 | 1.76 | 0.061 |
| 300 | 0.6684 | - | - | - | - | 13.00 | 8.36 | 9.74 | 4.02 | 7.56 | 2.11 | 4.81 | 0.683 | 3.33 | 0.275 | 1.92 | 0.072 |
| 350 | 0.7798 | | | - | - | - | - | 11.36 | 5.41 | 8.82 | 2.84 | 5.62 | 0.919 | 3.89 | 0.367 | 2.24 | 0.095 |
| 400 | 0.8912 | | | | | - | - | 12.98 | 7.03 | 10.08 | 3.68 | 6.42 | 1.19 | 4.44 | 0.471 | 2.56 | 0.121 |
| 450 | 1.0030 | **10"** | | | | - | - | 14.61 | 8.80 | 11.34 | 4.60 | 7.22 | 1.48 | 5.00 | 0.590 | 2.89 | 0.151 |
| 500 | 1.114 | 2.03 | 0.059 | **12"** | | - | - | - | - | 12.60 | 5.65 | 8.02 | 1.81 | 5.55 | 0.720 | 3.21 | 0.182 |
| 600 | 1.337 | 2.44 | 0.083 | | | | | - | - | 15.12 | 8.04 | 9.63 | 2.55 | 6.66 | 1.02 | 3.85 | 0.258 |
| 700 | 1.560 | 2.85 | 0.112 | 2.01 | 0.047 | **14"** | | - | - | - | - | 11.23 | 3.43 | 7.78 | 1.35 | 4.49 | 0.343 |
| 800 | 1.782 | 3.25 | 0.143 | 2.29 | 0.061 | | | | | - | - | 12.83 | 4.43 | 8.88 | 1.75 | 5.13 | 0.443 |
| 900 | 2.005 | 3.66 | 0.179 | 2.58 | 0.075 | 2.13 | 0.047 | **16"** | | - | - | 14.44 | 5.58 | 9.99 | 2.18 | 5.77 | 0.554 |
| 1000 | 2.228 | 4.07 | 0.218 | 2.87 | 0.091 | 2.37 | 0.057 | | | | | 16.04 | 6.84 | 11.10 | 2.68 | 6.41 | 0.675 |
| 1200 | 2.674 | 4.88 | 0.306 | 3.44 | 0.128 | 2.85 | 0.080 | 2.18 | 0.042 | | | - | - | 13.33 | 3.81 | 7.70 | 0.948 |
| 1400 | 3.119 | 5.70 | 0.409 | 4.01 | 0.171 | 3.32 | 0.107 | 2.54 | 0.055 | **18"** | | - | - | 15.55 | 5.13 | 8.98 | 1.28 |
| 1600 | 3.565 | 6.51 | 0.527 | 4.59 | 0.219 | 3.79 | 0.138 | 2.90 | 0.071 | | | - | - | 17.77 | 6.61 | 10.26 | 1.65 |
| 1800 | 4.010 | 7.32 | 0.663 | 5.16 | 0.276 | 4.27 | 0.172 | 3.27 | 0.088 | 2.58 | 0.050 | | | 19.99 | 8.37 | 11.54 | 2.08 |
| 2000 | 4.456 | 8.14 | 0.808 | 5.73 | 0.339 | 4.74 | 0.209 | 3.63 | 0.107 | 2.87 | 0.060 | | | 22.21 | 10.3 | 12.82 | 2.55 |




## Valve & Fitting Losses in Expressed in Equivalent Feet of Pipe

| | Pipe Fitting or Valve | 3/8 | 1/2 | 3/4 | 1 | 1 1/4 | 1 1/2 | 2 | 2 1/2 | 3 | 3 1/2 | 4 | 5 | 6 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nominal Pipe or Tube Size (inches) | | | | | | | | | | | | | |
| 1 | 90° Standard Elbow | 1.4 | 1.6 | 2.0 | 2.6 | 3.3 | 4.0 | 5.0 | 6.0 | 7.5 | 9.0 | 10 | 13 | 16 | 20 |
| 2 | 45° Standard Elbow | 0.7 | 0.8 | 0.9 | 1.3 | 1.7 | 2.1 | 2.6 | 3.2 | 4.0 | 4.7 | 5.2 | 6.5 | 7.9 | 10 |
| 3 | Flow-Through Branch Tee | 2.7 | 3.0 | 4.0 | 5.0 | 7.0 | 8.0 | 10 | 12 | 15 | 18 | 21 | 25 | 30 | 40 |
| 4 | Straight Through Flow Tee - No Reduction | 0.9 | 1.0 | 1.4 | 1.7 | 2.3 | 2.6 | 3.3 | 4.1 | 5.0 | 5.9 | 6.7 | 8.2 | 10 | 13 |
| 5 | Straight Through Flow Tee- Reduced 1/4 | 1.2 | 1.4 | 1.9 | 2.3 | 3.1 | 3.7 | 4.7 | 5.6 | 7.0 | 8.0 | 9.0 | 12 | 14 | 18 |
| 6 | Straight Through Flow Tee - Reduced 1/8 | 1.4 | 1.6 | 2.0 | 2.6 | 3.3 | 4.0 | 5.0 | 6.0 | 7.5 | 9.0 | 10 | 13 | 16 | 20 |
| 7 | Globe Valve - Fully opened | 17 | 18 | 22 | 29 | 38 | 43 | 55 | 69 | 84 | 100 | 120 | 140 | 170 | 220 |
| 8 | Gate Valve - Fully opened | 0.6 | 0.7 | 0.9 | 1.0 | 1.5 | 1.8 | 2.3 | 2.8 | 3.2 | 4.0 | 4.5 | 6.0 | 7.0 | 9.0 |

# Notes!

## *FLOW OF AIR THROUGH SCHEDULE 40 STEEL PIPE*

| Free Air $ft^3$/min. at 60°F & 14.7 psia | Compressed Air $ft^3$/min. at 60°F at 100 psig | Pressure Drop per 100' of Schedule 40 Pipe For Air For 60°F and 100 Pounds Per Square Inch (PSI) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **1/8"** | **1/4"** | **3/8"** | **1/2"** | **3/4"** | **1"** | **1 1/4"** | **1 1/2"** | **2"** |
| **1** | 0.128 | 0.361 | 0.083 | 0.018 | | | | | | |
| **2** | 0.256 | 1.31 | 0.285 | 0.064 | 0.020 | | | | | |
| **3** | 0.384 | 3.06 | 0.605 | 0.133 | 0.042 | | | | | |
| **4** | 0.513 | 4.83 | 1.04 | 0.226 | 0.071 | | | | | |
| **5** | 0.641 | 7.45 | 1.58 | 0.343 | 0.106 | 0.027 | | | | |
| **6** | 0.769 | 10.6 | 2.23 | 0.408 | 0.148 | 0.037 | | | | |
| **8** | 1.025 | 18.6 | 3.89 | 0.848 | 0.255 | 0.062 | 0.019 | | | |
| **10** | 1.282 | 28.7 | 5.96 | 1.26 | 0.356 | 0.094 | 0.029 | | | |
| **15** | 1.922 | | 13.0 | 2.73 | 0.834 | 0.201 | 0.062 | | | |
| **20** | 2.563 | | 22.8 | 4.76 | 1.43 | 0.345 | 0.102 | 0.026 | | |
| **25** | 3.204 | | 35.6 | 7.34 | 2.21 | 0.526 | 0.156 | 0.039 | 0.019 | |
| **30** | 3.845 | | | 10.5 | 3.15 | 0.748 | 0.219 | 0.055 | 0.026 | |
| **35** | 4.486 | | | 14.2 | 4.24 | 1.00 | 0.293 | 0.073 | 0.035 | |
| **40** | 5.126 | | | 18.4 | 5.49 | 1.30 | 0.379 | 0.095 | 0.044 | |
| **45** | 5.767 | | | 23.1 | 6.90 | 1.62 | 0.474 | 0.116 | 0.055 | |
| **50** | 6.408 | **2 1/2"** | | 28.5 | 8.49 | 1.99 | 0.578 | 0.149 | 0.067 | 0.019 |
| **60** | 7.690 | | | 40.7 | 12.2 | 2.85 | 0.819 | 0.200 | 0.094 | 0.027 |
| **70** | 8.971 | | | | 16.5 | 3.83 | 1.10 | 0.270 | 0.126 | 0.036 |
| **80** | 10.25 | 0.019 | | | 21.4 | 4.96 | 1.43 | 0.350 | 0.162 | 0.046 |
| **90** | 11.53 | 0.023 | | | 27.0 | 6.25 | 1.80 | 0.437 | 0.203 | 0.058 |

# Pipe Dimensions & Weights

| Nominal Pipe Size NPS [DN] | OD in [mm] | Schedule | | | Wall Thickness in | ID in | Weight lb/ft |
|---|---|---|---|---|---|---|---|
| **1/8** [6] | **0.405** [10.3] | | 10 | 10S | 0.049 | 0.307 | 0.19 |
| | | STD | 40 | 40S | 0.068 | 0.269 | 0.25 |
| | | XS | 80 | 80S | 0.095 | 0.215 | 0.32 |
| **1/4** [8] | **0.540** [13.7] | | 10 | 10S | 0.065 | 0.410 | 0.33 |
| | | STD | 40 | 40S | 0.088 | 0.364 | 0.43 |
| | | XS | 80 | 80S | 0.119 | 0.302 | 0.54 |
| **3/8** [10] | **0.675** [17.1] | | 10 | 10S | 0.065 | 0.545 | 0.42 |
| | | STD | 40 | 40S | 0.091 | 0.493 | 0.57 |
| | | XS | 80 | 80S | 0.126 | 0.423 | 0.74 |
| **1/2** [15] | **0.840** [21.3] | | 5 | 5S | 0.065 | 0.710 | 0.54 |
| | | | 10 | 10S | 0.083 | 0.674 | 0.67 |
| | | STD | 40 | 40S | 0.109 | 0.622 | 0.85 |
| | | XS | 80 | 80S | 0.147 | 0.546 | 1.09 |
| | | | 160 | | 0.188 | 0.464 | 1.31 |
| | | XX | | | 0.294 | 0.252 | 1.71 |
| **3/4** [20] | **1.050** [26.7] | | 5 | 5S | 0.065 | 0.920 | 0.68 |
| | | | 10 | 10S | 0.083 | 0.884 | 0.86 |
| | | STD | 40 | 40S | 0.113 | 0.824 | 1.13 |
| | | XS | 80 | 80S | 0.154 | 0.742 | 1.47 |
| | | | 160 | | 0.219 | 0.612 | 1.94 |
| | | XX | | | 0.308 | 0.434 | 2.44 |
| **1** [25] | **1.315** [33.4] | | 5 | 5S | 0.065 | 1.185 | 0.87 |
| | | | 10 | 10S | 0.109 | 1.097 | 1.40 |
| | | STD | 40 | 40S | 0.133 | 1.049 | 1.68 |
| | | XS | 80 | 80S | 0.179 | 0.957 | 2.17 |
| | | | 160 | | 0.250 | 0.815 | 2.84 |
| | | XX | | | 0.358 | 0.599 | 3.66 |
| **1-1/4** [32] | **1.660** [42.2] | | 5 | 5S | 0.065 | 1.530 | 1.11 |
| | | | 10 | 10S | 0.109 | 1.442 | 1.81 |
| | | STD | 40 | 40S | 0.140 | 1.380 | 2.27 |
| | | XS | 80 | 80S | 0.191 | 1.278 | 3.00 |
| | | | 160 | | 0.250 | 1.160 | 3.77 |
| | | XX | | | 0.382 | 0.896 | 5.21 |
| **1-1/2** [40] | **1.900** [48.3] | | 5 | 5S | 0.065 | 1.770 | 1.27 |
| | | | 10 | 10S | 0.109 | 1.682 | 2.09 |
| | | STD | 40 | 40S | 0.145 | 1.610 | 2.72 |
| | | XS | 80 | 80S | 0.200 | 1.500 | 3.63 |
| | | | 160 | | 0.281 | 1.338 | 4.86 |
| | | XX | | | 0.400 | 1.100 | 6.41 |
| **2** [50] | **2.375** [60.3] | | 5 | 5S | 0.065 | 2.245 | 1.60 |
| | | | 10 | 10S | 0.109 | 2.157 | 2.64 |
| | | STD | 40 | 40S | 0.154 | 2.067 | 3.65 |
| | | XS | 80 | 80S | 0.218 | 1.939 | 5.02 |
| | | | 160 | | 0.344 | 1.687 | 7.46 |
| | | XX | | | 0.436 | 1.503 | 9.03 |
| **3** [80] | **3.500** [88.9] | | 5 | 5S | 0.083 | 3.334 | 3.03 |
| | | | 10 | 10S | 0.120 | 3.260 | 4.33 |
| | | STD | 40 | 40S | 0.216 | 3.068 | 7.58 |
| | | XS | 80 | 80S | 0.300 | 2.900 | 10.25 |
| | | | 160 | | 0.438 | 2.624 | 14.32 |
| | | XX | | | 0.600 | 2.300 | 18.58 |
| **3-1/2** [90] | **4.000** [101.6] | | 5 | 5S | 0.083 | 3.834 | 3.47 |
| | | | 10 | 10S | 0.120 | 3.760 | 4.97 |
| | | STD | 40 | 40S | 0.226 | 3.548 | 9.11 |
| | | XS | 80 | 80S | 0.318 | 3.364 | 12.51 |
| | | XX | | | 0.636 | 2.728 | 22.85 |

| Nominal Pipe Size NPS [DN] | OD in [mm] | Schedule | | | Wall Thickness in | ID in | Weight lb/ft |
|---|---|---|---|---|---|---|---|
| **4** [100] | **4.500** [114.3] | | 5 | 5S | 0.083 | 4.334 | 3.92 |
| | | | 10 | 10S | 0.120 | 4.260 | 5.61 |
| | | STD | 40 | 40S | 0.237 | 4.026 | 10.79 |
| | | XS | 80 | 80S | 0.337 | 3.826 | 14.98 |
| | | | 120 | | 0.438 | 3.624 | 19.00 |
| | | | 160 | | 0.531 | 3.438 | 22.51 |
| | | XX | | | 0.674 | 3.152 | 27.54 |
| **6** [150] | **6.625** [168.3] | | 5 | 5S | 0.109 | 6.407 | 7.59 |
| | | | 10 | 10S | 0.134 | 6.357 | 9.29 |
| | | STD | 40 | 40S | 0.280 | 6.065 | 18.97 |
| | | XS | 80 | 80S | 0.432 | 5.761 | 28.57 |
| | | | 120 | | 0.562 | 5.501 | 36.39 |
| | | | 160 | | 0.719 | 5.187 | 45.35 |
| | | XX | | | 0.864 | 4.897 | 53.16 |
| **8** [200] | **8.625** [219.1] | | | 5S | 0.109 | 8.407 | 9.91 |
| | | | 10 | 10S | 0.148 | 8.329 | 13.40 |
| | | | 20 | | 0.250 | 8.125 | 22.36 |
| | | | 30 | | 0.277 | 8.071 | 24.70 |
| | | STD | 40 | 40S | 0.322 | 7.981 | 28.55 |
| | | | 60 | | 0.406 | 7.813 | 35.64 |
| | | XS | 80 | 80S | 0.500 | 7.625 | 43.39 |
| | | | 100 | | 0.594 | 7.437 | 50.95 |
| | | | 120 | | 0.719 | 7.187 | 60.71 |
| | | | 140 | | 0.812 | 7.001 | 67.76 |
| | | XX | | | 0.875 | 6.875 | 72.43 |
| | | | 160 | | 0.906 | 6.813 | 74.69 |
| **10** [250] | **10.750** [273.1] | | | 5S | 0.134 | 10.482 | 15.19 |
| | | | | 10S | 0.165 | 10.420 | 18.65 |
| | | | 20 | | 0.250 | 10.250 | 28.04 |
| | | | 30 | | 0.307 | 10.136 | 34.24 |
| | | STD | 40 | 40S | 0.365 | 10.020 | 40.48 |
| | | XS | 60 | 80S | 0.500 | 9.750 | 54.74 |
| | | | 80 | | 0.594 | 9.562 | 64.43 |
| | | | 100 | | 0.719 | 9.312 | 77.03 |
| | | | 120 | | 0.844 | 9.062 | 89.29 |
| | | | 140 | | 1.000 | 8.750 | 104.13 |
| | | | 160 | | 1.125 | 8.500 | 115.65 |
| **12** [300] | **12.750** [323.9] | | | 5S | 0.156 | 12.438 | 20.98 |
| | | | | 10S | 0.180 | 12.390 | 24.17 |
| | | | 20 | | 0.250 | 12.250 | 33.38 |
| | | | 30 | | 0.330 | 12.090 | 43.77 |
| | | STD | | 40S | 0.375 | 12.000 | 49.56 |
| | | | 40 | | 0.406 | 11.938 | 53.53 |
| | | XS | | 80S | 0.500 | 11.750 | 65.42 |
| | | | 60 | | 0.562 | 11.626 | 73.16 |
| | | | 80 | | 0.688 | 11.374 | 88.63 |
| | | | 100 | | 0.844 | 11.062 | 107.32 |
| | | | 120 | | 1.000 | 10.750 | 125.49 |
| | | | 140 | | 1.125 | 10.500 | 139.68 |
| | | | 160 | | 1.312 | 10.126 | 160.27 |

# BETE Fog Nozzle, Inc.
# Application Information Sheet

**FAX: 413 772-6729**

**Name:** ______________________ **Company:** ______________________

**Telephone:** ______________________ **Company Address:** ______________________

**FAX:** ________________ **email:** ________________ **BETE Cust. #** ________

Sketch a simple representation of the application below:

| |
|---|
| • What are you trying to accomplish with the spray? |

| | |
|---|---|
| • What is the available pressure? | • What is the desired material of construction? |
| • What is the flow rate? | • What is the piping material? |
| • What is the desired flow rate? | • What are the size and connection types desired? |
| • What liquid is being sprayed? | • What is the distance from the nozzle to the target? |
| • What is the desired spray angle or coverage? | • What are the environmental conditions surrounding the nozzle? |