Engineering Information

SPECIFYING SPRAY NOZZLES

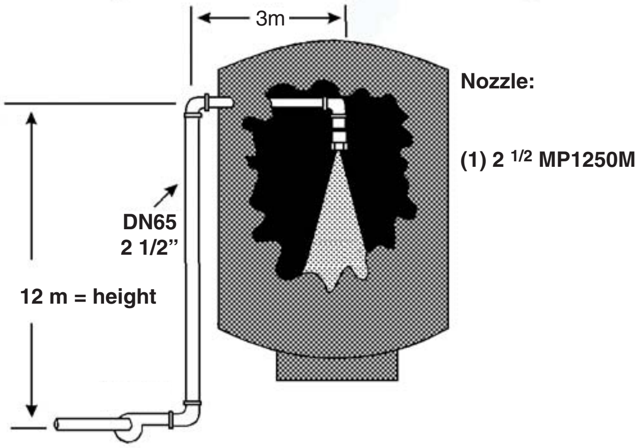
Spray nozzles have three basic functions:

- 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)

System Design Example



Calculate Total Water Flow and Pressure at Pump for Nozzles Operating at 0.5 bar

Total Flow *(p. 26, 27)* = (1 nozzles)(381 l/min/nozzle) = **381 l/min**

Pump Pressure Formula:

$$P_{pump} = P_{nozzle} + P_{pipe\ losses} + \rho gh/100000$$

Calculate Pipe Loss:
Pipe Friction: (15 m)(0.7 bar/100 m) = 0.11 bar
Fitting Loss: (3 elbows)(1.52 m/elbow) = 4.56 m
(4.56 m)(0.7 bar/100 m) = 0.03 bar
Total Piping Losses: 0.11 bar + 0.03 bar = **0.14 bar**
Elevation Losses: (1000)(9.81)(12 m) / 100000 = **1.17 bar**

P_{pump} = 0.5 bar + 0.14 bar + 1.17 bar = 1.81 bar

Pump must be sized to provide 381 l/min at 1.81 bar

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 lpm/bar^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:

$$l/min = K\,(Bar_{Inlet} - Bar_{Vessel})^{x}$$

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:

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

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

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.

SYSTEM DESIGN

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

$$P_{Pump} = P_{Nozzle} + P_{Pipe\ Losses} + \frac{\rho g h}{100000}$$

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

where:
ρ = density of fluid (kg/m^3)
[water = 1000 kg/m^3]
g = 9.81 m/s^2
h = height of nozzle above pump (m) - negative if the nozzle is below the pump
p = pressure (bar)

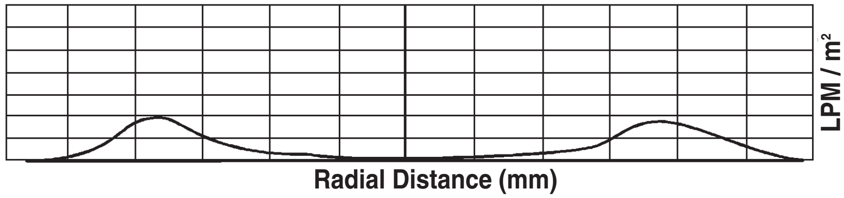
A chart of pipe friction losses is presented on page 125. In using the chart be sure to look at the *total* system flow if there are multiple nozzles to be supplied by one pipe. Elbows, tees and other pipe fittings (see p. 125) also contribute to pressure loss and can be significant, especially in short, convoluted runs.

SPRAY ANGLE

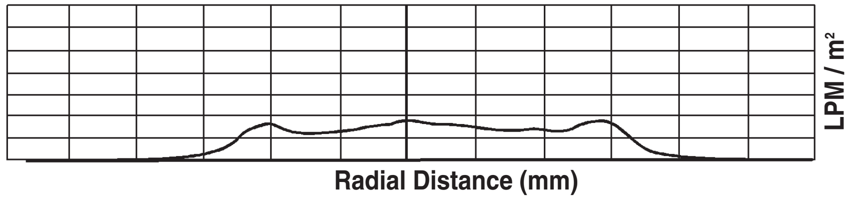
The spray angle chosen for a particular application depends on the coverage required.

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 124.

HOLLOW CONE SPRAY PATTERN



FULL CONE SPRAY PATTERN



NOZZLE SPRAY PATTERN

The term "Spray Pattern" describes the location and spray density of the liquid emitted from a nozzle. Two examples of pattern measurement are shown above. The height of the curve at any point is the spray density in units of LPM/m^2.

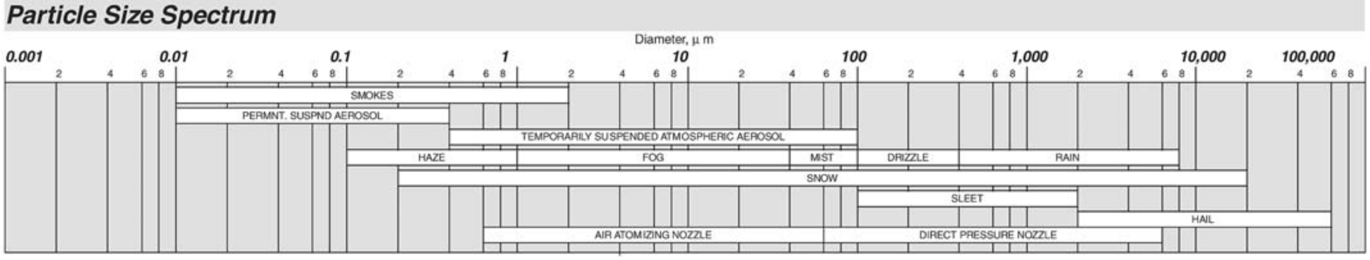
DROPLET SIZE

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.

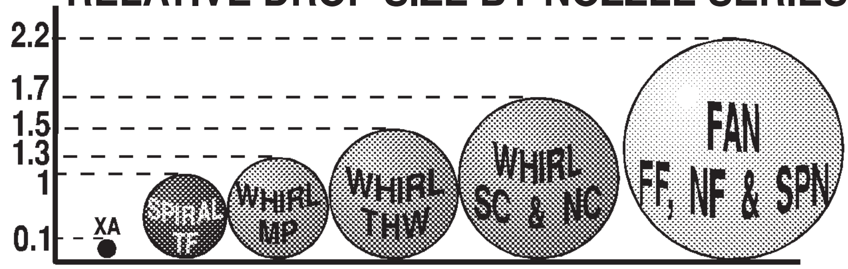
Exposing the maximum surface area requires breaking the liquid into droplets as small as possible. To get an idea of how this works, imagine a cube of water with a volume of 1 m^3. This cube has a surface area of 6 m^2. If we now split it in two, we expose some of the inner surface and increase the total surface area to 8 m^2. Atomizing the liquid into spheres 1 mm (1,000 microns) in diameter would increase the surface area of this gallon of liquid to 6000 m^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.

Particle Size Spectrum



RELATIVE DROP SIZE BY NOZZLE SERIES



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.

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,

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

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.

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

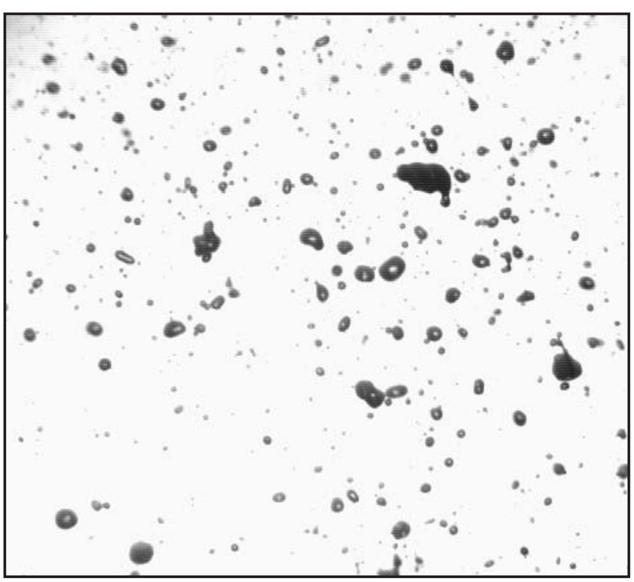
Incorrect Nozzle Location

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

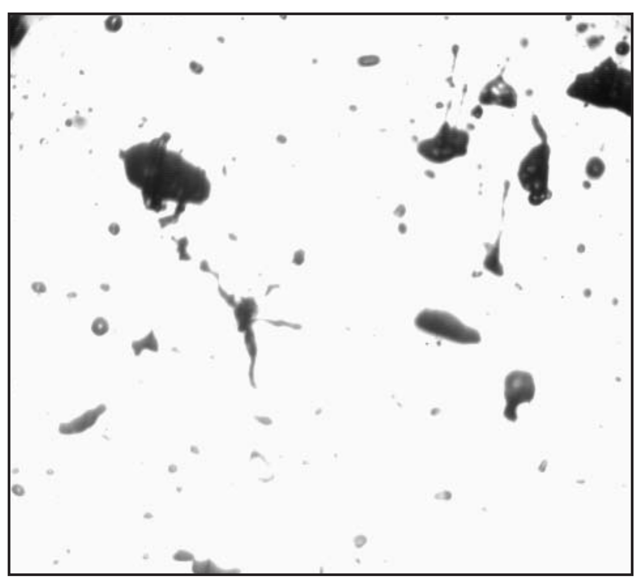
Incorrect Nozzle for Application

- 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

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 0.04 to 7500 l/min
- Flow rate (air) measurements from 0.5 to 2550 Nm^3/h
- Pressure measurements to 210 bar
- Automated drop size distribution measurement from less than 2 to greater than 15,000 microns
- Computerized spray distribution analysis
- Two-fluid capabilities up to 2550 Nm^3/h air / 3000 l/m water
- 9 m x 15 m x 7 m 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.

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 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

Spray Coverage

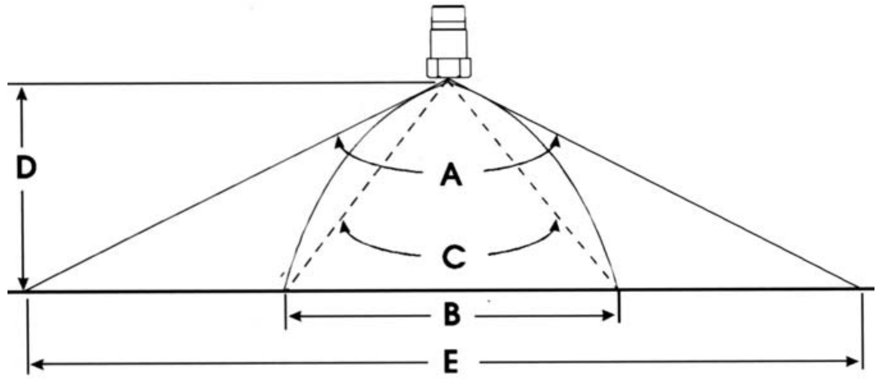
SPRAY ANGLE TERMS
Four terms are commonly used to describe spray coverage:

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.
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 200mm diameter spray coverage from a nozzle mounted 150mm from the target, what spray angle would be required?
Solution: 70° Spray Angle

Problem: How far from the target should a nozzle with a 110° spray angle be mounted in order to achieve a 550mm diameter spray?
Solution: Approximately 200mm. (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 Applications Intake form on page 128.*



THEORETICAL SPRAY COVERAGE (E) IN MILLIMETERS

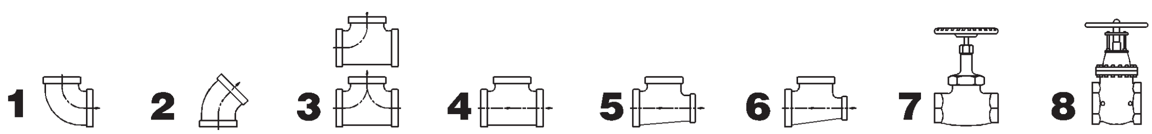
Included Spray Angle (A)	Distance From Nozzle Orifice (D) (mm) 50	75	100	150	200	300	400	600	800	1000
10°	9	13	17	26	35	52	70	105	140	175
20°	18	26	35	53	71	106	141	212	282	353
30°	27	40	54	80	107	161	214	322	429	536
40°	36	55	73	109	146	218	291	437	582	728
50°	47	70	93	140	187	280	373	560	746	933
60°	58	87	115	173	231	346	462	693	924	1155
70°	70	105	140	210	280	420	560	840	1120	1400
80°	84	126	168	252	336	503	671	1007	1343	1678
90°	100	150	200	300	400	600	800	1200	1600	2000
100°	119	179	238	358	477	715	953	1430	1907	2384
110°	143	214	286	428	571	857	1143	1714	2285	
120°	173	260	346	520	693	1039	1386	2078		
130°	214	322	429	643	858	1287	1716			
140°	275	412	549	824	1099	1648	2198			
150°	373	560	746	1120	1493	2239				
170°	1143	1715	2286							

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

Discharge	Pressure Drop per 100 meters and Velocity in Schedule 40 Pipe for Water at 15° C															
	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop	Velocity	Press. Drop
l/min	m/sec	bar	m/sec	bar	m/sec	bar	m/sec	bar	m/sec	bar	m/sec	bar	m/sec	bar	m/sec	bar
	1/8"		**1/4"**		**3/8"**		**1/2"**		**3/4"**		**1"**					
1	0.459	0.726	0.251	0.17												
2	0.918	2.59	0.501	0.60	0.272	0.136	0.170	0.044								
3	1.38	5.59	0.752	1.22	0.407	0.29	0.255	0.091	0.144	0.023						
4	1.84	9.57	1.00	2.09	0.543	0.48	0.340	0.151	0.192	0.038	0.120	0.012				
5	2.29	14.45	1.25	3.18	0.679	0.70	0.425	0.223	0.241	0.057	0.150	0.017				
													1 1/4"		**1 1/2"**	
6	2.75	20.29	1.50	4.46	0.815	0.98	0.510	0.309	0.289	0.077	0.180	0.024				
8	3.67	35.16	2.01	7.36	1.09	1.69	0.680	0.524	0.385	0.129	0.240	0.041	0.138	0.011		
10			2.51	11.81	1.36	2.52	0.850	0.798	0.481	0.193	0.300	0.061	0.172	0.015	0.127	0.008
15			3.76	25.67	2.04	5.37	1.28	1.69	0.722	0.403	0.450	0.124	0.258	0.032	0.190	0.015
20					2.72	9.24	1.70	2.84	0.962	0.683	0.600	0.210	0.344	0.054	0.254	0.026
	2"		**2 1/2"**													
30	0.231	0.016					2.55	6.17	1.44	1.45	0.90	0.442	0.517	0.114	0.380	0.053
40	0.308	0.027	0.216	0.010			3.4	10.72	1.92	2.50	1.20	0.758	0.689	0.193	0.507	0.091
50	0.385	0.039	0.270	0.017					2.41	3.83	1.50	1.14	0.861	0.290	0.634	0.135
60	0.462	0.055	0.324	0.023					2.89	5.41	1.80	1.61	1.03	0.400	0.761	0.187
70	0.539	0.098	0.378	0.031					3.37	7.27	2.10	2.15	1.21	0.541	0.888	0.248
					3"											
80	0.616	0.092	0.432	0.039	0.280	0.014			3.85	9.27	2.40	2.76	1.38	0.690	1.01	0.315
							3 1/2"		**4"**							
90	0.693	0.115	0.486	0.048	0.315	0.017	0.235	0.008			2.70	3.47	1.55	0.862	1.14	0.397
100	0.770	0.141	0.540	0.059	0.350	0.020	0.261	0.010			3.00	4.25	1.72	1.05	1.27	0.488
150	1.15	0.295	0.810	0.125	0.524	0.042	0.392	0.021	0.304	0.011	4.50	9.30	2.58	2.26	1.90	1.03
200	1.54	0.512	1.08	0.212	0.699	0.072	0.523	0.036	0.405	0.019			3.44	3.91	2.54	1.81
											5"		**6"**			
250	1.92	0.773	1.35	0.322	0.874	0.108	0.653	0.053	0.507	0.028					3.17	2.74
300	2.31	1.10	1.62	0.449	1.05	0.152	0.784	0.074	0.608	0.040	0.387	0.014			3.80	3.82
350	2.69	1.47	1.89	0.606	1.22	0.203	0.915	0.099	0.710	0.053	0.452	0.018			4.44	5.18
400	3.08	1.92	2.16	0.780	1.40	0.264	1.05	0.128	0.811	0.068	0.516	0.023	0.357	0.009	5.07	6.69
450	3.46	2.39	2.43	0.979	1.57	0.329	1.18	0.161	0.912	0.084	0.581	0.028	0.402	0.012	5.71	8.45
500	3.85	2.95	2.70	1.20	1.75	0.403	1.31	0.196	1.01	0.101	0.646	0.034	0.447	0.014		
550	4.23	3.55	2.97	1.44	1.92	0.479	1.44	0.232	1.11	0.122	0.710	0.041	0.491	0.016		
600	4.62	4.20	3.24	1.69	2.10	0.566	1.57	0.273	1.22	0.146	0.775	0.047	0.536	0.019		
650	5.00	6.88	3.51	1.97	2.27	0.658	1.70	0.319	1.32	0.169	0.839	0.055	0.581	0.022		
700	5.39	5.63	3.78	2.28	2.45	0.759	1.83	0.368	1.42	0.194	0.904	0.063	0.625	0.025		
															8"	
750	5.77	6.44	4.05	2.60	2.62	0.863	1.96	0.420	1.52	0.218	0.968	0.072	0.670	0.029		
800			4.32	2.95	2.80	0.977	2.09	0.473	1.62	0.246	1.03	0.081	0.715	0.032		
850			4.59	3.31	2.97	1.09	2.22	0.528	1.72	0.277	1.10	0.091	0.760	0.036	0.439	0.009
900					3.15	1.22	2.35	0.585	1.82	0.308	1.16	0.010	0.804	0.041	0.465	0.010
950					3.32	1.35	2.48	0.649	1.93	0.342	1.23	0.111	0.849	0.045	0.491	0.012
1000					3.50	1.50	2.61	0.714	2.03	0.377	1.29	0.122	0.894	0.049	0.516	0.013
1100					3.85	1.75	2.87	0.860	2.23	0.452	1.42	0.147	0.983	0.059	0.568	0.015
1200					4.20	2.14	3.14	1.02	2.43	0.534	1.55	0.172	1.07	0.069	0.620	0.018
1300							3.40	1.19	2.64	0.627	1.68	0.200	1.16	0.080	0.671	0.021
1400							3.66	1.37	2.84	0.722	1.81	0.232	1.25	0.091	0.723	0.024



Valve & Fitting Losses Expressed in Equivalent Meters of Pipe

	Pipe Fitting or Valve	Nominal Pipe or Tube Size (mm)												
		10	15	20	25	32	40	50	65	80	90	100	125	150
1	90° Standard Elbow	0.43	0.49	0.61	0.79	1.01	1.22	1.52	1.83	2.29	2.74	3.05	3.96	4.88
2	45° Standard Elbow	0.21	0.24	0.27	0.40	0.52	0.64	0.79	0.98	1.22	1.43	1.58	1.98	2.41
3	Flow-Through Branch Tee	0.82	0.91	1.22	1.52	2.13	2.44	3.05	3.66	4.57	5.49	6.40	7.62	9.14
4	Straight Through Flow Tee - No Reduction	0.27	0.30	0.43	0.52	0.70	0.79	1.01	1.25	1.52	1.80	2.04	2.50	3.05
5	Straight Through Flow Tee- Reduced 1/4	0.37	0.43	0.58	0.70	0.94	1.13	1.43	1.71	2.13	2.44	2.74	3.66	4.27
6	Straight Through Flow Tee - Reduced 1/8	0.43	0.49	0.61	0.79	1.01	1.22	1.52	1.83	2.29	2.74	3.05	3.96	4.88
7	Globe Valve - Fully opened	5.18	5.49	6.71	8.84	11.6	13.1	16.8	21.0	25.6	3.05	36.6	42.7	51.8
8	Gate Valve - Fully opened	0.18	0.21	0.27	0.30	0.46	0.55	0.70	0.85	0.98	1.22	1.37	1.83	2.13

Notes!

FLOW OF AIR THROUGH SCHEDULE 40 STEEL PIPE

Free Air m³/min at 15°C & 1.013 bar abs	Compressed Air m³/min at 15°C at 7 bar gauge	Pressure Drop per 100m of Schedule 40 Pipe For Air For 15°C and 7 bar gauge pressure								
		1/8" (**2 1/2"** from 2.25)	**1/4"**	**3/8"**	**1/2"**	**3/4"**	**1"**	**1 1/4"**	**1 1/2"**	**2"**
0.03	0.0038	0.093	0.021	0.0045						
0.06	0.0076	0.337	0.072	0.016	0.0051					
0.09	0.0114	0.719	0.154	0.033	0.011					
0.12	0.0152	1.278	0.267	0.058	0.018					
0.15	0.0190	1.942	0.405	0.087	0.027	0.0067				
0.2	0.0253	3.357	0.698	0.146	0.047	0.011	0.0035			
0.3	0.0379	7.554	1.57	0.319	0.099	0.024	0.0073			
0.4	0.0506		2.71	0.548	0.170	0.041	0.012			
0.5	0.0632		4.10	0.842	0.257	0.062	0.018			
0.6	0.0759		5.90	1.19	0.370	0.088	0.026	0.0066		
0.7	0.0885		8.03	1.62	0.494	0.117	0.035	0.0086	0.0041	
0.8	0.101			2.12	0.634	0.150	0.044	0.011	0.0053	
0.9	0.114			2.64	0.803	0.187	0.055	0.014	0.0065	
1.0	0.126			3.26	0.991	0.231	0.067	0.017	0.0079	
1.25	0.158			4.99	1.55	0.353	0.102	0.026	0.012	
1.5	0.190			7.20	2.19	0.499	0.147	0.036	0.017	0.0048
1.75	0.221			9.79	2.98	0.679	0.196	0.047	0.022	0.0064
2.0	0.253				3.82	0.871	0.257	0.062	0.029	0.0082
2.25	0.284	0.0042			4.84	1.10	0.325	0.076	0.036	0.010
2.5	0.316	0.0051			5.97	1.36	0.393	0.094	0.045	0.012

Pipe Dimensions & Weights

Nominal Pipe Size	OD	Schedule			Wall Thickness	ID	Weight
NPS [DN]	in [mm]				mm	mm	kg/m
1/8	**0.405**		10	10S	1.24	7.8	0.28
[6]	[10.3]	STD	40	40S	1.73	6.8	0.36
		XS	80	80S	2.41	5.5	0.47
1/4	**0.540**		10	10S	1.65	10.4	0.49
[8]	[13.7]	STD	40	40S	2.24	9.3	0.63
		XS	80	80S	3.02	7.7	0.80
3/8	**0.675**		10	10S	1.65	13.8	0.63
[10]	[17.1]	STD	40	40S	2.31	12.5	0.85
		XS	80	80S	3.20	10.7	1.10
1/2	**0.840**		5	5S	1.65	18.0	0.80
[15]	[21.3]		10	10S	2.11	17.1	1.00
		STD	40	40S	2.77	15.8	1.27
		XS	80	80S	3.73	13.9	1.62
			160		4.78	11.8	1.95
		XX			7.47	6.4	2.55
3/4	**1.050**		5	5S	1.65	23.4	1.02
[20]	[26.7]		10	10S	2.11	22.5	1.28
		STD	40	40S	2.87	20.9	1.68
		XS	80	80S	3.91	18.9	2.19
			160		5.56	15.5	2.89
		XX			7.82	11.0	3.63
1	**1.315**		5	5S	1.65	30.1	1.29
[25]	[33.4]		10	10S	2.77	27.9	2.09
		STD	40	40S	3.38	26.6	2.50
		XS	80	80S	4.55	24.3	3.23
			160		6.35	20.7	4.23
		XX			9.09	15.2	5.45
1-1/4	**1.660**		5	5S	1.65	38.9	1.65
[32]	[42.2]		10	10S	2.77	36.6	2.69
		STD	40	40S	3.56	35.1	3.38
		XS	80	80S	4.85	32.5	4.46
			160		6.35	29.5	5.60
		XX			9.70	22.8	7.76
1-1/2	**1.900**		5	5S	1.65	45.0	1.90
[40]	[48.3]		10	10S	2.77	42.7	3.10
		STD	40	40S	3.68	40.9	4.04
		XS	80	80S	5.08	38.1	5.40
			160		7.14	34.0	7.23
		XX			10.16	27.9	9.54
2	**2.375**		5	5S	1.65	57.0	2.39
[50]	[60.3]		10	10S	2.77	54.8	3.93
		STD	40	40S	3.91	52.5	5.44
		XS	80	80S	5.54	49.3	7.47
			160		8.74	42.9	11.10
		XX			11.07	38.2	13.44
3	**3.500**		5	5S	2.11	84.7	4.51
[80]	[88.9]		10	10S	3.05	82.8	6.45
		STD	40	40S	5.49	77.9	11.27
		XS	80	80S	7.62	73.7	15.26
			160		11.13	66.7	21.32
		XX			15.24	58.4	27.65
3-1/2	**4.000**		5	5S	2.11	97.4	5.17
[90]	[101.6]		10	10S	3.05	95.5	7.40
		STD	40	40S	5.74	90.1	13.56
		XS	80	80S	8.08	85.5	18.61
		XX			16.15	69.3	34.00

Nominal Pipe Size	OD	Schedule			Wall Thickness	ID	Weight
NPS [DN]	in [mm]				in	in	lb/ft
4	**4.500**		5	5S	2.11	110.1	5.83
[100]	[114.3]		10	10S	3.05	108.2	8.35
		STD	40	40S	6.02	102.3	16.06
		XS	80	80S	8.56	97.2	22.30
			120		11.13	92.1	28.28
			160		13.49	87.3	33.50
		XX			17.12	80.1	40.99
6	**6.625**		5	5S	2.77	162.7	11.29
[150]	[168.3]		10	10S	3.40	161.5	13.83
		STD	40	40S	7.11	154.1	28.24
		XS	80	80S	10.97	146.3	42.52
			120		14.27	139.7	54.16
			160		18.26	131.8	67.49
		XX			21.95	124.4	79.11
8	**8.625**			5S	2.77	213.5	14.75
[200]	[219.1]		10	10S	3.76	211.6	19.94
			20		6.35	206.4	33.28
			30		7.04	205.0	36.75
		STD	40	40S	8.18	202.7	42.49
			60		10.31	198.5	53.04
		XS	80	80S	12.70	193.7	64.57
			100		15.09	188.9	75.82
			120		18.26	182.6	90.35
			140		20.62	177.8	100.83
		XX			22.23	174.6	107.78
			160		23.01	173.1	111.15
10	**10.750**			5S	3.40	266.2	22.61
[250]	[273.1]			10S	4.19	264.7	27.76
			20		6.35	260.4	41.72
			30		7.80	257.5	50.96
		STD	40	40S	9.27	254.5	60.25
		XS	60	80S	12.70	247.7	81.46
			80		15.09	242.9	95.88
			100		18.26	236.5	114.63
			120		21.44	230.2	132.88
			140		25.40	222.3	154.97
			160		28.58	215.9	172.10
12	**12.750**			5S	3.96	315.9	31.23
[300]	[323.9]			10S	4.57	314.7	35.96
			20		6.35	311.2	49.67
			30		8.38	307.1	65.14
		STD		40S	9.53	304.8	73.76
			40		10.31	303.2	79.65
		XS		80S	12.70	298.5	97.35
			60		14.27	295.3	108.87
			80		17.48	288.9	131.90
			100		21.44	281.0	159.71
			120		25.40	273.1	186.75
			140		28.58	266.7	207.86
			160		33.32	257.2	238.51

BETE Fog Nozzle, Inc.
Application Information Sheet

FAX: 413 772-6729
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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?

Conversions & Equations

Q = Flow rate **P = Pressure SG= Specific Gravity**

$$Q = K(P)^x$$

$$P = \left(\frac{Q}{K}\right)^{1/X}$$

$$\left(\frac{Q_2}{Q_1}\right) = \left(\frac{P_2}{P_1}\right)^x$$

$$\left(\frac{Q_2}{Q_1}\right) = \sqrt{\frac{SG_1}{SG_2}}$$

Vessel with internal pressure:

$$l/min = K\left(P_{inlet} - P_{Vessel}\right)^x$$

Nozzle Series	Exponent x	Nozzle Series	Exponent x
BJ	0.50	PJ	0.50
CW	0.47	PSR	0.50
FF	0.50	SC	0.47
IS	0.50	SPN	0.50
L	0.50	ST	0.50
LP	0.50	STXP	0.50
MaxiPass	0.47	TC	0.46
MPL	0.43	TD/TDL	0.50
MicroWhirl	0.50	TF	0.50
N	0.50	TFXP	0.50
NC	0.47	TH, THW	0.50
NCJ	0.47	TW	0.50
NCK	0.47	WL	0.47
NCS	0.47	WT	0.50
NF	0.50	WTX	0.50
P	0.50	WTZ	0.50

Dropsize

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

System Design

$$P_{Pump} = P_{Nozzle} + P_{Pipe\ Losses} + \rho h / 100000$$

Conversion Data

MULTIPLY	BY	TO OBTAIN
atmospheres	1.013	bar
atmospheres	33.931	feet of water
atmospheres	1.0332	kg/cm²
atmospheres	101.3	kiloPascals (kPa)
atmospheres	14.696	psi
bar	100	kPa
bar	14.5	psi
barrels (oil)	42	gallons
centimeters	0.3937	inches
centiStokes	Sp. gravity	centiPoise
cm³	0.061	in³
cm³	0.000264	gallons
cm³	0.001	liters
ft³	1728	inches
ft³	0.02832	m³
ft³	7.48	gallons
ft³	28.32	liters
ft³ (water)	62.43	pounds (water)
in³	16.39	cm³
in³	0.00433	gallons
in³	0.164	liters
m³	35.31	ft³
m³	61.024	in³
m³	264.2	gallons
m³	1000	liters
degree (angle)	60	minutes
degree (Celsius)	(°C x 1.8) +32	degree (Fahrenheit)
degree (Fahrenheit)	(°F-32) x 5/9	degree (Celsius)
feet	0.3048	meters
feet/sec	30.48	centimeters/sec

Conversion Data

MULTIPLY	BY	TO OBTAIN
feet/sec	18.29	meters/min
feet of water	0.0295	atmospheres
feet of water	0.884	inches of mercury
feet of water	0.433	psi
gallons	3785	cm³
gallons	0.1337	ft³
gallons	0.83267	imperial gallons
gallons	3.785	liters
gallons/min	0.06309	liters/sec
imperial gallons	1.2	gallons
horsepower	1.014	horsepower (metric)
horsepower	33,000	foot pounds/min
horsepower	746	Watts
inches	2.54	centimeters
kg/cm²	14.22	psi
kiloWatts	1.340	horsepower
liters	1000	cm³
liters	0.264	gallons
liters	0.22	imperial gallons
liters	33.8	ounces (fluid)
meters	3.281	feet
microns (µm)	0.0394	thousandth of an inch
miles/hr	44.7	centimeters/sec
miles/hr	1.467	feet/sec
millimeters	0.0394	inches
psi	0.068	atmospheres
psi	0.06895	bar
psi	2.307	feet of water
psi	0.0703	kg/cm²
psi	6.895	kPa

Terms and Conditions.

Prices quoted are FOB, Greenfield, MA. Terms are Net 30 days for approved accounts. Minimum order is $50.00 net. A restocking charge of 30% will apply for standard product accepted for return up to one year from the date of purchase. BETE FOG NOZZLE reserves the right to charge interest on past-due accounts. No goods may be returned without prior authorization. Non-Standard items are not subject to return.

BETE FOG NOZZLE reserves the right to make changes in specifications or design at any time without notice. Illustrations shown in this catalog are for information only.
Warranty—all goods are warranteed for good workmanship in accordance with industry standard and will perform in accordance with the products' specification.
Limitation of Liability—BETE's liability shall be limited to the value of the product billed arising from a purchase order.