

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:

- its flow-rate-versus-pressure characteristics (see catalog flow rate tables)
- how the droplets will be distributed after leaving the nozzle (see spray pattern, pp. 2, 3)
- the size of the droplets that will be produced (contact BETE Applications Engineering if droplet size is critical)
- the nozzle connection to the feed pipe (see dimension tables)
- the material of construction (see page 13 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 $\text{gpm} \div \text{PSI}^x$.

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

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:

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

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**

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

Pump must be sized to provide 99 GPM at 26.4 PSI

vessel from the gauge pressure at the nozzle inlet as shown:

$$\text{GPM} = K (\text{PSI}_{\text{Inlet}} - \text{PSI}_{\text{Vessel}})^x$$

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 of fluids with different specific gravities:

$$\frac{Q_2}{Q_1} = \sqrt{\frac{\text{SG}_1}{\text{SG}_2}}$$

Viscosity also affects nozzle performance. High viscosities inhibit

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

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

Notes!

PHONE: 413-772-2166 or Fax to: 413-772-6729

FLOW OF AIR THROUGH SCHEDULE 40 STEEL PIPE

Free Air q' 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° and 100 Pounds Per Square Inch (PSI)									
		1/8"	1/4"	3/8"	1/2"						
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	3/4"					
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	1"	1 1/4"			
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			1 1/2"	
15	1.922		1 3.0	2.73	0.834	0.201	0.062				
20	2.563		2 2.8	4.76	1.43	0.345	0.102	0.026			
25	3.204		3 5.6	7.34	2.21	0.526	0.156	0.039	0.019		
30	3.845		1	0.5	3.15	0.748	0.219	0.055	0.026		
35	4.486		1	4.2	4.24	1.00	0.293	0.073	0.035		
40	5.126		1	8.4	5.49	1.30	0.379	0.095	0.044		
45	5.767		2	3.1	6.90	1.62	0.474	0.116	0.055		2"
50	6.408		2	8.5	8.49	1.99	0.578	0.149	0.067	0.019	
60	7.690	2 1/2"	4	0.7	12.2	2.85	0.819	0.200	0.094	0.027	
70	8.971		1		6.5	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	

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		Pressure Drop per 100 feet and Velocity in Schedule 40 Pipe for Water at 60° F															
		Velocity		Press. Drop		Velocity		Press. Drop		Velocity		Press. Drop		Velocity		Press. Drop	
Gallons per Minute	Cubic Ft. per Second	feet per Second	Lbs. per Sq. In.	feet per Second	Lbs. per Sq. In.	feet per Second	Lbs. per Sq. In.	feet per Second	Lbs. per Sq. In.	feet per Second	Lbs. per Sq. In.	feet per Second	Lbs. per Sq. In.	feet per Second	Lbs. per Sq. In.	feet per Second	Lbs. per Sq. In.
0.2	0.000446	1/8"		1/4"		3/8"		1/2"		3/4"		1"		1 1/4"		1 1/2"	
0.3	0.000668	1.13	1.86	0.616	0.359												
0.4	0.000891	1.69	4.22	0.924	0.903	0.504	0.159	0.317	0.061								
0.5	0.001114	2.26	6.98	1.23	1.61	0.672	0.345	0.422	0.086								
0.6	0.001337	2.82	10.5	1.54	2.39	0.840	0.539	0.528	0.167	0.301	0.033						
0.8	0.001782	3.39	14.7	1.85	3.29	1.01	0.751	0.633	0.240	0.361	0.041						
1	0.00223	4.52	25.0	2.46	5.44	1.34	1.25	0.844	0.408	0.481	0.102						
2	0.00446	5.65	37.2	3.08	8.28	1.68	1.85	1.06	0.600	0.602	0.155	0.371	0.048				
3	0.00668	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		
4	0.00891			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
5	0.01114	2"		2 1/2"		3"		3 1/2"		4"		5"		6"		8"	
6	0.01337	0.574	0.044	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
8	0.01782	0.765	0.073	8.40	36.7	8.40	36.7	5.28	11.2	3.01	2.75	1.86	0.835	1.073	0.223	0.788	0.104
10	0.02228	0.956	0.108	10.08	51.9	10.08	51.9	6.33	15.8	3.61	3.84	2.23	1.17	1.29	0.309	0.946	0.145
15	0.03342	1.43	0.224	13.44	91.1	13.44	91.1	8.45	27.7	4.81	6.60	2.97	1.99	1.72	0.518	1.26	0.241
20	0.04456	1.91	0.375	0.670	0.046	0.868	0.056	10.56	42.4	6.02	9.99	3.71	2.99	2.15	0.774	1.58	0.361
25	0.05570	2.39	0.561	1.01	0.094	1.30	0.114			9.03	21.6	5.57	6.36	3.22	1.63	2.37	0.755
30	0.06684	2.87	0.786	1.34	0.158	1.68	0.234			12.03	37.8	7.43	10.9	4.29	2.78	3.16	1.28
35	0.07798	3.35	1.05	1.68	0.234	2.01	0.327	0.812	0.041	9.28	16.7	5.37	4.22	5.37	4.22	3.94	1.93
40	0.08912	3.83	1.35	2.01	0.327	2.39	0.436	0.974	0.056	11.14	23.8	6.44	5.92	6.44	5.92	4.73	2.72
45	0.1003	4.30	1.67	2.35	0.436	2.68	0.556	1.14	0.074	12.99	32.2	7.51	7.90	7.51	7.90	5.52	3.64
50	0.1114	4.78	2.03	2.68	0.556	2.74	0.192	1.30	0.095	14.85	41.5	8.59	10.24	8.59	10.24	6.30	4.65
60	0.1337	5.74	2.87	2.95	0.668	3.02	0.239	1.46	0.117			9.67	12.80	9.67	12.80	7.09	5.85
70	0.1560	6.70	3.84	3.35	0.339	3.35	0.339	1.62	0.142			10.74	15.66	10.74	15.66	7.88	7.15
80	0.1782	7.65	4.97	4.02	1.18	3.68	0.406	1.95	0.204			12.89	22.2	12.89	22.2	9.47	10.21
90	0.2005	8.60	6.20	4.69	1.59	3.91	0.253	2.27	0.261			1.12	0.047			11.05	13.71
100	0.2228	9.56	7.59	5.36	2.03	4.16	0.253	2.60	0.334			1.28	0.060			12.62	17.59
125	0.2785	11.97	11.76	6.03	2.53	4.34	1.05	2.92	0.416			1.44	0.074			14.20	22.0
150	0.3342	14.36	16.70	4.34	1.05	5.43	1.61	3.25	0.509	2.52	0.272	1.60	0.090	1.11	0.036	15.78	26.9
175	0.3899	16.75	22.3	5.43	1.61	6.51	2.24	4.06	0.769	3.15	0.415	2.01	0.135	1.39	0.055	19.72	41.4
200	0.4456	19.14	28.8	6.51	2.24	7.60	3.00	4.87	1.08	3.78	0.580	2.41	0.190	1.67	0.077		
225	0.5013	-	-	7.60	3.00	8.68	3.87	5.68	1.44	4.41	0.774	2.81	0.253	1.94	0.102		
250	0.5570	-	-	8.68	3.87	9.77	4.83	6.49	1.85	5.04	0.985	3.21	0.323	2.22	0.130		
275	0.6127	-	-	9.77	4.83	10.85	5.93	7.30	2.32	5.67	1.23	3.61	0.401	2.50	0.162	1.44	0.043
300	0.6684	-	-	10.85	5.93	11.94	7.14	8.12	2.84	6.30	1.46	4.01	0.495	2.78	0.195	1.60	0.051
350	0.7798	-	-	11.94	7.14	13.00	8.36	8.93	3.40	6.93	1.79	4.41	0.583	3.05	0.234	1.76	0.061
400	0.8912	-	-	13.00	8.36	14.11	9.57	9.74	4.02	7.56	2.11	4.81	0.683	3.33	0.275	1.92	0.072
450	1.0030	-	-	14.11	9.57	15.26	10.81	10.56	4.61	8.22	2.84	5.62	0.919	3.89	0.367	2.24	0.095
500	1.114	10"		12"		14"		16"		18"		20"		22"		24"	
600	1.337	2.03	0.059	-	-	-	-	-	-	12.60	5.65	8.02	1.81	5.55	0.720	3.21	0.182
700	1.560	2.44	0.083	-	-	-	-	-	-	15.12	8.04	9.63	2.55	6.66	1.02	3.85	0.258
800	1.782	2.85	0.112	2.01	0.047	-	-	-	-	-	-	11.23	3.43	7.78	1.35	4.49	0.343
900	2.005	3.25	0.143	2.29	0.061	-	-	-	-	-	-	12.83	4.43	8.88	1.75	5.13	0.443
1000	2.228	3.66	0.179	2.58	0.075	2.13	0.047	-	-	-	-	14.44	5.58	9.99	2.18	5.77	0.554
1200	2.674	4.07	0.218	2.87	0.091	2.37	0.057	-	-	-	-	16.04	6.84	11.10	2.68	6.41	0.675
1400	3.119	4.48	0.306	3.44	0.128	2.85	0.080	2.18	0.042	-	-	-	-	13.33	3.81	7.70	0.948
1600	3.565	5.70	0.409	4.01	0.171	3.32	0.107	2.54	0.055	-	-	-	-	15.55	5.13	8.98	1.28
1800	4.010	6.51	0.527	4.59	0.219	3.79	0.138	2.90	0.071	-	-	-	-	17.77	6.61	10.26	1.65
2000	4.456	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	11.54	2.08
		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	12.82	2.55



Valve & Fitting Losses in Expressed in Equivalent Feet of Pipe

Pipe Fitting or Valve	Nominal Pipe or Tube Size (inches)													
	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
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

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:

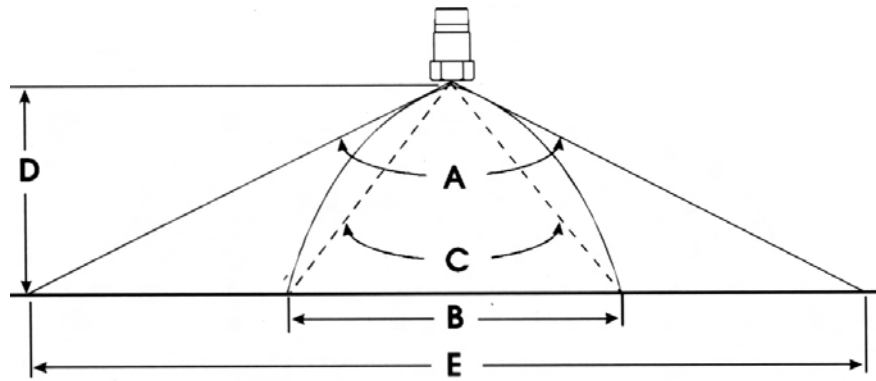
(B) The actual coverage at a specified distance **(D)** from the nozzle.

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.



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.

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 109.

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 0.01 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 tap this modeling and simulation technology to offer customized spray nozzle solutions to some of the most vexing problems facing industry today.

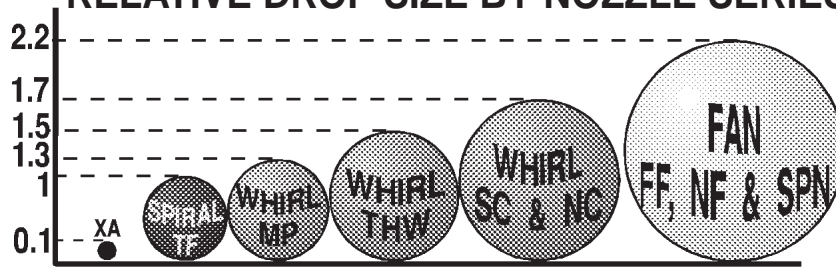
INDUSTRY COOPERATIVE DEVELOPMENT PROGRAMS

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

RELATIVE DROP SIZE BY NOZZLE SERIES



Sauter Mean Diameter (D₃₂):

- 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 (DV₀₅):

- 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

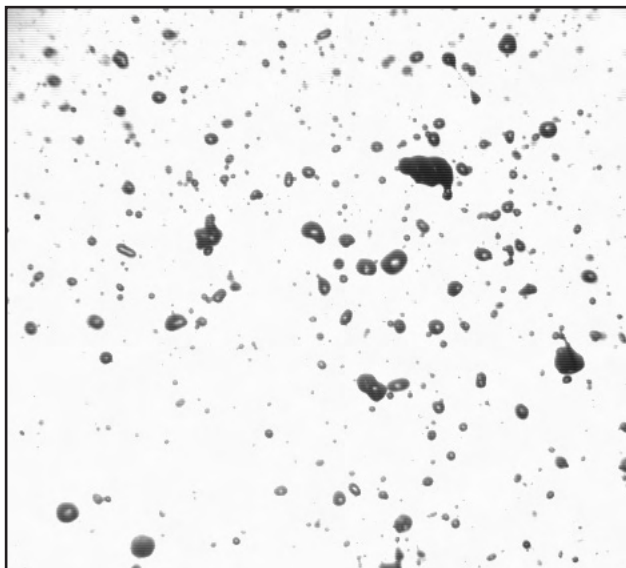
Incorrect Nozzle Location

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

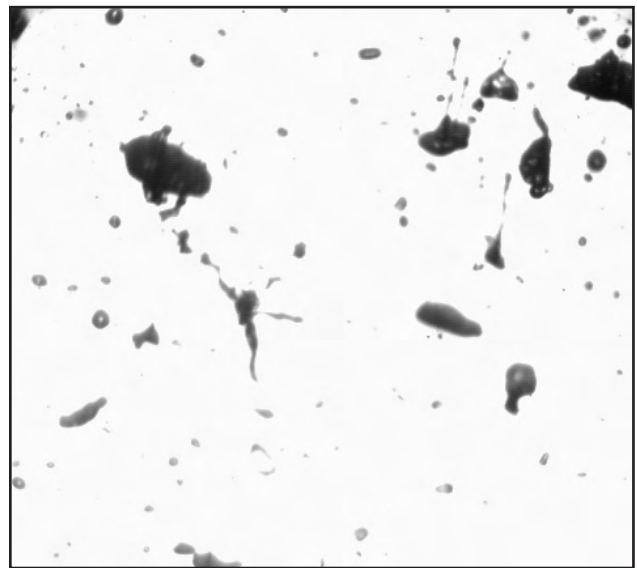
Incorrect Nozzle for Application

- 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.

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

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

a nozzle system:

where:

ρ = density of fluid (lbs/ft³)
[water = 62.4 lbs/ft³]

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 115. 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. 115) also contribute to pressure loss and can be significant, especially in short, convoluted runs.

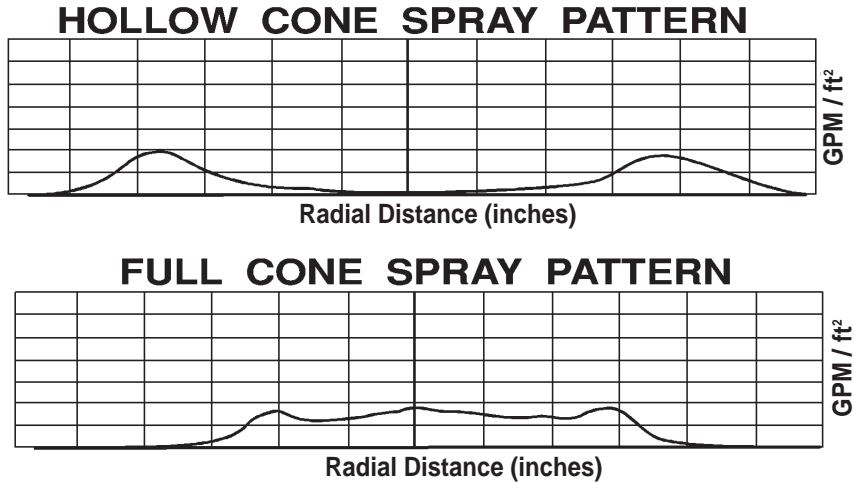
SPRAY ANGLE

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 114.

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 GPM/ft².

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 ft². If we now split it in two, we expose some of the inner surface and increase the total surface area to 2.1 ft². Atom-

izing the liquid into spheres 1 mm (1,000 microns) in diameter would increase the surface area of this gallon of liquid to 244 ft².

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:

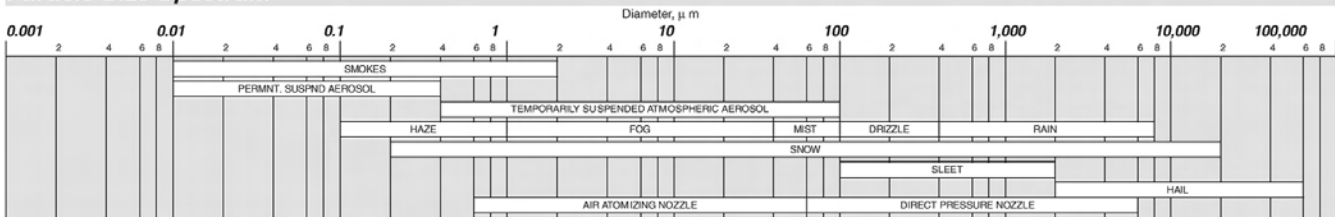
Arithmetic Mean Diameter (D₁₀):

- The average of the diameters of all the droplets in the spray sample.

Volume Mean Diameter (D₃₀):

- 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



Conversions & Equations

Flow rate

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

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

$$PSI = \left(\frac{Q}{K}\right)^{1/x}$$

Vessel with internal pressure:

$$\left(\frac{Q_2}{Q_1}\right) = \left(\frac{PSI_2}{PSI_1}\right)^x$$

$$GPM = K (PSI_{inlet} - PSI_{Vessel})^x$$

Dropsizes

System Design

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

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

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
LEM	0.50	STXP	0.50
LP	0.50	TC	0.46
MaxiPass	0.47	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

Conversion Data		
MULTIPLY	BY	TO OBTAIN
atmospheres	1.013	bar
atmospheres	33.931	feet of water
atmospheres	1.0332	kg/cm ²
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
cm ³	0.061	in ³
cm ³	0.000264	gallons
cm ³	0.001	liters
ft ³	1728	inches
ft ³	0.02832	m ³
ft ³	7.48	gallons
ft ³	28.32	liters
ft ³ (water)	62.43	pounds (water)
in ³	16.39	cm ³
in ³	0.00433	gallons
in ³	0.164	liters
m ³	35.31	ft ³
m ³	61.024	in ³
m ³	264.2	gallons
m ³	1000	liters
degree (angle)	60	minutes
degree (Celsius)	(°C x 1.8) +32	degree (Fahrenheit)
degree (Fahrenheit)	(°F-32) x 0.56	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	cm ³
gallons	0.1337	ft ³
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/cm ²	14.22	psi
kiloWatts	1.340	horsepower
liters	1000	cm ³
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/cm ²
psi	6.895	kPa

Terms and Conditions.

Prices quoted are FOB, Greenfield, MA. Terms are 1%/10 net 30 days for approved ac-accounts. Minimum order is \$50.00 net. A restocking charge of 15% 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 warranted 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.