TECHNICAL REFERENCE

TABLE OF EQUIVALENTS

VOLUMETRIC UNIT EQUIVALENTS

	Cubic Centimeter	Fluid Ounce	Pound of Water	Liter	US Gallon	Cubic Foot	Cubic Meter
Cubic Centimeter	1	.034	2.2×10^{-3}	.001	2.64×10^{-4}	3.53×10^{-5}	1.0×10^{-6}
Fluid Ounce	29.4	1	.065	.030	7.81×10^{-3}	1.04×10^{-3}	2.96×10^{-5}
Pound of Water	454	15.4	1	.454	.12	.016	4.54×10^{-4}
Liter	1000	33.8	2.2	1	.264	.035	.001
US Gallon	3785	128	8.34	3.785	1	.134	3.78×10^{-3}
Cubic Foot	28320	958	62.4	28.3	7.48	1	.028
Cubic Meter	1.0×10^{6}	3.38×10^{4}	2202	1000	264	35.3	1

LIQUID PRESSURE EQUIVALENTS

	Lb/In² (psi)	Ft Water	Kg/Cm²	Atmosphere	Bar	Inch Mercury	kPa
Lb/In² (psi)	1	2.31	.070	.068	.069	2.04	6.895
Ft Water	.433	1	.030	.029	.030	.882	2.99
Kg/Cm²	14.2	32.8	1	.968	.981	29.0	98
Atmosphere	14.7	33.9	1.03	1	1.01	29.9	101
Bar	14.5	33.5	1.02	.987	1	29.5	100
Inch Mercury	.491	1.13	.035	.033	.034	1	3.4
kPa (kilopascal)	.145	.335	.01	.009	.01	.296	1

LINEAR UNIT EQUIVALENTS

	Micron	Mil	Millimeter	Centimeter	Inch	Foot	Meter
Micron	1	.039	.001	1.0×10^{-4}	3.94×10^{-5}	–	–
Mil	25.4	1	2.54×10^{-2}	2.54×10^{-3}	.001	8.33×10^{-5}	–
Millimeter	1000	39.4	1	.10	.0394	3.28×10^{-3}	.001
Centimeter	10000	394	10	1	.394	.033	.01
Inch	2.54×10^{4}	1000	25.4	2.54	1	.083	.0254
Foot	3.05×10^{5}	1.2×10^{4}	305	30.5	12	1	.305
Meter	1.0×10^{6}	3.94×10^{4}	1000	100	39.4	3.28	1

MISCELLANEOUS EQUIVALENTS AND FORMULAS

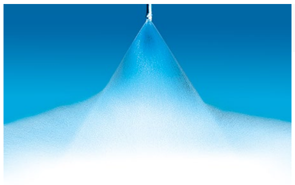
Unit	Equivalent	Unit	Equivalent
Ounce	28.35 Gr.	Acre	43,560 ft²
Pound	.4536 Kg.	Fahrenheit (°F)	= 9/5 (°C) + 32
Horse-Power	.746 Kw.	Celsius (°C)	= 5/9 (°F – 32)
British Thermal Unit	.2520 Kg. Cal.	Circumference of a Circle	= 3.1416 x D
Square Inch	6.452 cm²	Area of a Circle	= .7854 x D²
Square Foot	.09290 m²	Volume of a Sphere	= .5236 x D³
Acre	.4047 Hectare	Area of a Sphere	= 3.1416 x D²

DIMENSIONS

The catalog tabulations show orifice dimensions as “Nom.” (nominal). Specific dimensions are available on request.

BASIC NOZZLE CHARACTERISTICS

Spray nozzles are precision components designed to yield very specific performance under specific conditions. To help you determine the best nozzle type for your application, the following reference chart summarizes the performance that each nozzle type is designed to deliver.



FLAT SPRAY (TAPERED)

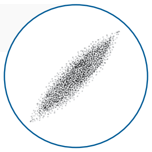
General Spray Characteristics

A tapered-edge flat spray pattern nozzle is usually installed on a header to provide uniform coverage over the entire swath as a result of overlapping distributions.

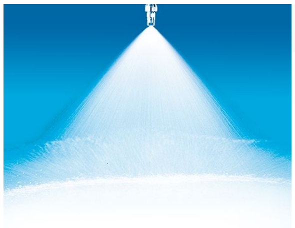
Comments

Designed to be used on a spray manifold or header for uniform, overall coverage across the impact area.

Spray pattern:



Spray angles: 15° to 110°



FULL CONE

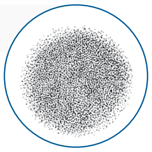
General Spray Characteristics

Provides relatively coarse drops in a full cone pattern with minimal flow obstruction.

Comments

Provides full spray pattern coverage with medium-to-large flow rates. Some vaneless models and oval spray models are also available.

Spray pattern:



Spray angles: 15° to 125°

ATOMIZING (HYDRAULIC, FINE MIST)

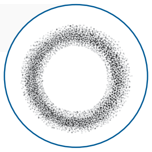
General Spray Characteristics

A hydraulic, finely atomized, low-capacity spray in a hollow cone pattern.

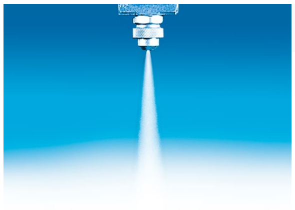
Comments

Used to produce finely atomized sprays when compressed air is not desirable.

Spray pattern:



Spray angles: 35° to 165°



AIR ATOMIZING AND AIR ASSISTED

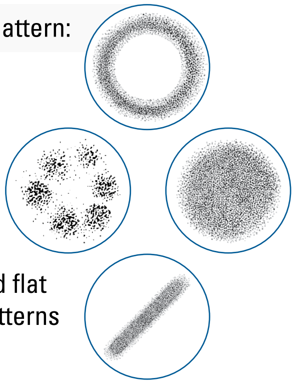
General Spray Characteristics

Atomization produced by a combination of air and liquid pressures. Air assisted nozzles feature internal impingement atomization to assist fine drop formation.

Comments

The most widely used nozzle group for producing finely atomized sprays in a wide range of capacities.

Spray pattern:



Cone and flat spray patterns

SPRAY DROP SIZE (ATOMIZATION)

Accurate drop size information is an important factor in the overall effectiveness of spray nozzle operation. Drop size refers to the size of the individual spray drops that comprise a nozzle's spray pattern. Each spray provides a range of drop sizes; this range is referred to as drop size distribution. Drop size distribution is dependent on the spray pattern type and varies significantly from one type to another. The smallest drop sizes are achieved by air atomizing nozzles while the largest drops are produced by full cone hydraulic spray nozzles.

Liquid properties, nozzle capacity, spraying pressure and spray angle also affect drop size. Lower spraying pressures provide larger drop sizes. Conversely, higher spraying pressures yield smaller drop sizes. Within each type of spray pattern, the smallest capacities produce the smallest spray drops, and the largest capacities produce the largest spray drops.

DROP SIZE (BY SPRAY PATTERN TYPE AT VARIOUS PRESSURES AND CAPACITIES)

Spray Pattern Type	10 psi (0.7 bar)			40 psi (2.8 bar)			100 psi (7 bar)		
	Capacity gpm	Capacity l/min	VMD microns	Capacity gpm	Capacity l/min	VMD microns	Capacity gpm	Capacity l/min	VMD microns
Air Atomizing	.005 .02	.02 .08	20 100	.008 8	.03 30	15 200	12	45	400
Fine Spray	.22	.83	375	.03 .43	.1 1.6	110 330	.05 .69	.2 2.6	110 290
Hollow Cone	.05 12	.19 45	360 3400	.10 24	.38 91	300 1900	.16 38	.61 144	200 1260
Flat Fan	.05 5	.19 18.9	260 4300	.10 10	.38 38	220 2500	.16 15.8	.61 60	190 1400
Full Cone	.10 12	.38 45	1140 4300	.19 23	.72 87	850 2800	.30 35	1.1 132	500 1720

Based on a sampling of nozzles selected to show the wide range of possible drop sizes available.

One of the most common drop size distribution functions used in the industry is the **ASTM® Standard E799-03** analysis:

$$d_{pq}^{(p-q)} = \left[\frac{\Sigma\ N_i d_i^{\,p}}{\Sigma\ N_i d_i^{\,q}} \right]$$

The ASTM Standard E799-03 is best suited for use with analyzers that are classified as single particle counters such as the PMS-OAP and PDPA. This standard is used to classify the drop counts/diameters and also to calculate the distribution and the characteristic or mean diameters.

DROP SIZE TERMINOLOGY

Terminology is often the major source of discrepancy and confusion in understanding drop size. The mean and characteristic diameters are the diameters extracted from the drop size distribution (see Figure 1). To compare the drop size from one nozzle to another, the same diameters have to be used as the source of comparison.

For example, one cannot compare the $D_{V0.5}$ from one nozzle to the D32 from another nozzle. The following lists the most popular mean and characteristic diameters, definitions and most appropriate use. Drop size terminology can be found in ASTM® Standard E1620-97.

$D_{V0.5}$: Volume Median Diameter (also known as VMD or MVD). A means of expressing drop size in terms of the volume of liquid sprayed. The VMD is a value where 50% of the total volume (or mass) of liquid sprayed is made up of drops with diameters larger than the median value and 50% smaller than the median value. This is best used for comparing the average drop size from various analyzers.

D_{32} : Sauter Mean Diameter (also known as SMD) is a means of expressing the fineness of a spray in terms of the surface area produced by the spray. SMD is the diameter of a drop having the same volume to surface area ratio as the total volume of all the drops to the total surface area of all the drops. This diameter is best suited to calculate the efficiency and mass transfer rates in chemical reactions.

$D_{V0.1}$: A value where 10% of the total volume (or mass) of liquid sprayed is made up of drops with diameters smaller or equal to this value. This diameter is best suited to evaluate drift potential of individual drops.

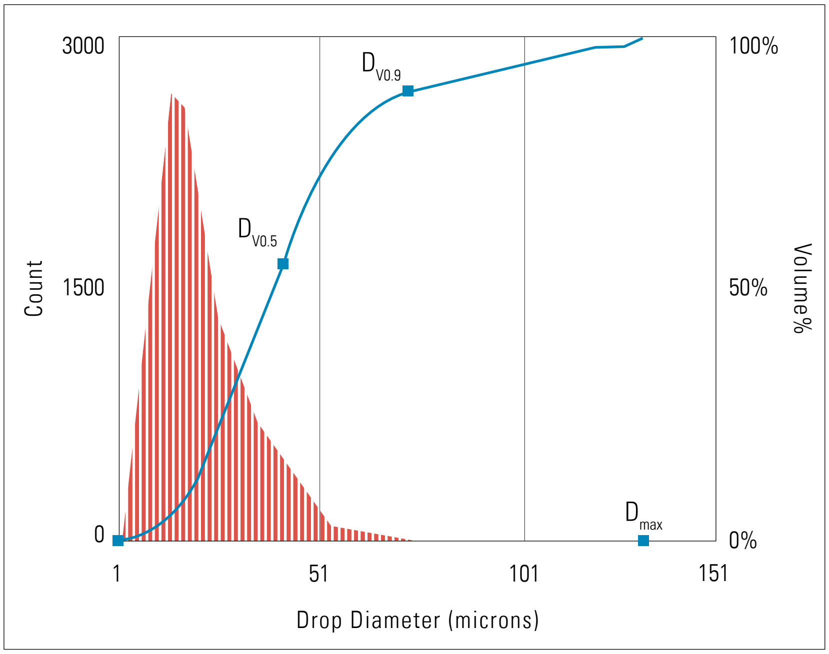
$D_{V0.9}$: A value where 90% of the total volume (or mass) of liquid sprayed is made up of drops with diameters smaller or equal to this value. This measurement is best suited when complete evaporation of the spray is required.

$D_{N0.5}$: Number Mean Diameter (also known as NMD) is a means of expressing drop size in terms of the number of drops in the spray. This means that 50% of the drops by count or number are smaller than the median diameter and 50% of the drops are larger than the median diameter.

Drop Size Distribution: The size distribution of drops present in a spray sample. This distribution is typically expressed by the size vs. the cumulative volume present.

Relative Span Factor (RSF): A dimensionless parameter indicative of the uniformity of the drop size distribution. RSF is defined as:

$$\frac{D_{V0.9} - D_{V0.1}}{D_{V0.5}}$$



Typical Drop Size Distribution

CAPACITY

Nozzle capacity varies with spraying pressure. In general, the relationship between flow rate and pressure is as follows:

$$\frac{Q_1}{Q_2} = \frac{(P_1)^n}{(P_2)^n}$$

Q: Flow rate (in gpm or l/min)

P: Liquid pressure (in psi or bar)

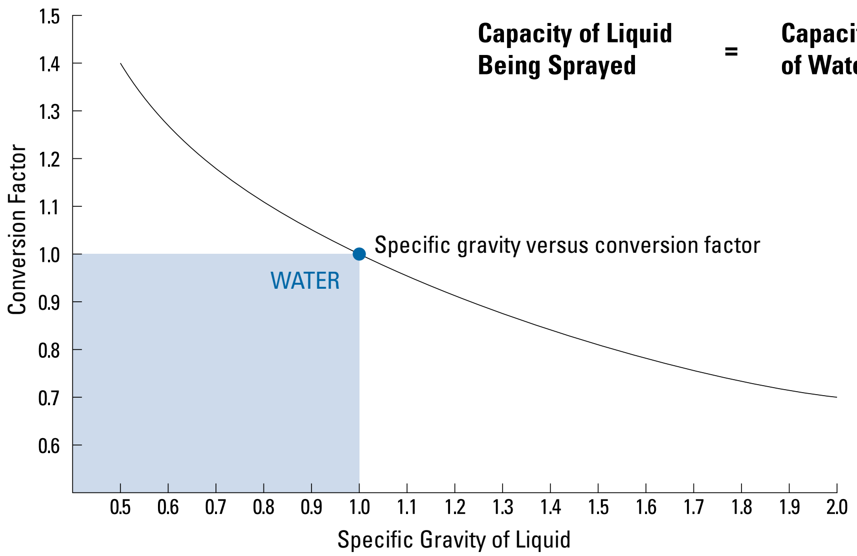
n: Exponent applying to the specific nozzle type

Nozzle Type	Exponent "n"
Hollow Cone Nozzles (All) Full Cone Nozzles (Vaneless) Full Cone Nozzles (15° and 30° Series) Flat Spray Nozzles (All) Solid Stream Nozzles (All) Spiral Nozzles (All)	.50
Full Cone Nozzles (Standard) Full Cone Nozzles (Square Spray) Full Cone Nozzles (Oval Spray) Full Cone Nozzles (Large Capacity)	.46

Since the specific gravity of a liquid affects its flow rate, tabulated catalog capacities must be multiplied by the conversion factor that applies to the specific gravity of the liquid being sprayed as explained in the Specific Gravity section below.

SPECIFIC GRAVITY

Specific gravity is the ratio of the mass of a given volume of liquid to the mass of the same volume of water. In spraying, the main effect of the specific gravity of a liquid (other than water) is on the capacity of the spray nozzle. Since the values in this catalog are based on spraying water, a conversion factor or formula can be applied to determine the nozzle capacity when using a liquid other than water.

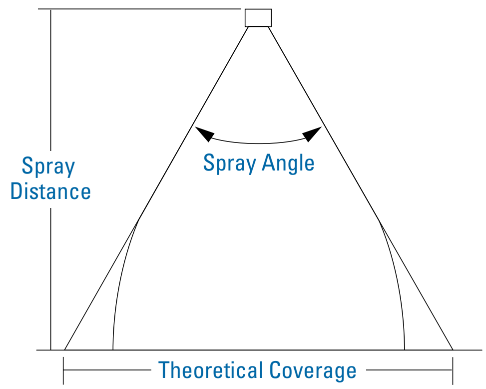


$$\text{Capacity of Liquid Being Sprayed} = \text{Capacity of Water} \times \sqrt{\frac{1}{\text{Specific Gravity}}}$$

KEY: Conversion factor multiplied by the capacity of the nozzle when spraying water gives the capacity of the nozzle when spraying a liquid with a specific gravity corresponding to the conversion factor. This conversion factor accounts only for the effect of specific gravity on capacity and does not account for other factors affecting capacity.

SPRAY ANGLE AND COVERAGE

Tabulated spray angles indicate approximate spray coverages based on spray of or distribution of water. In actual spraying, the effective spray angle varies with spray distance. Liquids more viscous than water form relatively smaller spray angles (or even a solid stream), depending upon viscosity, nozzle capacity and spraying pressure. Liquids with surface tensions lower than water will produce relatively wider spray angles than those listed for water. This table lists the theoretical coverage of spray patterns as calculated from the included spray angle of the spray and the distance from the nozzle orifice. Values are based on the assumption that the spray angle remains the same throughout the entire spray distance. In actual practice, the tabulated spray angle does not hold for long spray distances. If the spray coverage requirement is critical, request data sheets for specific spray coverage data.



THEORETICAL SPRAY COVERAGE (AT VARIOUS DISTANCES FROM NOZZLE ORIFICE)

Spray Angle	2 in.	5 cm	4 in.	10 cm	6 in.	15 cm	8 in.	20 cm	10 in.	25 cm	12 in.	30 cm	15 in.	40 cm	18 in.	50 cm	24 in.	60 cm	30 in.	70 cm	36 in.	80 cm	48 in.	100 cm
5°	0.2	0.4	0.4	0.9	.5	1.3	.7	1.8	.9	2.2	1.1	2.6	1.3	3.5	1.6	4.4	2.1	5.2	2.6	6.1	3.1	7.0	4.2	8.7
10°	0.4	0.9	0.7	1.8	1.1	2.6	1.4	3.5	1.8	4.4	2.1	5.3	2.6	7.0	3.1	8.8	4.2	10.5	5.2	12.3	6.3	14.0	8.4	17.5
15°	0.5	1.3	1.1	2.6	1.6	4.0	2.1	5.3	2.6	6.6	3.2	7.9	3.9	10.5	4.7	13.2	6.3	15.8	7.9	18.4	9.5	21.1	12.6	26.3
20°	0.7	1.8	1.4	3.5	2.1	5.3	2.8	7.1	3.5	8.8	4.2	10.6	5.3	14.1	6.4	17.6	8.5	21.2	10.6	24.7	12.7	28.2	16.9	35.3
25°	0.9	2.2	1.8	4.4	2.7	6.7	3.5	8.9	4.4	11.1	5.3	13.3	6.6	17.7	8.0	22.2	10.6	26.6	13.3	31.0	15.9	35.5	21.2	44.3
30°	1.1	2.7	2.1	5.4	3.2	8.0	4.3	10.7	5.4	13.4	6.4	16.1	8.1	21.4	9.7	26.8	12.8	32.2	16.1	37.5	19.3	42.9	25.7	53.6
35°	1.3	3.2	2.5	6.3	3.8	9.5	5.0	12.6	6.3	15.8	7.6	18.9	9.5	25.2	11.3	31.5	15.5	37.8	18.9	44.1	22.7	50.5	30.3	63.1
40°	1.5	3.6	2.9	7.3	4.4	10.9	5.8	14.6	7.3	18.2	8.7	21.8	10.9	29.1	13.1	36.4	17.5	43.7	21.8	51.0	26.2	58.2	34.9	72.8
45°	1.7	4.1	3.3	8.3	5.0	12.4	6.6	16.6	8.3	20.7	9.9	24.9	12.4	33.1	14.9	41.4	19.9	49.7	24.8	58.0	29.8	66.3	39.7	82.8
50°	1.9	4.7	3.7	9.3	5.6	14.0	7.5	18.7	9.3	23.3	11.2	28.0	14.0	37.3	16.8	46.6	22.4	56.0	28.0	65.3	33.6	74.6	44.8	93.3
55°	2.1	5.2	4.2	10.4	6.3	15.6	8.3	20.8	10.3	26.0	12.5	31.2	15.6	41.7	18.7	52.1	25.0	62.5	31.2	72.9	37.5	83.3	50.0	104
60°	2.3	5.8	4.6	11.6	6.9	17.3	9.2	23.1	11.5	28.9	13.8	34.6	17.3	46.2	20.6	57.7	27.7	69.3	34.6	80.8	41.6	92.4	55.4	115
65°	2.5	6.4	5.1	12.7	7.6	19.1	10.2	25.5	12.7	31.9	15.3	38.2	19.2	51.0	22.9	63.7	30.5	76.5	38.2	89.2	45.8	102	61.2	127
70°	2.8	7.0	5.6	14.0	8.4	21.0	11.2	28.0	14.0	35.0	16.8	42.0	21.0	56.0	25.2	70.0	33.6	84.0	42.0	98.0	50.4	112	67.2	140
75°	3.1	7.7	6.1	15.4	9.2	23.0	12.3	30.7	15.3	38.4	18.4	46.0	23.0	61.4	27.6	76.7	36.8	92.1	46.0	107	55.2	123	73.6	153
80°	3.4	8.4	6.7	16.8	10.1	25.2	13.4	33.6	16.8	42.0	20.2	50.4	25.2	67.1	30.3	83.9	40.3	101	50.4	118	60.4	134	80.6	168
85°	3.7	9.2	7.3	18.3	11.0	27.5	14.7	36.7	18.3	45.8	22.0	55.0	27.5	73.3	33.0	91.6	44.0	110	55.0	128	66.0	147	88.0	183
90°	4.0	10.0	8.0	20.0	12.0	30.0	16.0	40.0	20.0	50.0	24.0	60.0	30.0	80.0	36.0	100	48.0	120	60.0	140	72.0	160	96.0	200
95°	4.4	10.9	8.7	21.8	13.1	32.7	17.5	43.7	21.8	54.6	26.2	65.5	32.8	87.3	39.3	109	52.4	131	65.5	153	78.6	175	105	218
100°	4.8	11.9	9.5	23.8	14.3	35.8	19.1	47.7	23.8	59.6	28.6	71.5	35.8	95.3	43.0	119	57.2	143	71.6	167	85.9	191	114	238
110°	5.7	14.3	11.4	28.6	17.1	42.9	22.8	57.1	28.5	71.4	34.3	85.7	42.8	114	51.4	143	68.5	171	85.6	200	103	229	–	286
120°	6.9	17.3	13.9	34.6	20.8	52.0	27.7	69.3	34.6	86.6	41.6	104	52.0	139	62.4	173	83.2	208	104	243	–	–	–	–
130°	8.6	21.5	17.2	42.9	25.7	64.3	34.3	85.8	42.9	107	51.5	129	64.4	172	77.3	215	103	257	–	–	–	–	–	–
140°	10.9	27.5	21.9	55.0	32.9	82.4	43.8	110	54.8	137	65.7	165	82.2	220	98.6	275	–	–	–	–	–	–	–	–
150°	14.9	37.3	29.8	74.6	44.7	112	59.6	149	74.5	187	89.5	224	112	299	–	–	–	–	–	–	–	–	–	–
160°	22.7	56.7	45.4	113	68.0	170	90.6	227	113	284	–	–	–	–	–	–	–	–	–	–	–	–	–	–
170°	45.8	114	91.6	229	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note: The data in this table applies to hydraulic sprays only. Coverage data for pneumatic/air atomizing sprays will vary.

IMPACT

Impact, or the impingement of a spray onto the target surface, can be expressed in several different ways. The most useful impact value with regard to spray nozzle performance is the impact per square inch (cm). Basically, this value depends on the spray pattern distribution and spray angle.

To obtain the impact per square inch (cm) [pounds (kg)-force per square inch (cm)] of a given nozzle, first determine the theoretical total impact using the following formula:

$$I = K \times Q \times P \sqrt{I}$$

I: Total theoretical spray impact

K: Constant

Q: Flow Rate

P: Liquid Pressure

I	pounds	kilograms
K	.0526	.024
Q	gpm	l/min
P	psi	kg/cm^2

Then, from the chart below, obtain the impact per square inch (cm) as a percent of the theoretical total impact and multiply by the theoretical total. The result is the unit impact in lbs.-f/sq. inch (kg/cm^2) at 12" (30 cm) distance from the nozzle.

The highest unit impact in lbs.-f/sq. inch (kg/cm^2) is provided by solid stream nozzles and can be closely approximated by the formula: 1.9 x [spraying pressure, psi (bar)]. As with all spray patterns, the unit impact decreases as the distance from the nozzle increases, thereby increasing the impact area size.

UNIT IMPACT* PER $INCH^2$ / CM^2

Spray Pattern	Spray Angle	Percent of Theoretical
Flat Fan	15°	30%
	25°	18%
	35°	13%
	40°	12%
	50°	10%
	65°	7.0%
	80°	5.0%
Full Cone	15°	11%
	30°	2.5%
	50°	1.0%
	65°	0.4%
	80°	0.2%
	100°	0.1%

*At 12" (30 cm) distance from the nozzle.

OPERATING PRESSURE

The values given in the tabulation sections of this catalog indicate the most commonly used pressure ranges for the associated spray nozzle or accessory. Some spray nozzles and accessories can perform below or above the pressures shown, while others can be modified at our factory or redesigned to accommodate the requirements of specific new applications.

Contact your local Spraying Systems Co. sales engineer if your application requires pressure ranges beyond those stated in this catalog.

ESTIMATING PRESSURE DROPS THROUGH FLUIDLINE ACCESSORIES

The rated capacities listed in this catalog for valves, strainers and fittings typically correspond to pressure drops of approximately 5% of their maximum operating pressure. Use the following formula to estimate the pressure drop of other flow rates.

$$\frac{Q_1}{Q_2} = \frac{(P_1)^{.5}}{(P_2)^{.5}}$$

Q: Flow rate (in gpm or l/min)

P: Liquid pressure (in psi or bar)

For pressure drop information on a specific product, contact your local sales engineer for data sheets listing pressure drops at various flow rates.

Example:

$$\frac{3\text{ gpm}}{5\text{ gpm}} = \frac{(P_1)^{.5}}{(25\text{ psi})^{.5}} \qquad P_1 = 9\text{ psi}$$

$$\frac{11\text{ l/min}}{19\text{ l/min}} = \frac{(P_1)^{.5}}{(1.8\text{ bar})^{.5}} \qquad P_1 = 0.6\text{ bar}$$

Accessory rated capacity	5 gpm (19 l/min)
Maximum recommended operating pressure	500 psi (35 bar)

Estimated pressure drop at
5 gpm (19 l/min) = 5% x 500 psi (35 bar) = 25 psi (1.8 bar)

APPROXIMATE FRICTION LOSS IN PIPE SETTINGS

Pipe Size Std. Wt. (in.) (in.)	Actual Inside Dia. in. (mm)	Gate Valve FULL OPEN ft. (m)	Globe Valve FULL OPEN ft. (m)	45° Elbow ft. (m)	Run of Std. Tee ft. (m)	Std. Elbow or Run of Tee Reduced 1/2 ft. (m)	Std. Tee Through Side Outlet ft. (m)
1/8	.269 (6.8)	.15 (.05)	8.0 (2.4)	.35 (.11)	.40 (.12)	.75 (.23)	1.4 (.43)
1/4	.364 (9.2)	.20 (.06)	11.0 (3.4)	.50 (.15)	.65 (.20)	1.1 (.34)	2.2 (.67)
1/2	.622 (15.8)	.35 (.11)	18.6 (5.7)	.78 (.24)	1.1 (.34)	1.7 (.52)	3.3 (1.0)
3/4	.824 (21)	.44 (.13)	23.1 (7.0)	.97 (.30)	1.4 (.43)	2.1 (.64)	4.2 (1.3)
1	1.049 (27)	.56 (.17)	29.4 (9.0)	1.2 (.37)	1.8 (.55)	2.6 (.79)	5.3 (1.6)
1-1/4	1.380 (35)	.74 (.23)	38.6 (11.8)	1.6 (.49)	2.3 (.70)	3.5 (1.1)	7.0 (2.1)
1-1/2	1.610 (41)	.86 (.26)	45.2 (13.8)	1.9 (.58)	2.7 (.82)	4.1 (1.2)	8.1 (2.5)
2	2.067 (53)	1.1 (.34)	58 (17.7)	2.4 (.73)	3.5 (1.1)	5.2 (1.6)	10.4 (3.2)
2-1/2	2.469 (63)	1.3 (.40)	69 (21)	2.9 (.88)	4.2 (1.3)	6.2 (1.9)	12.4 (3.8)
3	3.068 (78)	1.6 (.49)	86 (26)	3.6 (1.1)	5.2 (1.6)	7.7 (2.3)	15.5 (4.7)
4	4.026 (102)	2.1 (.64)	113 (34)	4.7 (1.4)	6.8 (2.1)	10.2 (3.1)	20.3 (6.2)
5	5.047 (128)	2.7 (.82)	142 (43)	5.9 (1.8)	8.5 (2.6)	12.7 (3.9)	25.4 (7.7)

AIR FLOW (SCFM AND NL / MIN) THROUGH SCHEDULE 40 STEEL PIPE

Applied Pressure psig	Nominal Standard Pipe Size (scfm)											Applied Pressure bar	Nominal Standard Pipe Size (Nl/min)										
	1/8"	1/4"	3/8"	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"	2-1/2"	3"		1/8"	1/4"	3/8"	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"	2-1/2"	3"
5	.5	1.2	2.7	4.9	6.6	13.0	27	40	80	135	240	**0.3**	14.2	34.0	76.5	139	187	370	765	1130	2265	3820	6796
10	.8	1.7	3.9	7.7	11.0	21	44	64	125	200	370	**0.7**	22.7	48.1	110	218	310	595	1245	1810	3540	5665	10480
20	1.3	3.0	6.6	13.0	18.5	35	75	110	215	350	600	**1.4**	36.8	85.0	187	370	525	990	2125	3115	6090	9910	16990
40	2.5	5.5	12.0	23	34	62	135	200	385	640	1100	**2.8**	70.8	155	340	650	960	1755	3820	5665	10900	18120	31150
60	3.5	8.0	18.0	34	50	93	195	290	560	900	1600	**4.1**	99.1	227	510	965	1415	2630	5520	8210	15860	25485	45305
80	4.7	10.5	23	44	65	120	255	380	720	1200	2100	**5.5**	133	297	650	1245	1840	3400	7220	10760	20390	33980	59465
100	5.8	13.0	29	54	80	150	315	470	900	1450	2600	**6.9**	164	370	820	1530	2265	4250	8920	13310	25485	41060	73625

FLOW OF WATER THROUGH SCHEDULE 40 STEEL PIPE

Flow gpm (l/min)	Pressure Drop in psi (bar) for Various Pipe Diameters*															
	0.125″	0.25″	0.375″	0.5″	0.75″	1.0″	1.25″	1.5″	2.0″	2.5″	3.0″	3.5″	4.0″	5.0″	6.0″	8.0″
0.3 (1.0)	**.42 (.07)**															
0.4 (1.5)	**.70 (.16)**	**.16 (.04)**														
0.5 (2.0)	1.1 (.26)	**.24 (.06)**														
0.6 (2.5)	1.5 (.40)	**.33 (.08)**														
0.8 (3.0)	2.5 (.56)	**.54 (.12)**	**.13 (.03)**													
1.0 (4.0)	3.7 (.96)	.83 (.21)	**.19 (.05)**	**.06 (.02)**												
1.5 (6.0)	8.0 (2.0)	1.8 (.45)	**.40 (.10)**	**.12 (.03)**												
2.0 (8.0)	13.4 (3.5)	3.0 (.74)	.66 (.17)	**.21 (.05)**	**.05 (.01)**											
2.5 (10)		4.5 (1.2)	1.0 (.25)	**.32 (.08)**	**.08 (.02)**											
3.0 (12)		6.4 (1.7)	1.4 (.35)	**.43 (.11)**	**.11 (.03)**											
4.0 (15)		11.1 (2.6)	2.4 (.54)	.74 (.17)	**.18 (.04)**	**.06 (.01)**										
5.0 (20)			3.7 (.92)	1.1 (.28)	**.28 (.07)**	**.08 (.02)**										
6.0 (25)			5.2 (1.2)	1.6 (.45)	**.38 (.11)**	**.12 (.03)**										
8.0 (30)			9.1 (2.1)	2.8 (.62)	.66 (.15)	**.20 (.04)**	**.05 (.01)**									
10 (40)				4.2 (1.1)	1.0 (.25)	**.30 (.08)**	**.08 (.02)**									
15 (60)					2.2 (.54)	.64 (.16)	**.16 (.04)**	**.08 (.02)**								
20 (80)					3.8 (9.3)	1.1 (.28)	**.28 (.07)**	**.13 (.03)**	**.04 (.009)**							
25 (100)						1.7 (.43)	.42 (.12)	**.19 (.05)**	**.06 (.01)**							
30 (115)						2.4 (.58)	.59 (.14)	**.27 (.06)**	**.08 (.015)**							
35 (130)						3.2 (.72)	.79 (.18)	.36 (.08)	**.11 (.02)**	**.04 (.01)**						
40 (150)							1.0 (.23)	.47 (.10)	**.14 (.03)**	**.06 (.012)**						
45 (170)							1.3 (.29)	.59 (.13)	**.17 (.04)**	**.07 (.016)**						
50 (190)							1.6 (.36)	.72 (.16)	**.20 (.05)**	**.08 (.02)**						
60 (230)							2.2 (.50)	1.0 (.23)	.29 (.07)	**.12 (.03)**	**.04 (.009)**					
70 (260)								1.4 (.32)	.38 (.09)	**.16 (.04)**	**.05 (.01)**					
80 (300)								1.8 (.38)	.50 (.11)	**.20 (.04)**	**.07 (.02)**					
90 (340)								2.2 (.50)	.62 (.14)	**.25 (.06)**	**.09 (.02)**	**0.4 (.009)**				
100 (380)								2.7 (.61)	.76 (.18)	.31 (.07)	**.11 (.03)**	**0.5 (.01)**				
125 (470)									1.2 (.28)	.47 (.11)	**.16 (.04)**	**0.6 (.02)**	**.04 (.009)**			
150 (570)									1.7 (.39)	.67 (.15)	**.22 (.05)**	**0.8 (.03)**	**.06 (.01)**			
200 (750)									2.9 (.64)	1.2 (.26)	.39 (.09)	0.3 (.04)	**.10 (.02)**			
250 (950)											.59 (.14)	0.4 (.06)	**.15 (.03)**	**.05 (.01)**		
300 (1150)											.84 (.19)	0.5 (.09)	**.21 (.05)**	**.07 (.02)**		
400 (1500)												0.6 (.16)	.37 (.08)	**.12 (.03)**	**.05 (.01)**	
500 (1900)													.57 (.13)	.18 (.04)	**.07 (.02)**	
750 (2800)														.39 (.09)	.16 (.03)	**.04 (.009)**
1000 (3800)														.68 (.16)	.27 (.06)	**.07 (.02)**
2000 (7500)															1.0 (.23)	.26 (.06)

Recommended capacity range for each size is displayed in bold type.
*Psi values are based on a pipe length of 10 feet. Bar values are based on a pipe length of 10 meters.

OTHER SPRAY PERFORMANCE CONSIDERATIONS

VISCOSITY

Absolute (dynamic) viscosity is the property of a liquid which resists change in the shape or arrangement of its elements during flow. Liquid viscosity is a primary factor affecting spray pattern formation and, to a lesser degree, capacity. High viscosity liquids require a higher minimum pressure to begin formation of a spray pattern and provide narrower spray angles as compared to those of water. See the chart below for the general effects of viscosity other than water.

TEMPERATURE

The values given in this catalog are based on spraying water at 70°F (21°C). Although liquid temperature changes do not affect the spray performance of a nozzle, they often affect viscosity, surface tension and specific gravity which do influence spray nozzle performance. See the chart below for the effects of temperature changes on spray nozzle performance.

SURFACE TENSION

The surface of a liquid tends to assume the smallest possible size; acting, in this respect, like a membrane under tension. Any portion of the liquid surface exerts a tension upon adjacent portions or upon other objects with which it is in contact. This force is in the plane of the surface and its amount per unit of length is surface tension. Its value for water is about 73 dynes per cm at 70°F (21°C). The main effects of surface tension are on minimum operating pressure, spray angle and drop size.

SUMMARY OF SPRAY PERFORMANCE CONSIDERATIONS

This chart summarizes the various factors that affect a spray nozzle's performance. However, because there are so many different types and sizes of spray nozzles, the effects may vary for your specific application. In some applications, there are interrelated factors which may counteract certain effects. For instance, in the case of a hollow cone spray nozzle, increasing the temperature of the liquid decreases the specific gravity, thereby producing a greater flow rate while at the same time decreasing the viscosity which reduces the flow.

Nozzle Characteristics	Increase in Operating Pressure	Increase in Specific Gravity	Increase in Viscosity	Increase in Fluid Temperature	Increase in Surface Tension
Pattern Quality	Improves	Negligible	Deteriorates	Improves	Negligible
Drop Size	Decreases	Negligible	Increases	Decreases	Increases
Spray Angle	Increases then decreases	Negligible	Decreases	Increases	Decreases
Capacity	Increases	Decreases	Full cone – increases Flat – decreases	Depends on fluid sprayed and nozzle used	No effect
Impact	Increases	Negligible	Decreases	Increases	Negligible
Velocity	Increases	Decreases	Decreases	Increases	Negligible
Wear	Increases	Negligible	Decreases	Depends on fluid sprayed and nozzle used	No effect

COMMON CAUSES OF SPRAY NOZZLE PROBLEMS

Many spray nozzle problems cannot be easily detected with a visual inspection. You should check the performance of your nozzles for damage during every preventive maintenance shutdown. What to look for depends on your application – sometimes it's wear from a high-pressure process or caking from spraying a viscous liquid. Nozzle performance can be compromised or rendered totally ineffective by eroded, damaged or obstructed nozzle orifices.

EROSION / WEAR

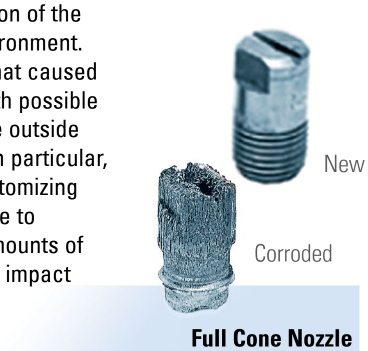
Gradual removal of the nozzle material causes the nozzle orifice and internal flow passages to enlarge and/or become distorted. As a result, flow is usually increased, pressure may be decreased, pattern becomes irregular and the spray drops become larger.

HIGH TEMPERATURE

Certain liquids must be sprayed at elevated temperatures or in high temperature environments. The nozzle may soften and break down unless special high temperature resistant materials are used.

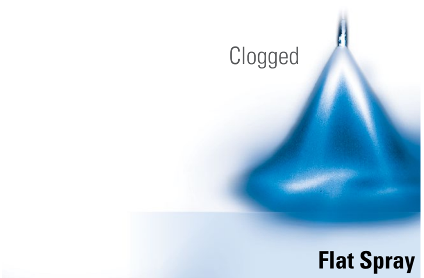
CORROSION

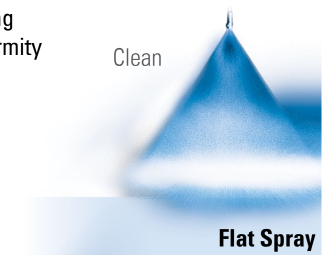
Nozzle material may break down due to the chemical action of the sprayed material or environment. The effect is similar to that caused by erosion and wear, with possible additional damage to the outside surfaces of the nozzle. In particular, the performance of air atomizing nozzles is highly sensitive to corrosion. Even small amounts of corrosion will negatively impact drop size and uniformity.



CLOGGING

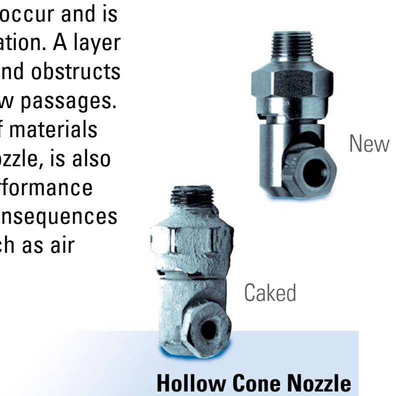
Unwanted solid particles can block the inside of the orifice, restricting the flow and disturbing the uniformity of the spray pattern.





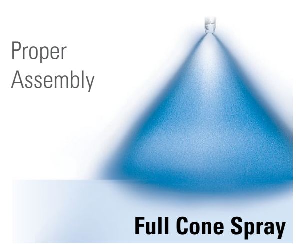
BEARDING / CAKING

Build-up of material on the inside or outer edges of the orifice can occur and is caused by liquid evaporation. A layer of dried solids remains and obstructs the orifice or internal flow passages. Bearding, the build-up of materials near the orifice of the nozzle, is also detrimental to nozzle performance and can have serious consequences in some nozzle types such as air atomizing.



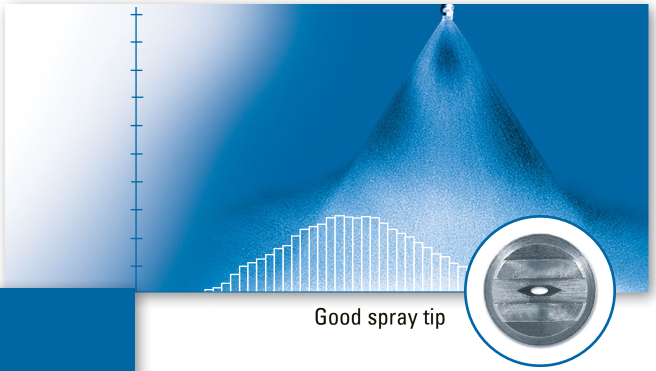
IMPROPER ASSEMBLY

Some nozzles require careful re-assembly after cleaning so that internal components, such as gaskets, O-rings and internal vanes, are properly aligned. Improper positioning may result in leakage and inefficient spray performance. Over-tightening of nozzle caps onto bodies can cause thread stripping.

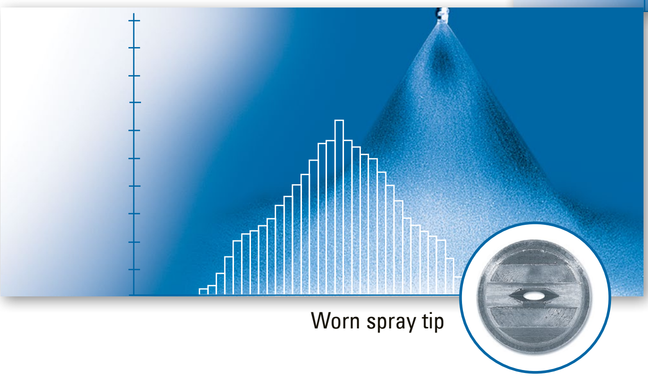


PREVENTING AND SOLVING SPRAY NOZZLE PROBLEMS

Some spray nozzle problems require special testing to detect. Consistent evaluation of the following factors will enable you to detect wear early and take appropriate action. Your own application will determine how often each factor should be checked. The proper frequency could range from the end of every shift to every few months. The checklist that follows should become the foundation of your maintenance program.



Good spray tip



Worn spray tip

Visual inspection of nozzle tips and spray patterns show little evidence of wear. An analysis of spray collection data reveals a 30% increase in capacity from the worn tip.

FLOW RATE

For centrifugal pumps:
Monitor flow meter readings to detect increases. Or, collect and measure the spray from the spray nozzle for a given period of time at a specific pressure. Compare these readings to the flow rates listed in the manufacturer's catalog or compare them to flow rate readings from new, unused spray nozzles.

For positive displacement pumps:

Monitor the liquid line pressure for decreases; the flow rate will remain constant.

SPRAY PRESSURE (IN SPRAY NOZZLE MANIFOLDS)

For centrifugal pumps:
Monitor for increases in liquid volume sprayed. The spraying pressure is likely to remain the same.

For positive displacement pumps:
Monitor pressure gauge for decreases in pressure and reduction in impact on sprayed surfaces. The liquid volume sprayed is likely to remain the same. Also, monitor for increases in pressure due to clogged spray nozzles.

DROP SIZE

Drop size increases are difficult to detect. Examine application results for changes. An increase in flow rate or decrease in spraying pressure will affect drop size.

SPRAY PATTERN

Visually inspect the spray pattern for changes. Check the spray angle with a protractor. Measure the width of the spray pattern on the sprayed surface. If the spray nozzle orifice is wearing gradually, you may not detect changes until there is a significant increase in flow rate.

SPRAY NOZZLE ALIGNMENT

Check uniformity of spray coverage of flat spray nozzles on a manifold. Spray patterns should be parallel to each other. Spray tips should be rotated 5° to 10° from the manifold centerline.

PRODUCT QUALITY / APPLICATION RESULTS

Check for uneven coating, cooling, cleaning or drying. Check for changes in temperature, dust content and humidity.

GENERAL SAFETY INSTRUCTIONS

Please read this important safety information before using any spray device, spray system or pressurized spray equipment.

WARNING
All safety related and operating instructions should be read before the nozzle is operated. Follow all operating instructions. Failure to do so could result in serious injury.

WARNING
It is important to recognize proper safety precautions when using a pressurized spray system. Fluids under pressure can penetrate skin and cause severe injury.

WARNING
When dealing with pressure applications, the system pressure should never exceed the lowest rated component. Always know your system and all component capabilities, maximum pressures, and flow rates.

WARNING
Before performing any maintenance, make sure all liquid supply lines to the machine are shut off and/or disconnected and any chemicals or fluids are drained.

WARNING
Spraying Systems Co. does not manufacture or supply any of the chemicals used with our nozzles and is not responsible for their effects. Because of the large number of chemicals that could be used (and their different chemical reactions), the buyer and user of this equipment should determine compatibility of the the materials used and any of the potential hazards involved.

NOTE: Always remember to carefully read the chemical manufacturer's label and follow all directions.

WARNING
The use of any chemicals requires careful control of all worker hygiene.

WARNING
Spraying Systems Co. strongly recommends the use of appropriate safety equipment when working with potentially hazardous chemicals.

This equipment includes, but is not limited to:

- Protective headgear
- Safety glasses and/or face shields
- Chemical-resistant gloves and aprons
- Long sleeve shirts and long pants

WARNING
Before use, be sure appropriate connections are secure and made to withstand weight and reaction forces of the operating unit.

WARNING
It is important to operate equipment within the temperature range of all components. Always ensure that the appropriate time has elapsed or proper safety equipment is used when handling components after they've been exposed to high temperatures.

WARNING
Do not use any equipment or product outside of its intended use or purpose. Misuse can result in personal injury or product damage.