TECHNICAL REFERENCE

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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 chart summarizes the performance that each nozzle type is designed to deliver. Visit **youtube.com/sprayingsystems** for video demonstrations of spray patterns.

The spray pattern images on the right were acquired in our spray laboratories using Laser Sheet Imaging (LSI). LSI images are collected by passing a laser sheet through a cross-section of the spray plume and imaging with a light-filtered camera. The distributions are directly proportional to the surface area distribution of the sprayed material (red: high; blue: low; black: zero). Volume distributions typically are similar to surface area distributions for these nozzles, depending on the local drop size distributions.

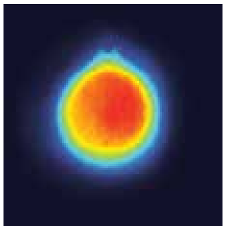
FULL CONE NOZZLES

- Uses a unique internal vane design to produce a solid cone-shaped spray pattern
- Spray pattern consists of medium- to large-sized drops

Typical applications:

- Chemical injection
- Dust suppression
- Fire protection
- Metal cooling
- Washing/rinsing

LASER SHEET IMAGE



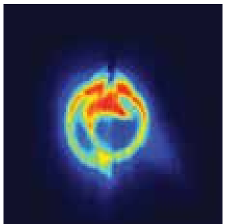
Spray Angle Range:
15° to 125°

FULL CONE (SPIRAL-TYPE) NOZZLES

- Produces a solid cone-shaped spray pattern when the fluid exits the voids in the spiral
- Spray pattern is not as uniform as full cone nozzles with an internal vane
- Spray pattern consists of relatively coarse drops

Typical applications:

- Dust suppression
- Fire protection
- Flue gas desulfurization (FGD)
- Quenching



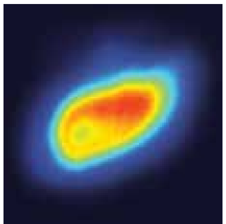
Spray Angle Range:
50° to 170°

FULL CONE (OVAL SPRAY) NOZZLES

- Uses a unique internal vane to produce a solid cone-shaped spray pattern with oval impact area with a width approximately one-half its length
- Spray pattern consists of medium- to large-sized drops

Typical applications:

- Air/gas washing
- Cooling and quenching
- Dust control
- Fire suppression



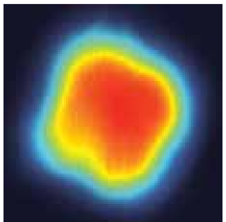
Spray Angle Range:
60° to 105°

FULL CONE (SQUARE SPRAY) NOZZLES

- Uses a unique internal vane to produce a solid cone-shaped spray with square impact area
- Spray pattern is uniform across entire spray area
- Spray pattern consists of medium- to large-sized drops

Typical applications:

- Air/gas washing
- Cooling and quenching
- Dust control
- Fire suppression



Spray Angle Range:
52° to 105°

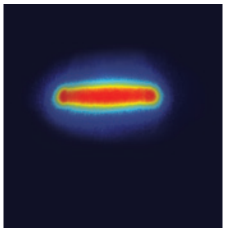
LASER SHEET IMAGE

FLAT (EVEN) NOZZLES

- Provides even distribution of medium-sized drops throughout the thin, rectangular spray pattern
- When used on a header, nozzles are positioned for edge-to-edge pattern contact

Typical applications:

- Descaling
- High-pressure cleaning
- Label removal



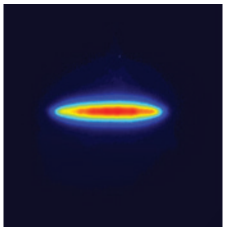
Spray Angle Range:
25° to 65°

FLAT SPRAY (TAPERED) NOZZLES

- Produces a tapered-edge flat spray pattern
- Used on spray headers to provide uniform coverage as a result of overlapping distributions

Typical applications:

- Coating
- Cooling
- Moisturizing
- Washing



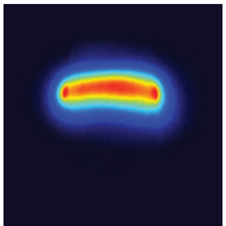
Spray Angle Range:
15° to 110°

FLAT SPRAY (DEFLECTED-TYPE) NOZZLES

- Uses a deflector surface to form an even flat spray pattern consisting of medium-sized drops
- Large free passage design reduces clogging through the round orifice

Typical applications:

- Showers in papermaking
- Washing



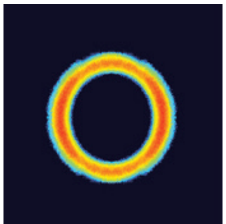
Spray Angle Range:
15° to 150°

HOLLOW CONE (WHIRLCHAMBER-TYPE) NOZZLES

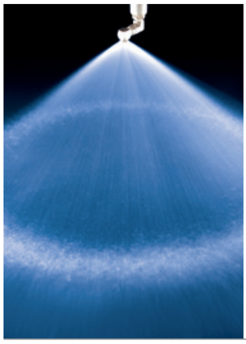
- Uses a whirlchamber to rotate the fluid and produce a circular spray pattern
- Ideal for use when a combination of small drop size and higher capacity is needed

Typical applications:

- Air, gas and water cooling
- Cooling products on conveyors
- Dust control
- Flue gas desulfurization (FGD)
- Water aeration



Spray Angle Range:
40° to 165°

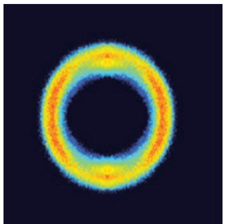


HOLLOW CONE (DEFLECTED-TYPE) NOZZLES

- Uses a deflector cap to form an umbrella-shaped hollow cone pattern

Typical applications:

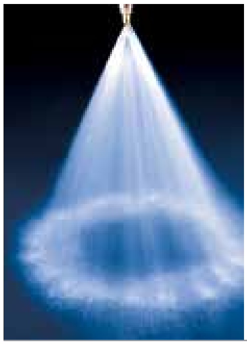
- Decorative spray
- Dust suppression
- Fire protection
- Flush cleaning of tube/pipe interiors
- Water curtain



Spray Angle Range:
100° to 180°

BASIC NOZZLE CHARACTERISTICS

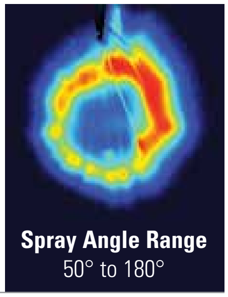
LASER SHEET IMAGE



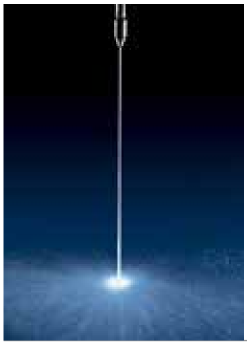
HOLLOW CONE (SPIRAL-TYPE) NOZZLES

- Produces a circular spray pattern when the fluid exits the voids in the spiral
- Drops are slightly coarser than those in other hollow cone sprays
- Provides a high flow rate in a compact nozzle size
- One-piece design produces maximum throughput for a given pipe size

Typical applications:
- Dust suppression
- Fire protection
- Flue gas desulfurization (FGD)



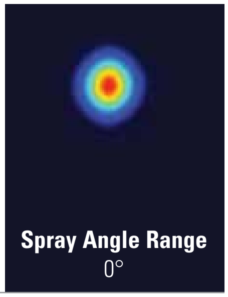
Spray Angle Range
50° to 180°



SOLID STREAM NOZZLES

- Produces a solid stream spray with the highest impact per unit area

Typical applications:
- Cleaning products when complete removal of dirt and debris is required
- Decorative spray ponds
- Laminar flow operations

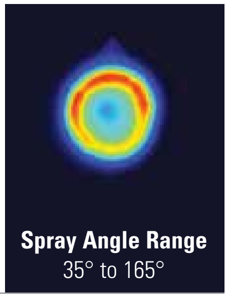


Spray Angle Range
0°

ATOMIZING (HYDRAULIC, FINE MIST) NOZZLES

- Produces a finely atomized, low capacity spray in a hollow cone pattern without use of compressed air

Typical applications:
- Dust suppression
- Evaporative cooling
- Moisturizing
- Spray drying

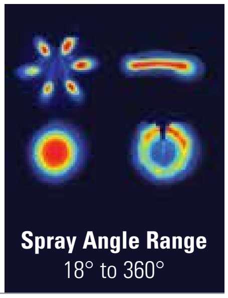


Spray Angle Range
35° to 165°

AIR ATOMIZING AND AIR ASSISTED NOZZLES

- Produces a variety of cone and flat spray patterns through atomization of liquid by compressed air
- Internal mix impingement atomization forms very fine drops

Typical applications:
- Coating
- Evaporative cooling
- Humidification
- Moisturizing



Spray Angle Range
18° to 360°

CAPACITY – FLUID CAPACITY VARIES WITH SPRAYING PRESSURE

The relationship of pressure and flow with a given orifice is:

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

Q = Flow Rate (in gpm or lpm)
P = Liquid pressure (in psi or bar)
n = Flow exponent

To approximate any unknown flow or pressure, use this formula when the other variables are known. The "n" exponent is used to approximate the ratio of pressure to flow based on the type of spray pattern.

Example:
To determine the flow rate of water for a 1/4G-10 standard full cone nozzle at 150 psi or at 10 bar, consult the performance charts in this catalog.

You will find that:

- The spray angle is 65°
- Flow (Q_1) at 40 psi = 1.9 gpm
- Pressure (P_1) = 40 psi
- Pressure (P_2) = 150 psi

Solving for Q_2 = 3.5 gpm

$$Q_2 = \frac{Q_1}{(P_1 / P_2)^n} = \frac{1.9 \text{ gpm}}{(40/150)^{.46}}$$

- The spray angle is 65°
- Flow (Q_1) at 3 bar = 7.5 lpm
- Pressure (P_1) = 3 bar
- Pressure (P_2) = 10 bar

Solving for Q_2 = 13 lpm

$$Q_2 = \frac{Q_1}{(P_1 / P_2)^n} = \frac{7.5 \text{ lpm}}{(3/10)^{.46}}$$

FLOW EXPONENT FOR SPECIFIC NOZZLE TYPES

Nozzle Type	Exponent "n"
Hollow Cone Nozzles – All Full Cone Nozzles – Vaneless, 15° and 30° Series Flat Spray Nozzles – All Solid Stream Nozzles – All Spiral Nozzles – All	.50
Full Cone Nozzles – Standard, Square, Oval and Large Capacity	.46
Full Cone Nozzles – Wide Spray and Wide Square Spray	.44

Visit spray.com/sprayware for online flow rate and spray coverage calculators.

SPECIFIC GRAVITY

All capacity tabulations in this catalog are based on water. 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 below.

Specific gravity is the ratio of the density of a fluid compared to the density of water. The specific gravity of water is defined as 1. When spraying fluids other than water, specific gravity must be considered in the flow calculations.

$$Q_2 = Q_1(\text{water}) \times \frac{1}{\sqrt{SG}}$$

Using the previous example:

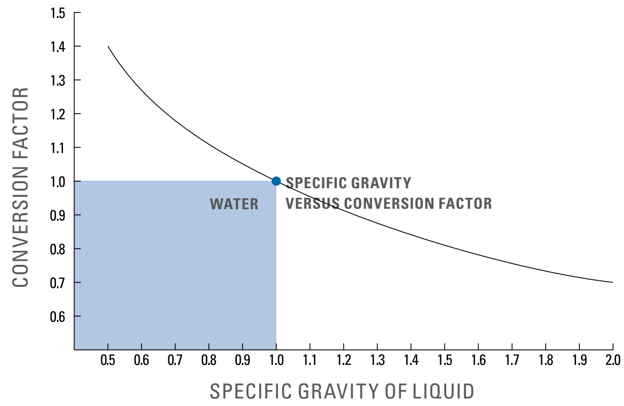
- Fluid sprayed is heavier than water and has a specific gravity of 1.4
- Flow of water at 150 psi = 3.5 gpm
- Heavy fluid (Q_2) = Q_1(water)*1/√1.4

$$Q_2 = \frac{3.5 \text{ gpm} * 1}{\sqrt{1.4}} = 2.95 \text{ gpm}$$

- Fluid sprayed is heavier than water and has a specific gravity of 1.4
- Flow of water at 10 bar = 13 lpm
- Heavy fluid (Q_2) = Q_1(water)*1/√1.4

$$Q_2 = \frac{13 \text{ lpm} * 1}{\sqrt{1.4}} = 11 \text{ lpm}$$

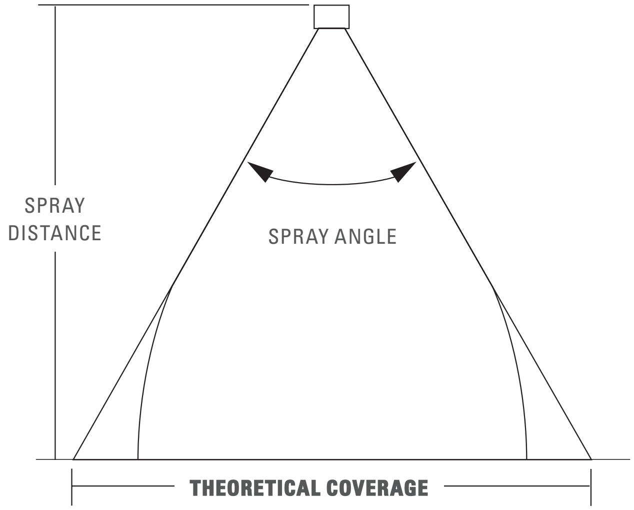
SPECIFIC GRAVITY VERSUS CONVERSION FACTOR



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 coverage based on spray 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.



Example: A spray nozzle with an angle of 65° spraying 15" (39 cm) from the target provides 19.2" (48.8 cm) of coverage

THEORETICAL SPRAY COVERAGE AT VARIOUS DISTANCES IN INCHES (CM) 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°	.2	.4	.4	.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°	.4	.9	.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°	.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°	.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°	.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	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Visit spray.com/sprayware for online flow rate and spray coverage calculators.

PUMPS

Every operation using spray nozzles requires a method to provide fluid flow. Fluid flow can be provided by gravity, air pressure or mechanical pumps. It is important to understand that pumping systems provide flow, not pressure. Pressure is the result of restricting flow. The output of an unrestricted pump is 0 psi (bar). When a restriction is placed in the flow, line pressure will result.

The main types of pumps are positive displacement and centrifugal. There are others, but the operational principles are the same as for positive displacement and centrifugal pumps.

Positive displacement pumps

A fixed volume of fluid is delivered for every stroke of a piston, or plunger or rotation of a shaft. Examples include piston pumps, plunger pumps, peristaltic pumps and gear pumps. Positive displacement pumps provide high pressure, and regardless of the system characteristics, will deliver a fixed flow every rotation. These pumps must have an unrestricted bypass valve and a pressure relief valve.

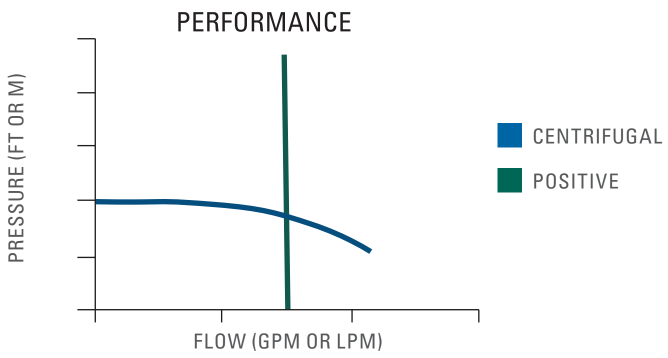
Centrifugal pumps (velocity pumps)

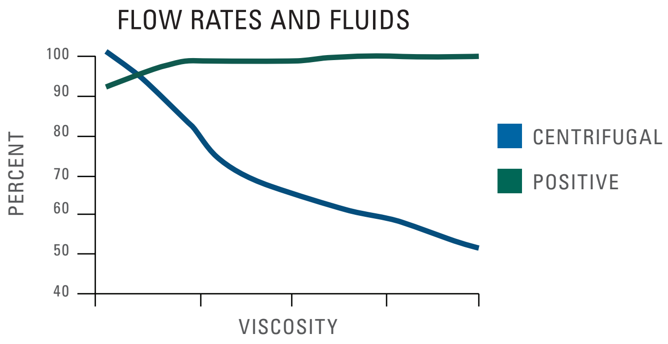
These pumps typically consist of a large vane (impeller) which is turned by a shaft inside a cavity (casing). The geometry of the impeller and casing moves the fluid in a tangential motion. The fluid gets restricted to a smaller volume and is then discharged into the system piping. These types of pumps typically operate at low pressure and high volume. They may also consist of several stages to increase the number of pressures available. These pumps have the unique feature of being able to run while the outlet is blocked. Since the pumps are velocity based, the impeller will spin in the casing fluid without “dead heading” the system itself. It will produce heat and may cavitate the fluid, but it will not build pressure like positive displacement pumps. However, a system bypass and pressure safety valve is still installed in the system to protect components.

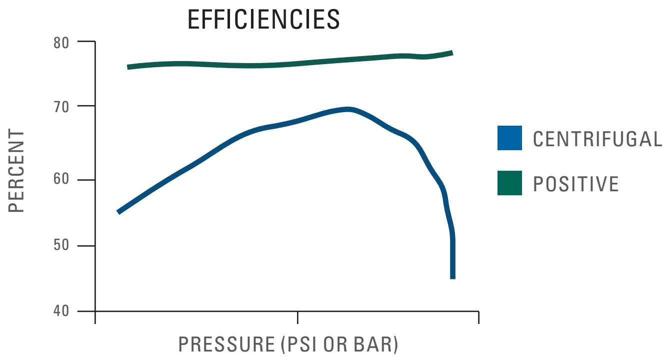
HOW PUMP TYPE AFFECTS NOZZLE SELECTION

The flow rates and pressures required by the system will determine the pump choice. There are many styles, sizes and types of pumps available but these general guidelines should prove helpful.

- High flows usually require a centrifugal style pump
- High pressures usually require a positive displacement pump
- Variable Frequency Drive (VFD) pumps may be an option. These pumps allow variable control of speed and flow rates
- Consider the fluid. Specific gravity will affect pump flow rates just as it affects nozzle flow rates
- Pump efficiencies, heat, available power, maintenance and plant conditions should also be considered







SPRAY DROP SIZE (ATOMIZATION)

Accurate drop size information is an important factor in optimizing spray nozzle performance, particularly in industrial applications such as gas cooling, gas conditioning, fire suppression and spray drying.

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.

ACTUAL DROP SIZES

- 500 µm
- 1200 µm
- 5500 µm

One inch = 25,400 µm
One millimeter = 1,000 µm
µm = micrometers

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		VMD	Capacity		VMD	Capacity		VMD
	gpm	lpm	microns	gpm	lpm	microns	gpm	lpm	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.

RELATIVE DROP SIZE

General drop size categories are used throughout this catalog. Actual drop size will vary based on flow rate and pressure, so for some nozzles, more than one drop size category is shown. If drop size is critical in your application, contact us for specific information.

IN MICRONS

FOG	LIGHT RAIN	MODERATE RAIN	INTENSE/HEAVY RAIN
10 to 100	100 to 500	500 to 1000	1000 to 5000
VERY SMALL	SMALL	MEDIUM	LARGE

DROP SIZE TERMINOLOGY

Terminology is often a major source of discrepancy and confusion in understanding drop size. To accurately compare drop sizes from one nozzle to another, the same diameters have to be used. Drop size is usually expressed in microns (micrometers). Following are the most popular characteristic diameters and their definitions.

$D_{V0.5}$: VOLUME MEDIAN DIAMETER (VMD)

A means of expressing drop size in terms of the volume of liquid sprayed. The Volume Median Diameter drop size when measured in terms of volume is a value where 50% of the total volume of liquid sprayed is made up of drops with diameters larger than the median value and 50% with smaller diameters.

$D_{V0.9}$:

A value where 90% of the total volume 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_{32} : SAUTER MEAN DIAMETER (SMD)

A means of expressing the fineness of a spray in terms of the surface area produced by the spray. The Sauter Mean Diameter 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.

More drop size data is available on all types of spray nozzles. For more information contact your local Spraying Systems Co. sales engineer.

IMPACT

Impact, is the measure of force imparted on a surface by a spray pattern at a given distance. It can be expressed in several ways. All definitions are derived from the most basic equation of total impact force. This is the force that any flow, at any pressure, is capable of making on a surface. This does not account for orifice shape, nozzle type, fluid properties and other factors.

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

Total theoretical impact = constant (based on units) x flow (at pressure P) x square root of pressure (P)

I = total theoretical spray impact

K = constant

Q = flow rate

P = liquid pressure

I	lbs.(f)	kg(f)	Newtons	Newtons
K	.0526	.024	.24	.745
Q	gpm	lpm	lpm	lpm
P	psi	kg/cm²	bar	MPa

The constant (K), is a unit conversion based on the measurement system used. The conversions are listed in the chart above.

Example:

I = .0526 x 3.5 gpm x √150 psi

I = 2.25 lbs(f) is available for distribution throughout the pattern

Contact your local sales engineer for assistance in determining impact in your application.

OPERATING PRESSURE AND NOZZLE MATERIALS

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.

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

NOZZLE MATERIALS

For each nozzle there is a selection of "standard" materials that have been determined to meet the usual requirements of the applications most commonly associated with that type of nozzle. Standard materials include brass, steel, various stainless steels, hardened stainless steels, many plastics and various carbides. Spray nozzles can also be supplied in other materials upon special request including:

- AMPCO® 8
- CARPENTER® 20 (Alloy 20)
- Ceramics
- CUPRO® NICKEL
- Graphite
- HASTELLOY®
- INCONEL®
- MONEL®
- Nylon
- Polypropylene, PVC and CPVC
- REFRAX®
- Silicon carbide
- Stellite®
- Titanium
- Zirconium

NOZZLE WEAR

Nozzle wear is typically characterized by an increase in nozzle capacity, followed by a general deterioration of the spray pattern. Flat fan spray nozzles with elliptical orifices experience a narrowing of the spray pattern. In other spray pattern types, the distribution within the spray pattern deteriorates without substantially changing the coverage area. The increase in nozzle capacity can sometimes be recognized by a decrease in system operating pressure, particularly when using positive displacement pumps.

Materials having harder surfaces generally provide longer wear life. The chart below provides standard abrasion resistance ratios for different materials to help you determine if you should consider a different material for your nozzles, orifice inserts and/or spray tips.

Materials that offer better corrosion resistance are also available. However, the rate of chemical corrosion on specific nozzle materials is dependent on the solution being sprayed. The corrosive properties of the liquid being sprayed, its percent concentration and temperature, as well as the corrosion resistance of the nozzle material to the chemical must all be considered.

APPROXIMATE ABRASION RESISTANCE RATIOS

Spray Nozzle Material	Resistance Ratio
Aluminum	1
Brass	1
Polypropylene	1–2
Steel	1.5–2
MONEL	2–3
Stainless Steel	4–6
HASTELLOY	4–6
Hardened Stainless Steel	10–15
Stellite	10–15
Silicon Carbide (Nitride Bonded)	90–130
Ceramics	90–200
Carbides	180–250
Synthetic Ruby or Sapphire	600–2000

See Trademark Registration and Ownership, page i-1.

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 – 100 cp or higher – require a higher minimum pressure to begin formation of a spray pattern and provide narrower spray angles as compared to those of 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.

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.

The property of surface tension is more apparent at low operating pressures. A higher surface tension reduces the spray angle, particularly on hollow cone and flat fan spray nozzles. Low surface tensions can allow a nozzle to be operated at a lower pressure.

SUMMARY OF SPRAY PERFORMANCE CONSIDERATIONS

The factors below can affect a spray nozzle's performance, and the effects can vary based on nozzle type and size. 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/hollow 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

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.

Visit spray.com/sprayware for an online pressure drop calculator. Or contact your local sales engineer.

APPROXIMATE FRICTION LOSS IN PIPE FITTINGS IN EQUIVALENT FEET (METERS) OF STRAIGHT PIPE

Use the chart below to determine the equivalent length of pipe through fittings to equate the friction loss.

Pipe Size Standard Wt. (in.)	Actual Inside Dia. in. (mm)	Gate Valve FULL OPEN ft. (m)	Globe Valve FULL OPEN ft. (m)	45° Elbow ft. (m)	Run of Standard Tee ft. (m)	Standard Elbow or Run of Tee Reduced 1/2 ft. (m)	Standard 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)
6	6.065 (154)	3.2 (.98)	170 (52)	7.1 (2.2)	10.2 (3.1)	15.3 (4.7)	31 (9.4)

AIR FLOW (SCFM AND NLPM) THROUGH SCHEDULE 40 STEEL PIPE

Applied Pressure psig	Nominal Standard Pipe Size (scfm)											Applied Pressure bar	Nominal Standard Pipe Size (nlpm)										
	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 – PRESSURE DROP

Flow	Pressure Drop in psi for Various Pipe Diameters 10 ft. Length Pipe															
gpm	1/8"	¼"	3/8"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	3½"	4"	5"	6"	8"
.3	.42															
.4	.70	.16														
.5	1.1	.24														
.6	1.5	.33														
.8	2.5	.54	.13													
1.0	3.7	.83	.19	.06												
1.5	8.0	1.8	.40	.12												
2.0	13.4	3.0	.66	.21	.05											
2.5		4.5	1.0	.32	.08											
3.0		6.4	1.4	.43	.11											
4.0		11.1	2.4	.74	.18	.06										
5.0			3.7	1.1	.28	.08										
6.0			5.2	1.6	.38	.12										
8.0			9.1	2.8	.66	.20	.05									
10				4.2	1.0	.30	.08									
15					2.2	.64	.16	.08								
20					3.8	1.1	.28	.13	.04							
25						1.7	.42	.19	.06							
30						2.4	.59	.27	.08							
35						3.2	.79	.36	.11	.04						
40							1.0	.47	.14	.06						
45							1.3	.59	.17	.07						
50							1.6	.72	.20	.08						
60							2.2	1.0	.29	.12	.04					
70								1.4	.38	.16	.05					
80								1.8	.50	.20	.07					
90								2.2	.62	.25	.09	.04				
100								2.7	.76	.31	.11	.05				
125									1.2	.47	.16	.08	.04			
150									1.7	.67	.22	.11	.06			
200									2.9	1.2	.39	.19	.10			
250											.59	.28	.15	.05		
300											.84	.40	.21	.07		
400												.70	.37	.12	.05	
500													.57	.18	.07	
750														.39	.16	.04
1000														.68	.27	.07
2000															1.0	.26

Flow	Pressure Drop in bar for Various Pipe Diameters 10 m Length Pipe															
lpm	1/8"	¼"	3/8"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	3½"	4"	5"	6"	8"
1	.07															
1.5	.16	.04														
2	.26	.06														
2.5	.40	.08														
3	.56	.12	.03													
4	.96	.21	.05	.02												
6	2.0	.45	.10	.03												
8	3.5	.74	.17	.05	.01											
10		1.2	.25	.08	.02											
12		1.7	.35	.11	.03											
15		2.6	.54	.17	.04	.01										
20			.92	.28	.07	.02										
25			1.2	.45	.11	.03										
30			2.1	.62	.15	.04	.01									
40				1.1	.25	.08	.02									
60					.54	.16	.04	.02	.006							
80					.93	.28	.07	.03	.009							
100						.43	.12	.05	.01							
115						.58	.14	.06	.015							
130						.72	.18	.08	.02	.01						
150							.23	.10	.03	.012						
170							.29	.13	.04	.016						
190							.36	.16	.05	.02						
230							.50	.23	.07	.03	.009					
260								.32	.09	.04	.01					
300								.38	.11	.04	.02	.007				
340								.50	.14	.06	.02	.009				
380								.61	.18	.07	.03	.01				
470									.28	.11	.04	.02	.009			
570									.39	.15	.05	.03	.01			
750									.64	.26	.09	.04	.02	.007		
950											.14	.06	.03	.01		
1150											.19	.09	.05	.02		
1500												.16	.08	.03	.01	
1900													.13	.04	.02	
2800														.09	.03	.009
3800														.16	.06	.02
7500															.23	.06

Recommended capacity range for each size is shown in shaded areas.
For pipe lengths greater than 10 ft. (3 m), the pressure loss is proportional to the length. For 50 ft. (15 m) of pipe, the pressure drop is approximately 5 times the value in the table.

MAINTAINING SPRAY NOZZLES

Like any precision component, spray nozzles wear over time. Spray nozzle wear can be hard to detect. Small changes in performance can result in quality problems and wasted water, chemicals and electricity. The cost of using worn nozzles can be very significant – tens of thousands of dollars or more per year. Detecting nozzle wear in the early stages can prevent a significant profit drain.

USING NOZZLES THAT ARE SPRAYING JUST 15% OVER THE RATED CAPACITY*

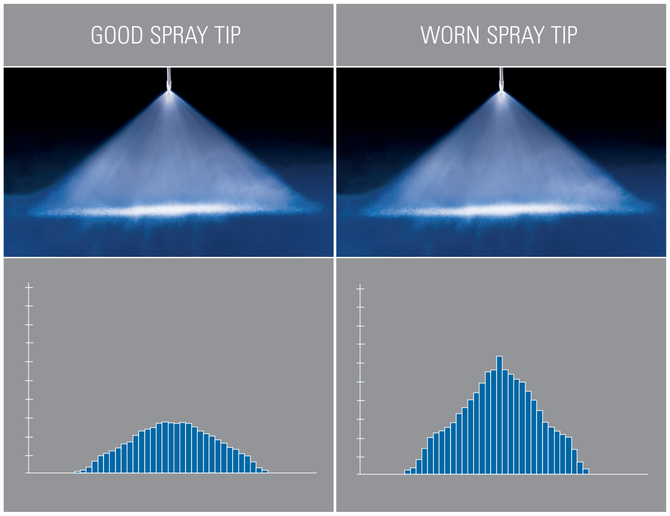
	WASTE	COST OF EXCESS
WATER	1,701,835 gallons (6,442,146 liters)	US $4,680
CHEMICALS	170,165 gallons (644,145 liters)	US $170,164
WASTEWATER DISPOSAL	1,872,000 gallons (7,086,291 liters)	US $7,956
TOTAL COST OF USING WORN NOZZLES:		**US $182,800**

*Based on total system flow of 100 gpm (379 lpm). Water cost of US $2.75/1000 gallons (3,785 liters). Chemical cost of US $1.00 per gallon (liter) and a dilution ratio of 10:1. System operates 2080 hours per year. Increased electricity cost, scrap and downtime due to quality problems are not included.

DETECTING WORN SPRAY NOZZLES

Visually inspecting nozzles is a start but unless wear is significant, it may not be detectable.

The graphic below illustrates this problem. The spray tip on the left is new and sprays properly. The spray tip on the right is worn and sprays 30% over capacity. The difference is undetectable by inspecting the nozzle, but spray collection data reveals the difference between the two tips.



WATCH FOR THESE SIGNS OF NOZZLE WEAR:

- **Quality control issues and increased scrap.** Check for uneven coating, cooling, drying or cleaning and changes in temperature, dust content and humidity
- **Flow rate change:**
  - For centrifugal pumps: monitor flow meter readings to detect increases or collect and measure the flow from the spray nozzle for a given period of time at a specific pressure and 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 the nozzle manifold:**
  - 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
- **Deterioration of spray pattern quality.** 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

REPLACING WORN NOZZLES

Inspecting and maintaining your nozzles on a regular basis will help identify wear and extend service life. However, wear will occur over time and the only solution is to replace your nozzles.

Here are a few guidelines to help you determine the optimal replacement interval:

- Are worn nozzles affecting product or process quality? If so, replace nozzles as soon as any wear is evident
- Is water conservation a priority? If so, replace nozzles as soon as wear is evident
- How much are you spending by continuing to use worn nozzles? How do the additional costs for water, chemicals, electricity and wastewater disposal compare with the cost of replacement nozzles?
- Is precise spray performance important to your overall process? If so, you may want to set pre-determined dates for nozzle replacement such as annual or semi-annual maintenance shutdowns

For more information on nozzle maintenance and replacement, visit spray.com. Or, contact your local sales engineer for assistance developing a nozzle maintenance program.

TABLE OF EQUIVALENTS

VOLUMETRIC UNIT

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

LIQUID PRESSURE

	lb/in² (psi)	Ft Water	Kg/Cm²	Atmosphere	Bar	Inch Mercury	kPa (kilopascal)
lb/in² (psi)	•	2.31	.070	.068	.069	2.04	6.895
Ft Water	.433	•	.030	.029	.030	.882	2.99
Kg/Cm²	14.2	32.8	•	.968	.981	29.0	98
Atmosphere	14.7	33.9	1.03	•	1.01	29.9	101
Bar	14.5	33.5	1.02	.987	•	29.5	100
Inch Mercury	.491	1.13	.035	.033	.034	•	3.4
kPa (kilopascal)	.145	.335	.01	.009	.01	.296	•

LINEAR UNIT

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

MISCELLANEOUS EQUIVALENTS

Unit	Equivalent
Ounce	28.35 g
Pound	.4536 kg
Horsepower	.746 kW
British Thermal Unit	.252 kcal
Square Inch	6.452 cm^2
Square Foot	.09290 m^2

MISCELLANEOUS FORMULAS

Unit	Formula
Fahrenheit (°F)	= 9/5 (°C) + 32
Celsius (°C)	= 5/9 (°F) – 32
Circumference of a Circle	= 3.1416 x Dia.
Area of a Circle	= .7854 x $(\text{Dia.})^2$
Volume of a Sphere	= .5236 x $(\text{Dia.})^3$
Area of a Sphere	= 3.1416 x $(\text{Dia.})^2$

DIMENSIONS

The catalog tabulations show orifice dimensions as “Nom.” (nominal).

READ THE FOLLOWING INSTRUCTIONS:

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 or fatal 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. Seek medical attention immediately.

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 chemicals/fluids are drained and not pressurized.

WARNING:
The use of any chemicals requires careful control of all worker hygiene. Follow all MSDS or safety precautions provided by the manufacturer.

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 materials used and any of the potential hazards involved.

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 hat
- Safety glasses or face shield
- Chemical-resistant gloves and apron
- Long sleeve shirt and long pants

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

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

WARNING:
It is important to operate equipment within the temperature range of all components. Also, insure appropriate time lapse or proper safety equipment is used when handling components after they're exposed to high temperatures.

WARNING:
Do not use any equipment outside the intended purposes of the product. Misuse can result in personal injury or product damage.