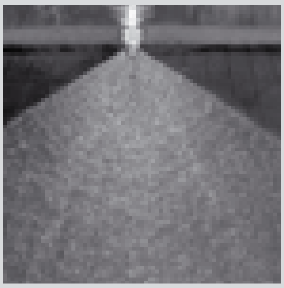
CTG SH 07 EU

SPRAY ENGINEERING HANDBOOK



PNR

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PNR manufactures a complete range of spray nozzles for industrial applications and many other products and systems designed according to the latest cutting-edge technologies. All our products are described in the following catalogues:

PRODUCT RANGE	CTG	TV
GENERAL PURPOSE SPRAY NOZZLES	CTG	UG
AIR ASSISTED ATOMIZERS	CTG	AZ
COMPLEMENTARY PRODUCTS AND ASSEMBLY FITTINGS	CTG	AC
INDUSTRIAL TANK WASHING SYSTEMS	CTG	LS
PAPER MILL PRODUCTS	CTG	PM
EVAPORATIVE COOLING LANCES	CTG	LN
STEELWORK NOZZLES	CTG	SW
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Our technical literature is continuously revised and updated and sent to our Customers who are listed in our Catalogues Delivery List. If you are interested in receiving the latest version of our catalogues, please contact the nearest PNR office.

GENERAL INFORMATION

Foreword

Along many years PNR engineers have been involved with Customers to find out the appropriate solution to specific application problems in numberless different industries.
This continuous cooperation has allowed us to gather a large quantity of information regarding practical spray nozzles applications, which we make available every day to our Customers.
We like to thank all our Customers for their past cooperation, and for the invaluable help they have given us in designing and manufacturing an always more complete and efficient range of spray nozzles and spraying systems.
To make this information readily available, and improve our service, we have now decided to gather and organize it within a manual.
We hope the reader will appreciate our work, and welcome any suggestion or addition which may lead to improve and complete this manual.

GENERAL INFORMATION *International system of units*

Description

The **INTERNATIONAL SYSTEM OF UNITS** sometimes called SI, has been defined by the International Standards Organization (ISO) and is based upon metric units. The following notes include most units which are likely to be used in handing of fluids. The system consists of nine base units, and supplementary units which are coherently derived from them. The coherence consists in the fact that the product, or the quotient of any two unit quantities in the system result in another unit quantity. Because of the world wide trend to use this modern metric system, we are providing in the following the conversion constants for the most useful units.

Base Units and derived units

The SI has defined the following base unit:

N°	QUANTITY UNIT	NAME UNIT	SYMBOL	
1	Length	meter	m	
2	Mass	kilogram	kg	
3	Time	second	s	
4	Thermodynamic temperature	Kelvin	K	
5	Molecular substance	mole	mol	
6	Electric current	Ampere	A	
7	Light intensity	candela	cd	
8	Plane angle	radiante	rad	
9	Solid angle	steradian	sr	

Out of these base units many other have been derived, the most interesting for our purposes being listed below.

N°	QUANTITY UNIT	NAME UNIT	SYMBOL	EQUIVALENCES
10	Area	square meter	m^2	
11	Volume	cubic meter	m^3	
12	Density	kilogram per cubic meter	Kg/m^3	
13	Velocity	meter per second	m/s	
14	Acceleration	meter per second squared	m/s^2	
15	Angular velocity	radian per second	rad /s	
16	Frequency	Hertz	Hz	Hz = cicli / s
17	Force	Newton	N	$N = kg \cdot m/s^2$
18	Pressure	Pascal	Pa	$Pa = N/m^2$
19	Momentum	kilogram meter per second	Kg m/s	
20	Energy	Joule	J	$J = N \cdot m$
21	Power	Watt	W	W = J/s
22	Moment of force	Newton meter	N m	
23	Kinematic viscosity	square meter per second	m^2/s	
24	Dynamic Viscosity	Pascal second	Pa s	
25	Thermal conductivity	Watt per meter Kelvin	$W (m \cdot K)$	

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Prefixes

SI units can be indicated together with a prefix to easily indicate very large or very small numbers.
As an example visible light has a wave length of approximately 0.0000005 m (meters) which can be more easily written as 500 nm (nanometers).
Please note it is not allowed to use prefixes together, you cannot write 10.000 m = 1da-km

10n	Prefix	Symbol	Denomination	Decimal equivalent
10^{24}	yotta	Y		1 000 000 000 000 000 000 000 000
10^{21}	zetta	Z		1 000 000 000 000 000 000 000
10^{18}	exa	E		1 000 000 000 000 000 000
10^{15}	peta	P		1 000 000 000 000 000
10^{12}	tera	T		1 000 000 000 000
10^{9}	giga	G		1 000 000 000
10^{6}	mega	M	Million	1 000 000
10^{3}	kilo	k	Thousand	1 000
10^{2}	etto	h	Hundred	100
10	deca	da	Ten	10
10^{-1}	deci	d	Tenth	0,1
10^{-2}	centi	c	Hundredth	0,01
10^{-3}	milli	m	Thousandth	0,001
10^{-6}	micro	µ	Millionth	0,000 001
10^{-9}	nano	n		0,000 000 001
10^{-12}	pico	p		0,000 000 000 001
10^{-15}	femto	f		0,000 000 000 000 001
10^{-18}	atto	a		0,000 000 000 000 000 001
10^{-21}	zepto	z		0,000 000 000 000 000 000 001
10^{-24}	yocto	y		0,000 000 000 000 000 000 000 001

Note
Because of discrepancies between some denominations in English and American, we only mention the commonly used denominations

GENERAL INFORMATION *Conversion table: American units to Si units*

QUANTITY	AMERICAN UNIT	CONVERSION FACTOR	SI UNIT
DENSITY	Pound mass/cubic feet	16.018	kilograms/cubic meter
FLOW RATE	Gallons per minute	3.785	liters per minute (lpm)
FLUID VOLUME	US Gallon	3.785	liter (l)
FORCE	Pound force	4.448	Newton (N)
HEAT	BTU (British Thermal Unit)	1055	Joule (J)
HEAT TRANSFER	BTU per hour	0.2931	Watt (W)
SPECIFIC HEAT CAPACITY	BTU per pound*deg F	4184	Joule / (kg K)
LENGTH	mil	25.4	Micrometer (micron)
LENGTH	Inches	25.4	millimeters (mm)
LENGTH	Foot	0.3048	meter (m)
POWER	Horsepower	0.746	kilowatt (kW)
PRESSURE	Pounds per square inch	0.0689	bar (1 bar = 100 kPa)
CALORIC VALUE ENTALPY	BTU per pound	2326	Joule per kg
SPECIFIC WEIGHT	Lbs per gallon	0.1198	kg per liter (kg/l)
SURFACE	Square inch	6,4516	square centimeter (cm2)
SURFACE	Square foot	0,0929	square meter (m2)
SURFACE	Acre	0,4047	hectares (ha)
VELOCITY	Foot per second	0.3048	meters per second (m/sec)
VELOCITY	Foot per minute	0.3048	meters per minute (m/min)
VELOCITY	Miles per hours	1.609	kilometers per hour (km/h)
VELOCITY	Knots	1.852	kilometers per hour (km/h)
VOLUME	Cubic foot	0.0283	cubic meter (m3)
VOLUME	Cubic inch	16.387	cubic centimeter (cm3)
WEIGHT	Pound	0.4536	kilogram (kg)
WEIGHT	Ton	0.90272	metric ton (t)

Multiply American Units on the left (by the conversion factor) to obtain SI Units on the right.
Divide SI Units on the right (by the conversion factor) to obtain American Units on the left.

GENERAL INFORMATION *Conversion table: temperature scales*

There are 4 principal types of temperature scales used for indicate the temperature: CENTIGRADE CELSIUS, FAHRENHEIT, KELVIN, and RANKINE; Kelvin and Celsius scales are used in Europe, Rankine, Fahrenheit are used in Anglo-Saxons countries.

MP = water melting point
BP = water boiling point

SYMBOL	NAME	MP	BP	NOTES
°C	Centigrade	0	100	0 and 100 are arbitrarily placed at the freezing point and boiling point of water.
°F	Fahrenheit	32	212	0°F is the stabilized temperature when equal amounts of ice, water, and salt are mixed. 96°F is the temperature “when the thermometer is held in the mouth or under the armpit of a living man in good health.”
°K	Kelvin	273.16	373.16	Based upon the definitions of the Centigrade scale and the experimental evidence that absolute zero is –273,16° C and that is an international standard temperature point.
°R	Rankine	491.67	671.67	Based upon the definitions of the Fahrenheit scale and the experimental evidence that absolute zero is –273,16° C

CONVERSION FORMULAE TABLE

	CELSIUS	FAHRENHEIT	KELVIN	RANKINE
°C=	-	$\frac{°F - 32}{1,8}$	K - 273,16	$\frac{R}{1,8}$ - 273,16
°F=	1,8 °C + 32		1,8·K - 459,69	R - 459,69
K=	°C + 273,16	$\frac{°F - 32}{1,8}$ + 273,16	-	$\frac{R}{1,8}$
°R=	1,8 (°C + 273,16)	°F + 459,67	1,8·K	-

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-10	14	19	66,2	43	109,4	67	152,6	91	195,8
-8	17,6	20	68	44	111,2	68	154,4	92	197,6
-6	21,2	21	69,8	45	113	69	156,2	93	199,4
-4	24,8	22	71,6	46	114,8	70	158	94	201,2
-2	28,4	23	73,4	47	116,6	71	159,8	95	203
0	32	24	75,2	48	118,4	72	161,6	96	204,8
1	33,8	25	77	49	120,2	73	163,4	97	206,6
2	35,6	26	78,8	50	122	74	165,2	98	208,4
3	37,4	27	80,6	51	123,8	75	167	99	210,2
4	39,2	28	82,4	52	125,6	76	168,8	100	212
5	41	29	84,2	53	127,4	77	170,6	105	221
6	42,8	30	86	54	129,2	78	172,4	110	230
7	44,6	31	87,8	55	131	79	174,2	115	239
8	46,4	32	89,6	56	132,8	80	176	120	248
9	48,2	33	91,4	57	134,6	81	177,8	125	257
10	50	34	93,2	58	136,4	82	179,6	130	266
11	51,8	35	95	59	138,2	83	181,4	135	275
12	53,6	36	96,8	60	140	84	183,2	140	284
13	55,4	37	98,6	61	141,8	85	185	145	293
14	57,2	38	100,4	62	143,6	86	186,8	150	302
15	59	39	102,2	63	145,4	87	188,6	160	320
16	60,8	40	104	64	147,2	88	190,4	170	338
17	62,6	41	105,8	65	149	89	192,2	180	356
18	64,4	42	107,6	66	150,8	90	194	190	374

mm	FRACTIONS OF ONE INCH						INCHES
0,3969						1/64	0,015625
0,79375					1/32		0,03125
1,1906						3/64	0,04687
1,5875				1/16			0,0625
1,9844						5/64	0,078125
2,38125					3/32		0,09375
2,7781						7/64	0,109375
3,1750			1/8				0,125
3,5719						9/64	0,14062
3,96875					5/32		0,15625
4,3656						11/64	0,171875
4,7625				3/16		13/64	0,1875
5,1594							0,203125
5,55625					7/32		0,21875
5,9531						15/64	0,234375
6,3500		1/4					0,25
6,7469						17/64	0,265625
7,14375					9/32		0,28125
7,5406						19/64	0,29687
7,9375				5/16			0,3125
8,3344						21/64	0,328125
8,73125					11/32		0,34375
9,1281						23/64	0,359375
9,5250			3/8				0,375
9,9219						25/64	0,390625
10,31875					13/32		0,40625
10,7156						27/64	0,42187
11,1125				7/16			0,4375
11,5094						29/64	0,453125
11,90625					15/32		0,46875
12,3031						31/64	0,484375
12,7000	1/2						0,5
13,0969						33/64	0,515625
13,49375					17/32		0,53125
13,8906						35/64	0,54687
14,2875				9/16			0,5625
14,6844						37/64	0,578125
15,08125					19/32		0,59375
15,4781						39/64	0,609375
15,8750			5/8				0,625
16,2719						41/64	0,64062
16,66875					21/32		0,65625
17,0656						43/64	0,671875
17,4625				11/16			0,6875
17,8594						45/64	0,703125
18,25625					23/32		0,71875
18,6531						47/64	0,734375
19,0500		3/4					0,75
19,4469						49/64	0,765625
19,84375					25/32		0,78125
20,2406						51/64	0,796875
20,6375				13/16			0,8125
21,0344						53/64	0,828125
21,43125					27/32		0,84375
21,8280						55/64	0,85937
22,2250			7/8				0,875
22,6219						57/64	0,890625
23,01875					29/32		0,90625
23,4156						59/64	0,921875
23,8125				15/16			0,9375
24,2094						61/64	0,953125
24,60625					31/32		0,96875
25,0031						63/64	0,984375
25,4000	1						1,0

LIQUID SPRAY AND SPRAY NOZZLES

A nozzle is a device which converts the energy from a fluid into velocity of the spray droplets.
Applications in many industrial processes are numberless, with spray nozzles being very often a critical component in determining the final quality of the product or the efficiency of the process.
For this reason the available nozzle range types for industrial applications can be found in PNR nozzle catalogue, as well as a concise but complete information about the most important parameters which can give a technical definition of a spray and its quality.
We have grouped in the following the most useful formulas for designing a spray system, showing the influence of the different factors which can affect the process of spraying.
More information about the working life of a nozzle and the best suited material for a given purpose can be found at page 17 of this publication.
All the following data, when not otherwise specified, refer to spraying water at 15° C.

LIQUID SPRAY AS A PROCESS

The process of spraying a liquid can be described as composed of two phases, namely:

1. Breaking up the liquid into separated drops.
2. Directing the liquid drops onto a surface or an object, to achieve the desired result.

The above two phases are normally performed, by the types of nozzles being used in industrial processes, at the same time by means of different techniques which shall be illustrated in the following.
The continuous progress in the manufacturing techniques in recent years has requested the nozzle manufacturer to make available to the industry an always more complete range of spray nozzle types to perform the different processes in a more efficient way.
It is the interest of the engineer using spray nozzles in manufacturing processes to become familiar with the different types of nozzles which are available today and with their individual characteristics, in order to be able to choose the nozzle which performs with the highest possible efficiency on a given application.

Spraying a liquid through a spray nozzle can serve different purposes, among which the most important are the following:

1. Cooling, by means of heat transfer between the product itself and the liquid running on its surface.
2. Washing, where the water directed onto the product takes away dirt or undesired substances from the product surface.
3. Humidifying, with sprays carrying very little liquid quantities to the product surface,into a chamber or into a room.
4. Metering the desired liquid quantity in a unit of time into the product being handled.
5. Applying a product on a surface, as in the case of spray painting or surface pre-treatment before painting.
6. Increasing the liquid surface to speed up heat transfer processes or chemical reactions and many others in numerous applications throughout modern industry.

It is self evident that the best results for every application are only obtained when the right choices in terms of nozzle type, flow value, spray angle, drop dimensions and nozzle material are made.
The purpose of the following pages is to give the reader the basic knowledge which is needed to properly select a spray nozzle for a given application.

Spray nozzles

a spray nozzle is a device which makes use of the pressure energy of a liquid to increase its speed through an orifice and break it into drops.
Its performances can be identified and described precisely, so that the design engineer can specify exactly the spray nozzle required for a given process.

The relevant characteristics which identify the performances of a nozzle are the following:

1. The liquid flow delivered as a function of the nozzle feed pressure.
2. The opening angle of the produced spray.
3. The nozzle efficiency, as the ratio between the energy of the spray and the energy used by the nozzle.
4. The evenness of the flow distribution over the target.
5. The droplet size distribution of the spray.
6. The jet impact of the spray.

The above characteristics will be discussed in the following pages, in connection with the different nozzle types.

TECHNIQUES FOR SPRAY PRODUCTION

Many different techniques can be used to produce a spray, and most of them are used today for nozzles to be applied in industrial processes. Based on the different techniques, the following nozzle types can be used in industrial applications to generate a liquid spray.

1. **Pressure nozzles**
   This is the simplest type of nozzles, where an orifice is opened into a chamber where the liquid to be sprayed is fed under pressure. A spray is produced through the orifice with spray pattern, flow rate and spray angle depending upon the orifice edge profile and the design of the inside pressure chamber.
   Typical pressure nozzles are the flat jet nozzles series GA, J, GX and GY.

2. **Turbulence nozzles**
   In these nozzles the liquid moving towards the chamber preceding the orifice is given a rotational speed component, so as to open up in a conical shape as soon as it leaves the orifice edge because of centrifugal force. Based on the nozzle design and the technique used to generate the rotational speed, the drops produced can be confined to the cone outer surface (hollow cone spray) or be evenly distributed to fill the entire volume of the cone (full cone spray).

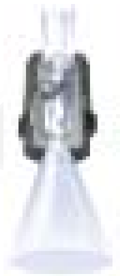
3. **Impact nozzles**
   Here the desired spray shape is obtained producing an impact of the liquid jet onto a properly designed surface. The liquid jet is subsequently changed into a fluid lamina and then broken into drops with the desired spray pattern after leaving the nozzle edge.

4. **Air assisted atomizers**
   Fine and very fine sprays can be obtained by means of air assisted atomizers, working upon various different principles. More detailed information about air assisted atomizing can be found in our Catalogue "Air assisted atomizers" (ordering code CTG AZ18).

FULL CONE PATTERN

In a full cone spray the droplets are distributed into a volume which is limited by a cone, having its origin point at the nozzle orifice. Such spray pattern is commonly used in a large variety of industrial processes, since it is the one which allows to distribute in an even way the water flow onto a surface: the full cone spray pattern is therefore useful, as a typical example, to evenly spray cooling liquid on a still surface. Another typical use is to distribute liquid droplets within a certain volume, like for example evenly distributing water droplets in the inside volume of a cooling tower.

Because of the wide number of processes performed by means of full cone nozzles the original shape has evolved into a range of specialised types, where the full cone spray pattern, or a pattern similar to a full cone one, is obtained by different techniques.


Standard full cone

Standard full cone (turbulence nozzle)

These nozzles use a specially shaped vane placed at the nozzle inlet, to give a rotational speed to the fluid flowing through the nozzle.
Because of the rotational speed of the fluid, water exiting the nozzle orifice is subjected to centrifugal force and opens up in the shape of a full cone.
The extent of the angle of the cone is a function of both exit speed (created from the inlet pressure) and the internal design of the nozzle. It can vary in practice from 15° to 120°.

These nozzles can be also produced as square full cone nozzles, where the square shape of the pyramidal spray is obtained by a special design of the outlet orifice.
Two important details have to be noted from the system designer when using these type of nozzles:

- the spray angle is measured on the side of the square section
- the square section of the spray rotates within the distance from the nozzle orifice to the target area.


Spiral full cone

Spiral full cone (deflection nozzle)

This is not properly a full cone, but rather a continuous liquid curtain evolving with the shape of a spiral inside a conical volume. The disadvantage of a scarcely even distribution is compensated by an exceptionally good resistance to plugging, which makes this nozzle the best choice in those applications where safety or system reliability are the prime concern, e.g. fire fighting systems.


Multiple full cone

Multiple full cone (turbulence nozzle, air atomizer)

This spray pattern is used in two cases, that is:

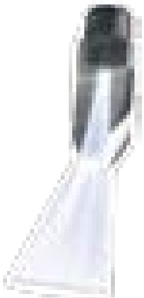
1. When a wide spray angle is to be reached with nozzles which inherently can only produce a narrow one, or in such cases where small size droplets and rather high capacities are required. Therefore several nozzles are grouped in a cluster with different spray directions: the resulting spray pattern occurs from the additional group of single nozzle sprays and the droplet size of the spray remains the same as one of single nozzle. It must be noted that a smaller nozzle will normally make smaller drops as compared to a larger size nozzle of the same type operating under the same conditions.
2. When it is necessary to obtain a wide angle jet using nozzles which inherently deliver a limited angle spray. In the case of a wide angle air atomizer, for example, the droplet distribution is obviously not homogeneous and the result is rather a number of small angle sprays with different directions, but still the liquid is atomized towards all the parts of the volume to be treated.

FLAT JET SPRAY PATTERN

In a flat jet spray the liquid droplets are sprayed in the shape of a flat liquid layer, with different thickness according to the principle used to generate the spray. A flat jet spray nozzle serves the purpose of spraying onto a surface or an object moving in a transverse direction with respect to the one of the jet surface, a typical example being the nozzles in a car washing tunnel. The vast majority of flat spray nozzles used in the industry work according to one of the following principles.

In line flat jet (pressure nozzle)

This is the general purpose flat jet nozzle, where the liquid enters the nozzle in line with the axis length and is fed to a pressure chamber, from where it is ejected through the nozzle orifice. Flow value and spray angle are determined respectively from the orifice cross section and the orifice edge profile.



In line straight jet (pressure nozzle)

These nozzles can be considered a special kind of flat jet nozzle, with naught degree spray angle. They are designed to produce a sharp stable stream, with powerful impact on a given point, and serve normally to perform cleaning processes or to cut soft materials.

Spoon flat jet (deflection nozzle)

In this type of nozzle the liquid is fed under pressure to a round outlet orifice, and then deflected onto a smooth profiled surface so as to assume a flat jet shape. This sophisticated design is of advantage since it offers a stronger jet impact using the same feed pressure.
Higher efficiency comes from the very little energy required to just change the direction of the liquid flow, this being the only energy required to generate the flat jet.

HOLLOW CONE SPRAY PATTERN

A hollow cone spray pattern consists of droplets concentrated onto the outer surface of a conical shape volume, with no droplets contained in the inside of the conical jet shape. These nozzles are normally used for smoke washing or gas cooling applications in several industrial processes.

Hollow cone (turbulence nozzle)

These nozzles use a tangential injection of liquid into a whirling chamber to generate centrifugal forces which break up the liquid vein as soon as it leaves the orifice. Precisely designed orifice profiles, making use of the Coanda effect, provides the ability to obtain very large spray angles.

Hollow cone (deflection nozzle)

A hollow cone can also be obtained taking a liquid flow to change direction onto a properly designed surface, in order to break the liquid into droplets and distributing them as a hollow cone spray pattern.
This kind of nozzle is mainly used for applications in dust control and fire fighting systems.

PNR CODING SYSTEM

As any other industrial product, spray nozzles need to be precisely identified by means of a code in order to avoid mistakes. PNR coding system has been designed with the following requirements in mind:

- Codes must be easily processed by a computer, in ascending order.
- Codes must describe completely the product without any need for additional description.
- Codes must show to the user the basic specifications of the nozzle in order to ease the search in the catalogue.

We have therefore determined our coding system described as follows:

AA U 2 305 B31 X Y

- Y — Thread type or other connection
- X — Special features
- B31 — Nozzle material code (see below)
- 305 — The three digits give the nozzle capacity in lpm at 3 bar according to rank value
- 2 — Rank of flow value, see table below
- U — Nozzle spray angle, see table below
- AA — Nozzle type, as described in the catalogue pages, shown in ascending order

Nozzle tables report on a blue background the nominal flow value, measured at 3,0 bar.
Flow values at different pressures have been calculated.

These codes serve as an indication only.
Based on different types of nozzles, their significance can occasionally be different.

CAPACITY RANK		
Rank	Flow digits	Actual flow (l/min)
0	0 490	0,49
1	1 490	4,90
2	2 490	49,0
3	3 490	490
4	4 490	4900

SOME SPRAY ANGLE CODES (DEGREES)		
A = 0	L = 40	T = 80
B = 15	M = 45	U = 90
C = 20	N = 50	J = 110
D = 25	Q = 60	W = 120
F = 30	R = 65	Y = 130
H = 35	S = 75	Z = 180

NOZZLE MATERIAL CODES

A1	Carbon steel
A2	High speed steel
A8	Zinc coated steel
A9	Nickel coated steel
B1	AISI 303 Stainless steel
B2	AISI 304 Stainless steel
B21	AISI 304 L Stainless steel
B3	AISI 316 Stainless steel
B31	AISI 316 L Stainless steel
C2	AISI 416 Stainless steel, hardened
D1	Polyvinylchloride (PVC)
D2	Polypropylene (PP)
d3	Polyamide (PA)
D5	Talcum filled Polypropylene

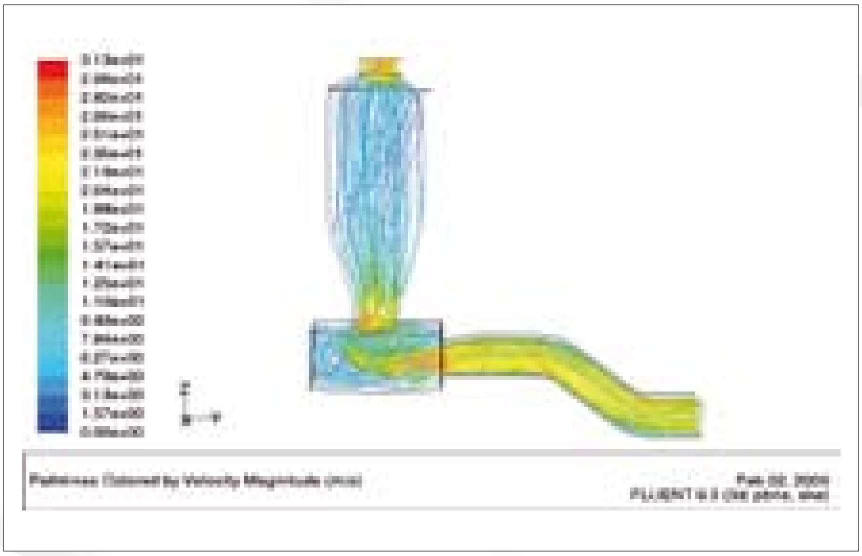
D6	Glassfibre reinforced PP
D7	High density polyethilene
D8	Polyvinylidenefluoride (PVDF)
E0	EPDM
E1	Polytetrafluorethylene (PTFE)
E2	PTFE (25% glassfibers)
E31	Acetalic resin (POM)
E7	Viton
E8	Synthetic rubber (NBR)
F5	Ceramic
F31	Ruby insert, 303 body
G1	Cast iron
H1	Titanium
L1	Monel 400

L2	Incolloy 825
L8	Hastelloy C276
P6	Acr. But. Styrene (ABS)
P8	EPDM 40 Shore
T1	Brass
T2	Brass, chrome plated
T3	Copper
T5	Bronze
T8	Brass, nickel plated
T81	Brass, electroless nickel plated
V1	Aluminum
V7	Aluminum, electroless n. plated

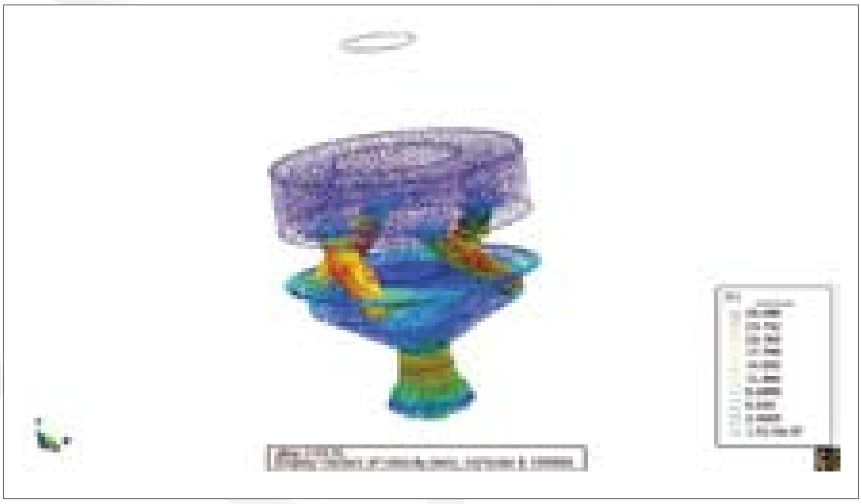
LIQUID SPRAY AND SPRAY NOZZLES *Computerized fluid dynamics*

The customers demand for an always higher efficiency requires to use not only the best tooling but in addition control instruments and design methods always more sophisticated, like for example new software for obtaining the velocity distribution of a fluid flowing through a conduit.

These software programs require that the geometry of the inner conduit to be geometrically defined, and in addition the process conditions (pressure, temperature, fluid capacity) and the fluid properties (specific weight, viscosity) to be Introduced.



Based on the above data it is possible to obtain a very precise distribution for the velocity value in each single point of the conduit, both under numeric form and flow diagrams.
These Information make it possible, as an example, to minimize the flow turbulence and consequently to Increase the nozzle efficiency through an increase in the fluid exit velocity.
This is of basic Importance for some kind of nozzles, for example those nozzles required to supply an high impact jet when performing descaling processes in a rolling mill.
By trial and error it is also possible to eliminate problems like jet Instability or cavitation.



The overall process efficiency in the flow path before the nozzle can also be considered, which often results into the design of geometry modification or the Introduction of special flow improving profiles along the conduit.

The diagram on the right shows the idealization of the process generating the droplets while the water jet exiting the nozzle is breaking up.
The theoretical model, whose exactitude seems to be confirmed by scientific research, considers that the liquid flowing through the nozzle and past the orifice edge evolves into a liquid lamina.
This lamina, because of instability induced by aerodynamic forces, breaks up first into elongated ligaments more or less cylindrical, and later into droplets.

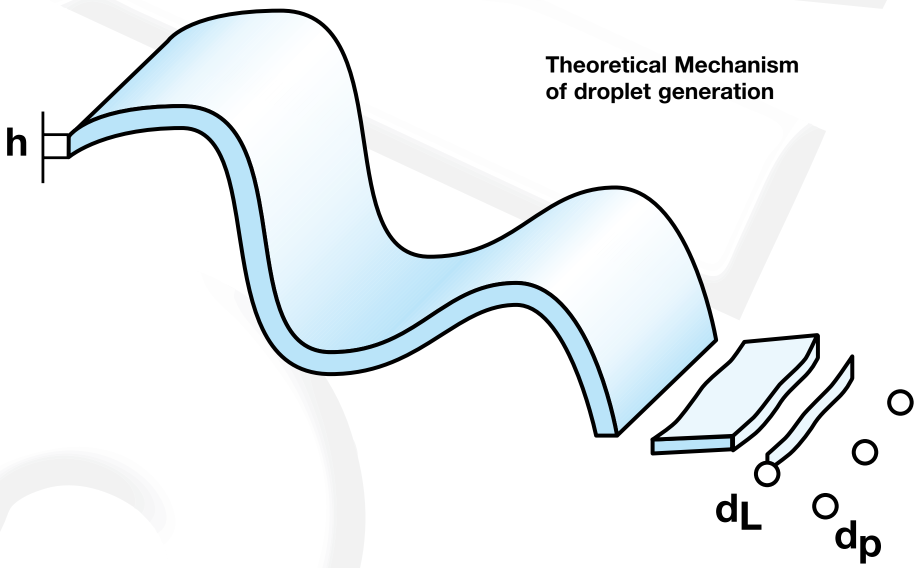
Taking the above process as a guideline, one can easily appreciate that the average droplet diameter is some what related to several factors, like:

1. The thickness of the lamina itself
2. The evenness of the lamina
3. A steady flow and break up process

For what has been said above, and limited to hydraulic nozzles, the system designer looking for fine droplet sprays should consider that the following results can be expected

Impact nozzles	*best*
Centrifugal hollow cone nozzles, multiple full cone nozzles	*good*
Turbulence nozzles	*fair*
Centrifugal Vaneless full cones	*worst*

The above choice is obviously based on the droplet generation process, which changes from one nozzle type to another and allows to forecast which type is best fro the application.
An additional consideration of interest is that the expected droplet size changes, for the same type of nozzle, with the nozzle size : it is possible to generate smaller drops spraying the same water quantity at the same pressure using a greater number of smaller nozzles.



Theoretical Mechanism of droplet generation

In cases where energy requirements are not a problem, or where a specified small droplet diameter is required, the smallest droplets can be obtained by means of an air assisted atomizer.
Here the shear action of a high speed compressed air flow is used with several different techniques to obtain a value for SMD (Sauter Mean Diameter) of 50 microns and less.

The atomization of a liquid by means of a compressible fluid like air, steam or a gas, is defined pneumatic, two-phase, or twin-fluid atomization. Many industrial processes require the availability of finely atomized droplets and the techniques to produce atomized jets have been largely improved in the recent years. In addition, more sophisticated process techniques have increased the demand for a precise definition about the characteristics of the spray and are now available to the design engineer. Since many years PNR can supply upon request complete documentation containing test reports about the more interesting and additional information, which are described below, for all PNR products.

Laser Interpherometer Test (By Pdpa)

PNR droplet size test reports are performed by means of a Laser Interpherometer (Phase Doppler Particle Analyzer), where two laser beams cross in a given point of the spray and define a test probe area. Droplet flying through the probe area cause a light scatter which is picked up by the instrument receiver and processed through a computer, in order to obtain relevant information about the spray characteristics.

Report information

Report information is made of data printed on three pages, where the first page contains the most interesting data which make possible to base process calculations upon precise data about spraying degrees, process efficiency and jet behavior in operational ambiance. These pages contain the Sauter Mean Diameter value whose knowledge is of special importance in heat exchange calculations about evaporative gas cooling processes, since it gives the possibility of evaluating the exchange surface obtained by atomizing for a given liquid volume.

The upper picture at page 18, referring to atomizing water by means compressed air, shows two following histograms:

- Distribution curve of droplet diameter (micron)
- Distribution curve of droplet velocities (mps)

and the below described values

- Arithmetic Mean Diameter (D_{10})
- Surface Mean Diameter (D_{20})
- Volume Mean Diameter (D_{30})
- Sauter Mean Diameter (D_{32})

$D_{10} = \frac{\sum_i n_i d_i}{\sum_i n_i}$	ARITHMETIC MEAN DIAMETER	This is a diameter value which, multiplied by the local number of droplets in the sample, equals the addition of all droplets diameters
$D_{20} = \sqrt{\frac{\sum_i n_i d_i^2}{\sum_i n_i}}$	SURFACE MEAN DIAMETER	This is the diameter of such a droplet whose surface, multiplied by the total droplets number, equals the sum of all droplets surfaces
$D_{30} = \sqrt[3]{\frac{\sum_i n_i d_i^3}{\sum_i n_i}}$	VOLUME MEAN DIAMETER	This is the diameter of such a droplet whose volume, multiplied by the total droplets number, equals the sum of all droplets volumes
$D_{32} = \frac{\sum_i n_i d_i^3}{\sum_i d_i^2}$	SAUTER MEAN DIAMETER	This is the diameter of such a droplet whose volume/area ratio, equals the ratio between the sum of all droplet volumes divided by the sum of all droplet surfaces

Attempts
Droplet number crossing probe area during test time. This includes both validated and not validated droplet.

Correct Count Criteria
A mathematic correction is applied to validate droplets which cross Probe Area in a peripheral belt, or to droplets without a perfect spherical shape. so that all validated droplets parameters are homogeneous. (This correction is necessary so that there is direct proportionally between laser beam phase and droplet number diameter).

Number Density
It is the number of droplets passing through probe area within test time.

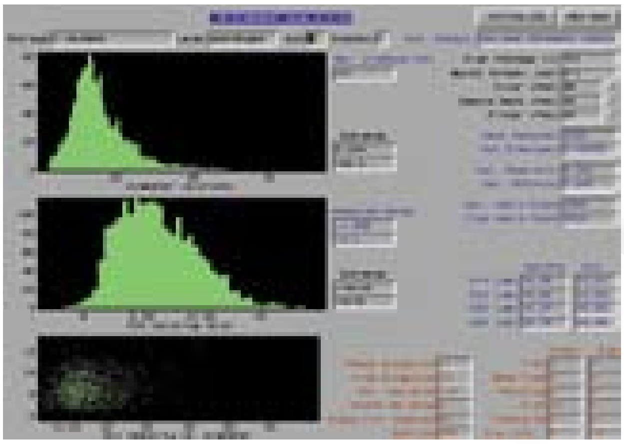
Probe area
This is the area where the two laser beams are crossing, so determining the probe area. All droplets intersecting probe area are checked. droplets which respect given parameters for shape are taken as valid droplets and make up the sample, whose size and velocity parameters are reported.

Validations
Droplets accepted, based on given shape parameters. to make up for test sample.

Velocity Mean
Droplets distribution speed histogram (m/s).

Volume Flow Rate
It is the volume, measured in cubic centimeter per second, of the validated droplets making up for the sample.

Volume Flux
It is the flow rate per specific area, measured in cubic centimeter per second and square centimeter, of the validated droplets making up the sample.



PNR can supply upon request complete documentation containing test reports about the aforementioned parameters and additional information, for all PNR atomizers.
The diagrams beside show the distribution of droplet diameters and droplet velocities of a spray under test as available to our customers.

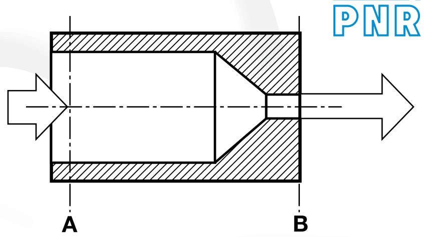
In the photo beside a test being performed at our laboratories. We use a computer driven laser interpherometer to detect and record the spray parameters, while fluid capacities and feed pressure values are monitored through high precision instruments

IMPORTANT NOTE

The droplet size values measured with a PDPA instrumentation are representative of a well specified volume inside the spray, and taking measurements in a different volume they can be considerably different.
A correct spray droplet size characterization requires then not only tests being performed in several volumes within the spray, but also that those measure volumes are selected with regard to the process the droplets are expected to perform.
As an example the droplet characterization of a spray should define how many volumes have been tested and which are the coordinates of each single test volume in relation to the nozzle orifice.

Most of the times pretending to describe the droplet spectrum of a spray nozzle at a given pressure with only one diagram is therefore not correct.

In order to calculate the discharge flow rate from a given nozzle the Bernoulli law shall be used, which says that the energy of a liquid flow remains unchanged over all the sections of the flow. Friction and turbulence losses are neglected, which is reasonable for our purposes if the calculation is performed over two sections not too far away from each other.



The energy of a given liquid flow crossing a given pipe section is composed of three parts, namely:

P Pressure energy of liquid particle per volume unit

$\frac{1}{2}\rho V^2$ Kinetic energy of liquid particle per volume unit

$\rho g z$ Potential Energy of liquid particle per volume unit

Where ρ = density of liquid, g = gravitational acceleration,
z = height respect to one plane of reference, V = liquid velocity

The Bernoulli law can be written as follows

$$P + \frac{1}{2}\rho V^2 + \rho g z = E \qquad (1)$$

Therefore, if we consider two sections of the same pipe, section A and section B, we can write that the flow energy remains constant in the form:

$$P_A + \frac{1}{2}\rho V_A{}^2 + \rho g z_A = P_B + \frac{1}{2}\rho V_B{}^2 + \rho g z_B \qquad (2)$$

If we finally consider that the two above sections are taken immediately before and immediately after the nozzle outlet orifice, being:

$Z_A = Z_B$

$P_B = 0$ (P_A is a differential pressure referred at the atmosphere pressure)

$V_A \cong 0$ negligible as compared to V_B (for orifice diameter much smaller than the duct diameter)

we shall come to the formula:

$$P_A = \frac{1}{2}\rho V_B{}^2 \Rightarrow V_B = \sqrt{\frac{2}{\rho} \cdot P_A} \Rightarrow \qquad (3) \quad V = C \cdot \sqrt{P}$$

EXIT VELOCITY DEPENDS UPON PRESSURE

When we define a new constant, k, to include the value of the nozzle orifice outlet area (A), then we come to the following equation which says that for a nozzle spraying into a room at ambient pressure, the exiting flow is proportional to the feed line pressure.

$$Q = A \cdot V \Rightarrow Q = A \times C \times \sqrt{P} \Rightarrow \qquad (4) \quad Q = K \cdot \sqrt{P}$$

NOZZLE CAPACITY DEPENDS UPON PRESSURE

Considering now two different pressure values for the same nozzle, since k is a constant quantity, we can write that:

$$K = \frac{Q}{\sqrt{P}} \Rightarrow K = \frac{Q_1}{\sqrt{P_1}} = \frac{Q_2}{\sqrt{P_2}} \Rightarrow \frac{Q_1}{Q_2} = \sqrt{\frac{P_1}{P_2}}$$

and derive from the above an equation that makes it possible to calculate the nozzle flow value at any given pressure value, once the flow value at another pressure value is known:

$$Q_2 = Q_1 \cdot \sqrt{\frac{P_2}{P_1}} \qquad (5)$$

NOZZLE CAPACITY AT A DIFFERENT PRESSURE

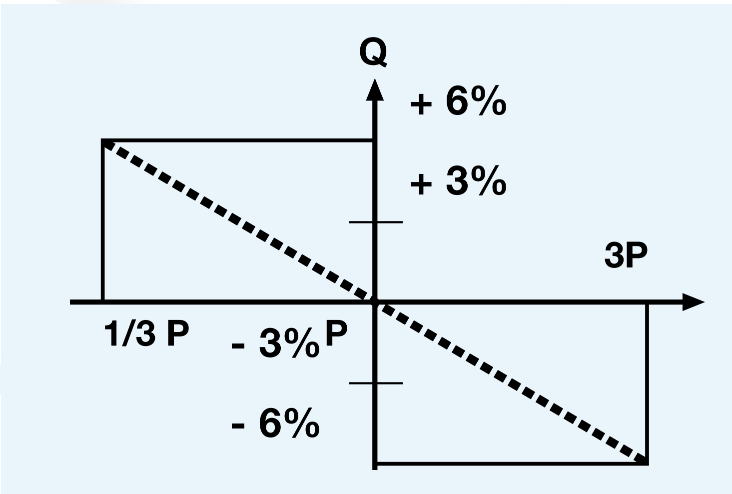
The Equation (5) has been obtained after having simplified the real problem, neglecting several factors like for example:

- In most of the practical application cases the flow is turbulent and not laminar.
- Friction losses tend to strongly increase with liquid velocity.
- Depending upon the type of nozzle, a different percentage of the available energy is used to break up the jet and give the desired spray pattern and spray angle.

For the above reason equation (5) gives reliable results if used in a limited pressure range around the pressure value where the flow rate is known, with this pressure range depending upon the type of nozzle.
Our experience has shown that one can expect the error in the calculated value to be lower than +/- 6% for pressure values ranging from 1/3 to 3 times the reference value.

As an example, a nozzle rated for 10 lpm at 3 bars would have, according to equation (5) the following flow values:
a 1 bar 5,77 lpm
a 9 bar 17,3 lpm
in real conditions it can be expected the flow rate values, to be:
as high as 6,1 lpm a 1 bar
as low as 16,2 lpm a 9 bar
Above considerations are to be used as a guideline only, because of the many factors influencing real operations which have not been considered here, for example liquid, temperature, viscosity and density.

Possible percentage deviation from theoretical flow rate values.



Also, above mentioned percentage errors have to be understood for nozzles using part of the flow energy to produce wide angle spray patterns.
Lower values can be expected for narrow angle nozzles, impact nozzles, and straight jet nozzles.
Laboratory tests and diagrams showing real flow rate values for each nozzles are used in practice when a precise result must be available.

Nozzle discharge coefficient

With reference to equation (4), if we consider the pressure value to be equal to 1, (P = 1 bar), the flow rate of the nozzle becomes

$$Q = K \cdot \sqrt{P} = K \cdot \sqrt{1} = K$$

NOZZLE CAPACITY FOR P=1 bar

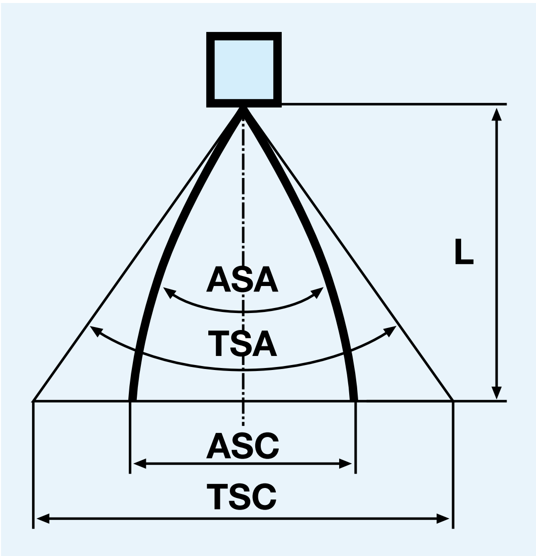
K is a parameter widely used in the fire fighting industry.

In some instances reference is made to the nozzle discharge coefficient or shortly to the nozzle coefficient to indicate the nozzle flow rate for a unitary pressure.
Of course, for a given pressure value P_n, the flow value will be

$$Q_n = K \sqrt{P_n} \qquad (6)$$

CAPACITY AT A GIVEN PRESSURE VALUE WHEN K KHOWN

The spray angle is the opening angle which the nozzle jet of droplets forms at the moment when it leaves the nozzle orifice, and it is one of the fundamental parameters for the choice of a given nozzle.
In fact the amplitude of the spray angle determines, in connection with the distance between the nozzle orifice and the target to be covered, the spray coverage and the density of liquid sprayed with respect to the cover area. See our Catalogue for description of the different nozzle spray patterns.
The table at the bottom of the page gives the theoretical spray width, based on the nozzle spray angle and the distance from the nozzle orifice.
It is important to note that, because of several factors like gravity forces and aerodynamic drag, the spray angle value cannot be maintained but in in a limited distance, normally up to 300 mm from the orifice.
For air assisted atomizers it is improper to use the term spray angle, since no precise value can be measured. Therefore the values given by Catalogues are to be intended as guidelines only.



$$TSC = 2 \cdot L \cdot ctan\left(\frac{TSA}{2}\right) \quad (7)$$

Where:
- **ASC** = Actual Spray Coverage
- **TSC** = Theoretical Spray Coverage
- **ASA** = Actual Spray Angle
- **TSA** = Theoretical Spray Angle
- **L** = Spray Distances

THEORETICAL SPRAY COVERAGE
at various distances from nozzle orifice

Spray Angle	50 mm	100 mm	150 mm	200 mm	250 mm	300 mm	400 mm	500 mm	600 mm	700 mm	800 mm	1000 mm
15°	13	26	40	53	66	79	105	132	158	184	211	263
25°	22	44	67	89	111	133	177	222	266	310	355	443
30°	27	54	80	107	134	161	214	268	322	375	429	536
35°	32	63	95	126	158	189	252	315	378	441	505	631
40°	36	73	109	146	182	218	291	364	437	510	582	728
45°	41	83	124	166	207	249	331	414	497	580	663	828
50°	47	93	140	187	233	280	373	466	560	653	746	933
60°	58	116	173	231	289	346	462	577	693	808	924	1150
65°	64	127	191	255	319	382	510	637	765	892	1020	1270
70°	70	140	210	280	350	420	560	700	840	980	1120	1400
75°	77	154	230	307	384	460	614	767	921	1070	1230	1530
80°	84	168	252	336	420	504	671	839	1010	1180	1340	1680
90°	100	200	300	400	500	600	800	1000	1200	1400	1600	2000
95°	109	218	327	437	546	655	873	1090	1310	1530	1750	2180
100°	119	238	358	477	596	715	953	1190	1430	1670	1910	2380
110°	143	286	429	571	714	857	1140	1430	1710	2000	2290	2856
120°	173	346	520	693	866	1040	1390	1730	2080	2430	2771	3464
130°	215	429	643	858	1070	1290	1720	2150	2570	3002	3431	4289

LIQUID SPRAY AND SPRAY NOZZLES *Spray angle*

Depending upon the nozzle design variations of feed pressure may have a great influence on the spray angle value.
Generally with increasing pressure turbulence full cone nozzles will produce narrower angles, flat jet nozzles will show a wider angle spray, while nozzles working on the deflection principle like spiral nozzles and K style flat jet nozzles will be less affected by pressure changes.
All nozzles will not function properly with very low pressure values (from 0.5 bar down depending upon nozzle type) with a marked decay in performance, larger drops, not well defined spray pattern, lower spray angle values.

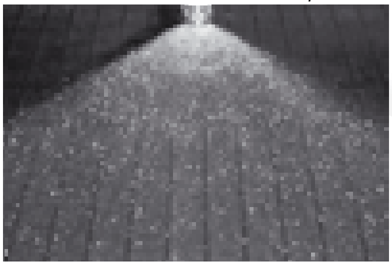
The above pictures show spray angles for different nozzles and different pressure values.
Should your application strictly require that a given value of the spray angle is obtained under a given pressure value or pressure range of values, please obtain a test report from our laboratories.

Full cone nozze
DDW 2235

Flat jet nozzle
JCW 2245

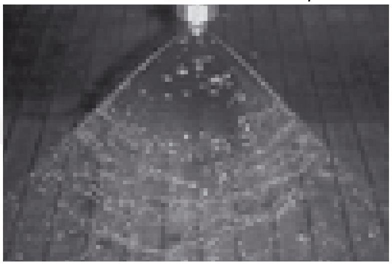
Spiral nozze
ECW 2230

picture 1



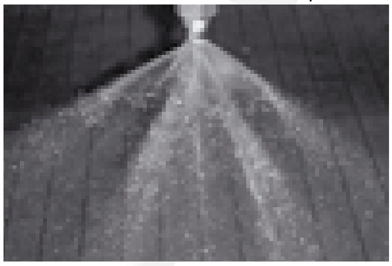
Pressure 0,5 bar

picture 2



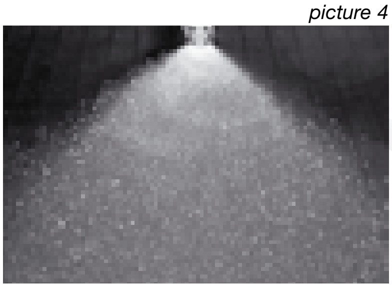
Pressure 0,5 bar

picture 3



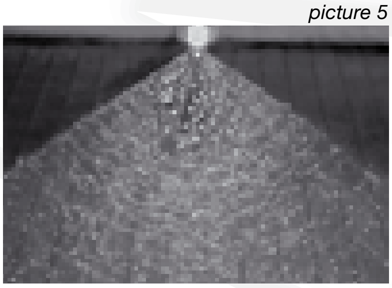
Pressure 0,5 bar

picture 4



Pressure 3 bar

picture 5

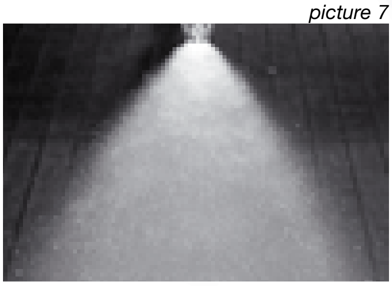


Pressure 3 bar

picture 6

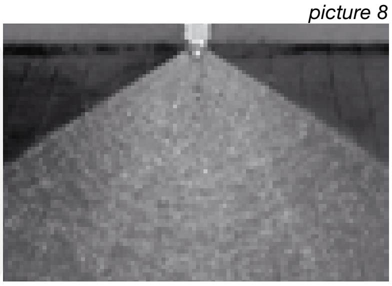
Pressure 3 bar

picture 7



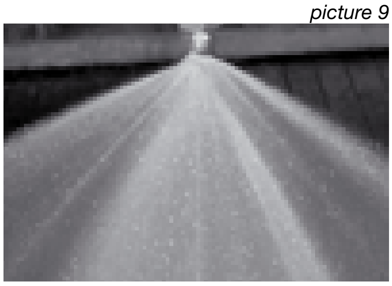
Pressure 10 bar

picture 8



Pressure 10 bar

picture 9



Pressure 10 bar

Photo obtained with 1/20.000s flashlight

Note
Picture 2 shows clearly the droplet generation mechanism as described at page 15

Terms and definitions

A very important characteristic of a spray nozzle is a parameter called Spray Distribution, which gives a precise information about how evenly the drops of the spray are distributed onto the area covered by the spray.
It is self understood that normally it is preferable to obtain the most even distribution possible.
In the past this was done through the visual examination of a diagram, reporting the quantity of water contained for example in glass pipes aligned onto the spray coverage area.
Pnr has determined to obtain such a result in a scientific way, through high technology instrumentation as shown in the pictures below, showing one of our patternators and a typical distribution diagram.

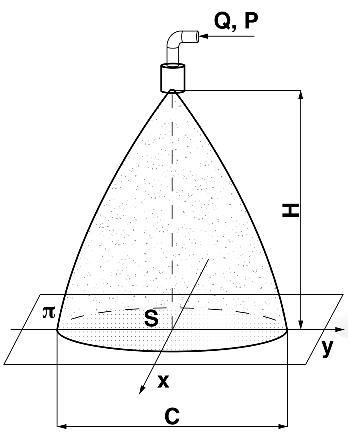


Diagram 1

Now to the spray geometry and some definition, let's consider a nozzle with a capacity Q at the pressure P.
At every value for distance H, which we call height of spray, we can define a plane 'n', normal to the nozzle axis on which a line can define the intersection of the spray onto the plane.
The area covered by the spray on the plane 'n' has a surface S, depending from the following parameters
a) Spray pattern **F**
b) Opening angle of the spray α
c) Height of the spray **H**

We can then write **S=S(F, α, H)**

In case of a full cone nozzle S is a circle, with diameter C and $S = 0{,}785\ C^2$
The capacity of the nozzle flows through the surface S, but each smaller area inside the surface S will probably have a different value for the flow passing through it.
We introduce then the value of Specific Capacity q

1) Specific Capacity

$$q = \lim_{\Delta S \to 0} \frac{\Delta Q}{\Delta S}$$

where ΔQ is the liquid flowing through a surface ΔS
ΔS is a fraction of the surface S

The function q depends upon the single point (x,y) in the section S and then

$$q = \frac{\partial Q}{\partial S} = f\,(x,\ y,\ H)$$

where x and y are the local coordinates in the section plane
H is the distance of the test surface from the nozzle orifice

Determining the function q is however very expensive, therefore in practice two different functions are used which give in most occurrences sufficient information

2) Linear Distribution

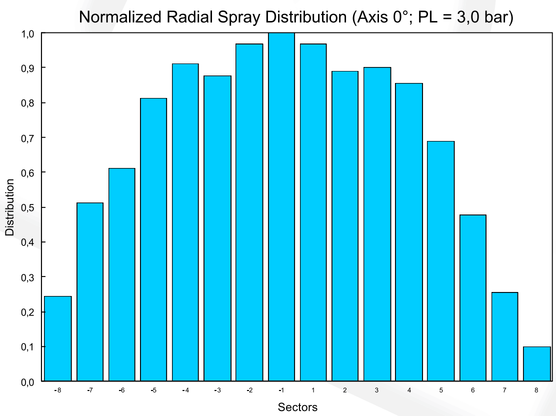
$$q_x = \frac{\partial Q}{\partial x}$$

where **∂Q** is the variation in capacity
∂x is the variation of a generic linear coordinate

3) Angular distribution

$$q_\varphi = \frac{\partial Q}{\partial \varphi}$$

where **∂Q** is the variation in capacity
∂φ is the variation of a generic angular coordinate



Values extracted from these functions can characterize the spray and allow for drawing the diagrams defined as 'Distribution Curves'.

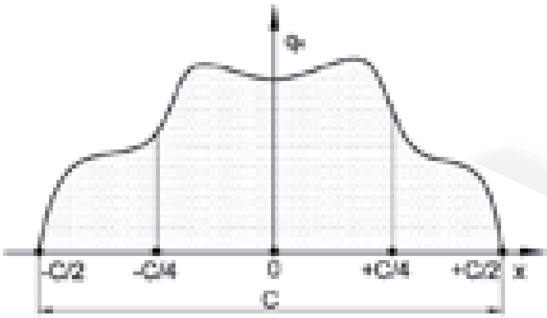


Diagram 2 : Linear distribution

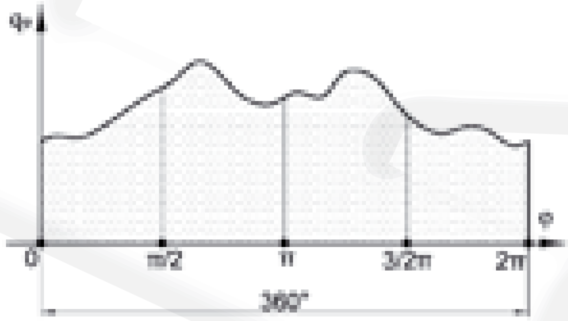


Diagram 3 : Angular distribution

Analyzing the above curves it is possible to determine the type of water distribution along the spray coverage and the type of spray pattern, like for example a full cone, hollow cone, flat or straight jet spray.

Distribution measurement

The water distribution along the spray coverage is determined by means of an instrument called Patternator.

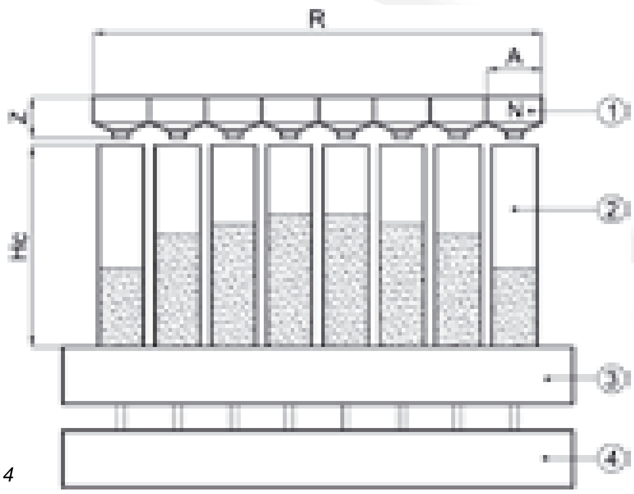


Diagram 4

A patternator consists of the following parts :
1) Liquid collector
2) Cell block
3) Measure block
4) Unloading block

The nozzle is above the instrument and it is orientated in such a way the jet is collected into the upper liquid collector.
The liquid collector can be linear (diagram 5) or round (diagram 6) according to the test being run.
From the single parts in the collector the liquid is sent into the corresponding cells below (2).

The Measure block (3) determines the liquid content in each single cell, then the unloading block (4) empties the instrument sending the liquid to the collection drain.

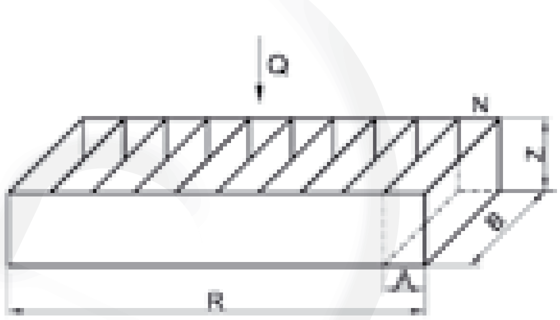


Diagram 5 : Linear collector

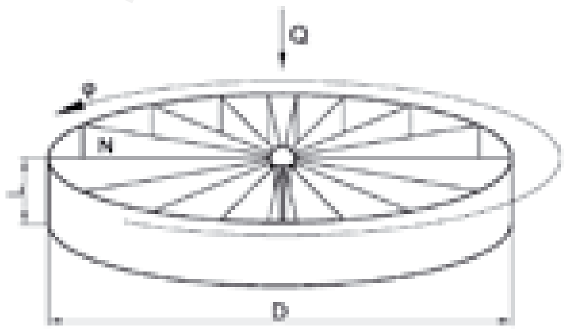


Diagram 6 : Circular collector

There are two types of patternators :

1. **Analogic**, the different levels of liquid is visible through the transparent walls of the cells, or pipes, sometimes containing some kind of floating balls, and a picture can be taken with a camera.
2. **Digital** Delivering an automatic reading of the values in the cells, the values being supplied as an electronic file from which a distribution curve can be easily obtained.

Normalizing distribution curve

The values obtained from the cells of the patternator, showing the water quantity collected in the single cells, allow for preparing a Distribution curve, which can be given as a single line curve or as a row of vertical bars.
These resemble the liquid level collected into the glass pipes of the old type instrumentation.

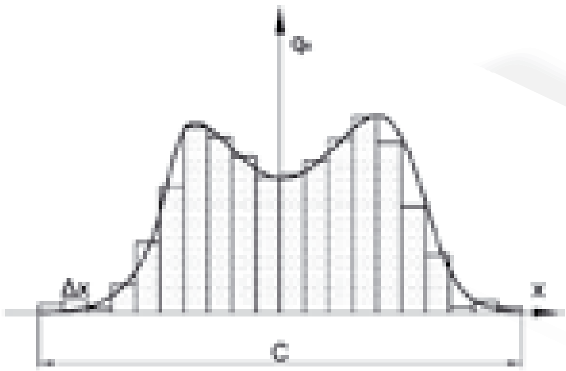


Diagram 7 : Effective linear distribution curve

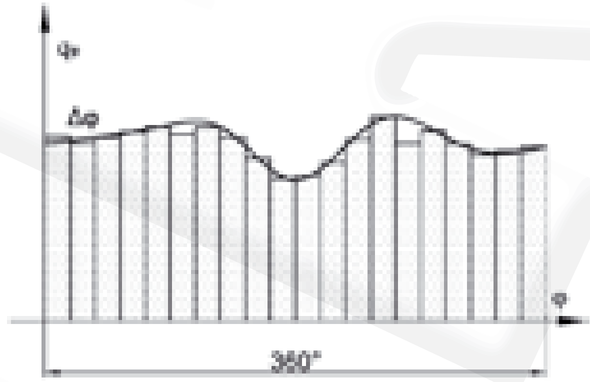


Diagram 8 : Effective angular distribution curve

The curves prepared based on the liquid level in the single cells still are not precise : they depend in fact from the testing time, the longer this time the larger the liquid quantity sprayed.
To eliminate the influence of time from the test it is necessary to transform the effective curves to normalized curves.

4) Normalized linear distribution

$$\delta_x = \frac{q_x}{q_x^M}$$

where q_x is the linear distribution of a generic cell
q_x^M is the maximum linear distribution measured

5) Normalized angular distribution

$$\delta_\varphi = \frac{q_\varphi}{q_\varphi^M}$$

where q_φ is the linear distribution of a generic cell
q_φ^M is the maximum linear distribution measured

Please note that Maximum value is the one belonging to the series of values measured in the cells.
In addition to the distribution it is possible to normalize the intervals to, with the following formulas

6) Normalized linear interval

$$\Delta\lambda = \frac{2}{N^*}$$

where 2 is the normalized linear amplitude of the spray
N* is the number of active cells
(active cells = cells containing liquid)

7) Normalized angular interval

$$\Delta\theta = \frac{2\pi}{N}$$

where 2π is the normalized angular amplitude of the spray
N is the number of active cells
(active cells = cells containing liquid)

The linear normalized amplitude is defined inside an interval [-1, +1]
The angular normalized amplitude is defined inside an interval [0,+2π]

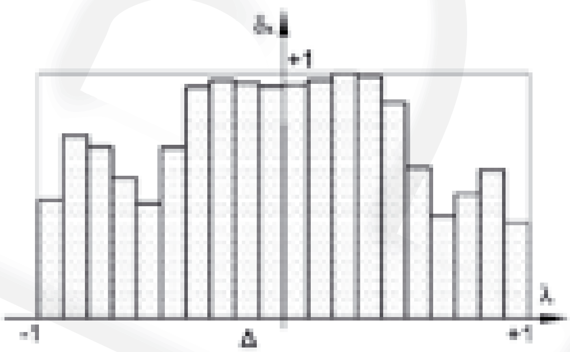


Diagram 9 : Normalized linear distribution curve

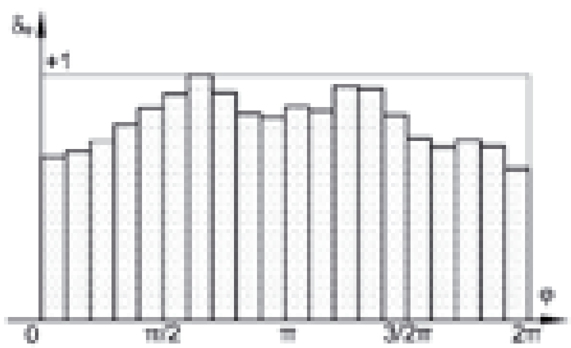


Diagram 10 : Normalized angular distribution curve

Evaluation of spray distribution

To evaluate distribution curves it is necessary to take three properties into consideration.

a) UNIFORMITY b) MONOTONY c) SIMMETRY

As described in the following diagrams and definitions

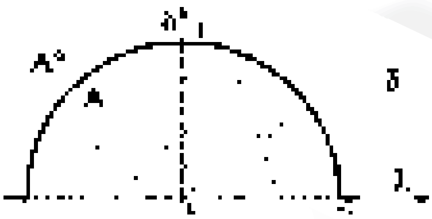


Diagram 11
Normalized and monotone distribution

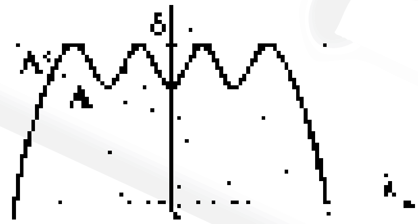


Diagram 12
Normalized and monotone distribution

a) **UNIFORM**
A distribution that minimizes the ratio A/A° *where* A is the area included in the normalized curve
A° is the rest of the area included in the 2x1 rectangle

b) **MONOTONE**
Is a distribution with a curve which grows on the left side and decreases on the left side *where* Left side is the area -1, 0
Right side is the area 0, +1

c) **SYMMETRIC**
Is a distribution which minimizes the Ratio A^+/A^- *where* A+ is the area included below the curve on the right side
A- is the area included below the curve on the left side

Based on the above definitions the following curves show the ideal situations

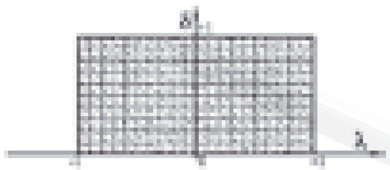


Diagram 13
Ideal uniformity

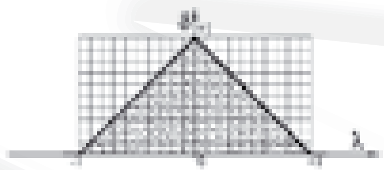


Diagram 14
Ideal monotony

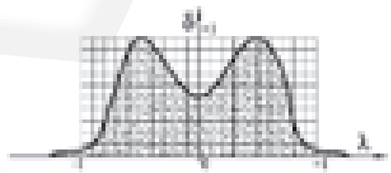


Diagram 15
Ideal symmetry

The three properties are then evaluated by means of the following parameters

1. Integral uniformity

$$U_1 = \frac{A}{A_M} \cdot 100$$

$$U_1 = \bar{\delta}^* \cdot 100$$

where A: area included below the curve
A_M: area included below the ideal curve

$$\bar{\delta}^* = \frac{\sum_i^{N^*} \delta_i}{N^*}$$

N* Number of cells containing liquid

2. Incremental uniformity

$$U_2 = \frac{2}{\sigma^*} \cdot 100$$

where

$$\sigma^* = \sum_i^{N^*} \left| \delta_{i+1} - \delta_i \right|$$

N* Number of cells containing liquid

3. Symmetry index

$$I_S = \left[1 - \frac{\varepsilon^*}{N^* \cdot \bar{\delta}^*} \right] \cdot 100$$

where

$$\varepsilon^* = \sum_i^{M^*} \left| \delta - \delta' \right|_i$$

δ' is the value of normalized liquid content in the symmetric cell
N* number of cells containing liquid in half of the diagram

Complete details about the above formulas and definition can be found in our Technical Bulletin REL 080002 which shall be released from our Technical Department on request.

Liquids are characterized for their property of undergoing continuous deformation when subjected to shear stress.
The property of fluids (liquids or gases) to resist flowing due to the existence of internal friction within the fluid is called viscosity.

Thus, if we imagine the different layers of fluid sliding one over the other with friction, we can imagine that viscosity is defined the force required to move a unit area of fluid for a unit distance. Viscosity is measured with many different systems, among which the most used are the following:

	METHOD	UNIT	DIMENSIONS	NOTES
1	Dynamic viscosity (Absolute viscosity)	Poise	$ML \cdot T^{-1}$	Poise = 100 Centipoises = (1 dyne per sec/cm^2)
2	Kinematic viscosity	Stoke	$L^2 \cdot T^{-1}$	1 Stoke = 100 Centistoke = (cm^2/sec) Kinematic viscosity = Dynamic viscosity/density
3	SSU/SSF	One of the most widely instruments to determine is the Saybolt viscosimeter, which measures the time in seconds required for a fixed volume of a given liquid to flow through an orifice. **SSU** = Seconds Saybolt Universal relates to a smaller orifice for less viscous liquids. **SSF** = Seconds Saybolt Furol relates to a larger orifice for more viscous liquids.		

The following table shows correspondences between the most used viscosity units.

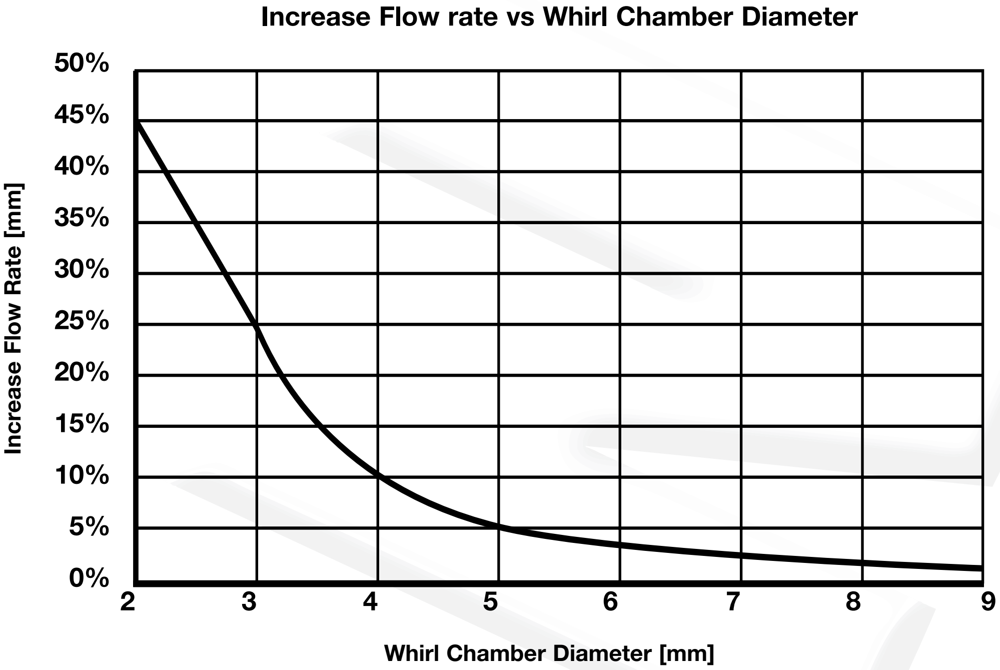
KINEMATIC VISCOSITY		SAYBOLT UNIVERSAL	SAYBOLT FUROL	ENGLER
Centistoke	**Sq feet/sec**	**SSU**	**SSF**	**Degrees**
1,00	0,00001076	31,0	---	1,00
5,00	0,00005382	42,4	---	1,37
10,00	0,0001076	58,8	---	1,83
15,66	0,0001686	80	---	2,45
20,52	0,0002209	100	---	3,02
25,15	0,0002707	120	---	3,57
42,95	0,0004623	200	---	5,92
108,0	0,001163	500	52,3	14,60
151,0	0,001625	700	72,0	20,44
194,2	0,002090	900	92,1	26,28
302,3	0,003254	1400	143	40,90
388,5	0,004182	1800	183	52,60
539,4	0,005806	2500	254	73,00
1078,8	0,01161	5000	509	146
1510,3	0,01626	7000	712	204
1941,9	0,02092	9000	916	263
3236,5	0,03483	15000	1526	438

The viscosity value of a liquid depends upon the temperature, therefore the viscosity value must always be given with reference to a temperature value.
The viscosity of water (20° C) is 1 Centipoise and 1 Centistoke, since water mass density = 1.

Viscosity influence on nozzle flow rate

All nozzle Catalogue data refer to spraying water (water cinematic viscosity is equal to 1 Centistoke).
A liquid with viscosity higher than water will require more energy to be pumped and sprayed and will flow with lower velocity at the same pressure, and this will cause a reduction in the turbulence of the flow.
For the above reason. nozzles working on the turbulence principle. like normal full cone nozzles and whirl hollow cone nozzles, will show an increase in capacity while spraying liquids with viscosity higher than water.
This increase is very consistent for small size nozzles, where the small radius of the whirl chamber tends. to cause high turbulence in the flow, and tends to diminish and to disappear for nominal capacity valves (capacity values at 3 bar) larger than 1,5 liters per minute.

The graph below shows, for a liquid with a viscosity of about 4 Centistokes, typical variations in the nozzle flow rate value, for different values of the nozzle whirl chamber diameter.
As it may be seen, these variations can be neglected in most practical applications, where nozzles with whirl chamber diameters well over 3 mm are used.



For other types of nozzles, not working on the turbulence principle, the increase on viscosity will simply reduce the liquid exit velocity at the orifice, thus causing a decrease in capacity.
Experience shows that this decrease ranges between 3 and 6% of nominal water capacity, that is to say that the variation introduced is in the same order of magnitude as the nozzle flow rate toler-ance.

Viscosity influence on nozzle spray angle and spray pattern

With reference to the theory of jet break-up and droplet information it can be easily imagined that spraying a liquid more viscous than water is a difficult task.

Al the properties of the spray tend to worsen, therefore one can expect

1. A higher value for the minimum operating pressure, that is the pressure value which allows for obtaining a well defined spray with the expected spray angle.
2. A worse spray distribution, since the viscous behavior of the liquid makes it more difficult to pro-duce fine droplets and to distribute them evenly with the desired spray pattern.
3. A narrower spray angle. It is difficult to give guidelines, since results on different nozzles, at different pressures and with different liquids are scarcely predictable.
   However, our experience shows that in many cases the use of impact nozzles can give acceptable results, where all other type of nozzle fails.
   A laboratory test, or a field test are stili the safest way to obtain sound results.

PNR

With reference to the Bernoulli Rule, as exposed in page 6, one can say that the pressure energy of the liquid flow at the nozzle inlet is transformed totally (minus some losses due to friction inside the nozzle) into liquid velocity at the nozzle orifice.
Catalogue figures give nozzle capacities when spraying water.
If the specific gravity or density of the liquid is different from that of water the available pressure energy will produce a different liquid velocity at the nozzle orifices.
In other words a given quantity of energy will spray always the same quantity of liquid mass, but different volumes (flow rates) according to the liquid specific gravity or density.

Therefore a liquid heavier than water will exit the nozzle with a lower velocity, at lower flow rate, while to the contrary a liquid lighter than water will be sprayed at higher velocity, at higher flow rate.

The following formula is to be applied:

8

$$Q_L = F \cdot Q_W$$

Where:
Q_L Liquid flow rate
Q_W Water flow rate
F Correction factor

The table below gives the value of a correction factor to obtain the flow rate of a liquid with different specific weight as water.

kg/liter	Libre/gallon	F
0,6	5,0	**1,29**
0,7	5,8	**1,20**
0,8	6,7	**1,12**
0,9	7,5	**1,05**
1,0	8,3	**1,00**
1,1	9,2	**0,95**
1,2	10,0	**0,91**
1,3	10,9	**0,88**
1,4	11,7	**0,85**
1,5	12,5	**0,82**
1,6	13,4	**0,79**
1,7	14,2	**0,77**
1,8	15,0	**0,75**
1,9	15,9	**0,73**
2,0	16,7	**0,71**

The spraying water impact of a nozzle depends on several factors and more precisely spray distribution pattern and spray angle. The first step to calculate the impact value, which is usually expressed in Kilograms per square centimeter, is to determine Total Theoretical Impact Value using the following formula:

9 $$TTI = 0{,}024 \cdot Q \cdot \sqrt{P} \quad [kgp/cm^2]$$

Where:
Q is the flow rate at working pressure in lpm
P is the pressure value in kgp/cm^2

The obtained value has to be multiplied by the **Total Theoretical Impact per Square Centimeter Coefficient (E)**.
The final value is the **Spraying Liquid Impact** expressed in kgp/cm^2.
Of course not all the energy of the fluid vein is transferred to the impact point.

10 $$SLI = E \cdot TTI \quad [kgp/cm^2]$$

A part of this energy, sometimes a considerable part, goes to obtain a desired spraying angle by having the liquid vein acquire a high rotational speed inside the whirl chamber.
The highest value of impact is obtained with straight jet nozzle and the value can be calculated multiplying spraying pressure per 1,9.
The tables below containing the Total Theoretical Impact sqcm coefficient values for different spray pattern nozzles for a distance of 300 mm.

TOTAL THEORETICAL IMPACT PER SQ CM COEFFICIENT AT DISTANCE OF 300 MM (E)					
Spray Angle	**Flat jet nozzle**	**Spray Angle**	**Full cone nozzle**	**Spray Angle**	**Hollow cone nozzle**
15°	0,300	15°	0,110		
25°	0,180				
35°	0,130	30°	0,025		
40°	0,120				
50°	0,100	50°	0,010		
65°	0,070	65°	0,004		
				60°/80°	0,01/0,02
80°	0,050	80°	0,002		
		100°	0,001		

Jet impact diagram

A further parameter to characterize the performance of a spray nozzle is the distribution of the jet impact force, which could be derived by means of mathematical methods from the values of the spray distribution onto the surface covered by the spray, but which can more easily be measured with the help of specifically designed instrumentation.

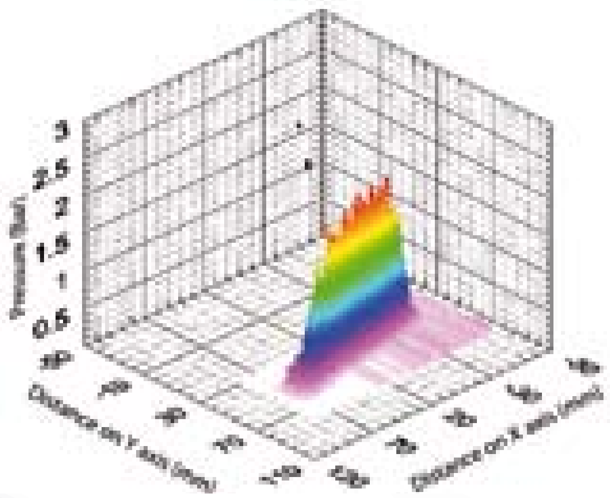
In some applications the jet impact force Is the most important parameter used to realize the required process.
Steel sheet descaling in a rolling mill is a typical example, where the jet impact is required to take away the surface scale and obtain a perfectly even surface.
For that reason special nozzles have been developed to perform this very task, where service life, impact value and spray distribution reach the values required for satisfactory result.
These test are performed in a laboratory equipped with a specifically designed instrumentation, where the high pressures involved in these process can be reached, which can measure the pressure values along a matrix of points distributed in the spray area covered by the nozzle.

These values are supplied both in a table of values and as a 3D pressure diagram, similar to those shown below.

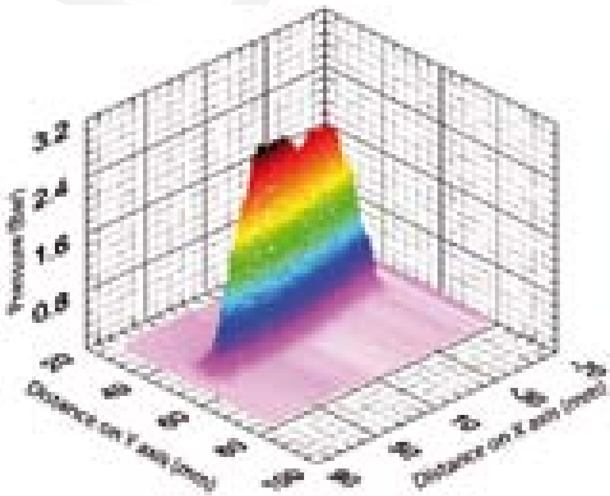
On such applications, where producing high impact values in the jet is necessary, it is of paramount importance that the liquid flow turbulence is kept to a minimum and therefore it is widely used to insert into the nozzle entrance devices designed to improve the operating conditions by forcing the liquid flow through straight passages with several different shapes : by doing so the impact delivered by the spray is increased with the same feed pressure.

One typical shape used by Pnr is shown on the right, and the two diagrams below show the impact force diagrams for the same nozzle with and without a flow straightener : the reduction of flow turbulence can lead in increase of impact force often higher than 20%.
Further improvements of course are available when the nozzle inside profile is properly designed in order to avoid sharp cross section changes and all surfaces are finished as smoothly as possible

Typical design of a Pnr flow straightener



Impact pressure diagram without flow straightener



Impact pressure diagram with flow straightener

Pressure drop through a nozzle

Some of our customers have asked us In the past which Is the pressure drop through a nozzle, since they consider a nozzle one of the parts in a piping, like a valve or an elbow, which causes a given pressure drop along the line.

The reality is different, and can be easily understood when considering the Bernoulli formula [2] as given at page 19 of this manual : the formula says that the total energy of a liquid flow is made from the addition of three facors :

- Potential energy due to elevation
- Pressure energy
- Velocity energy

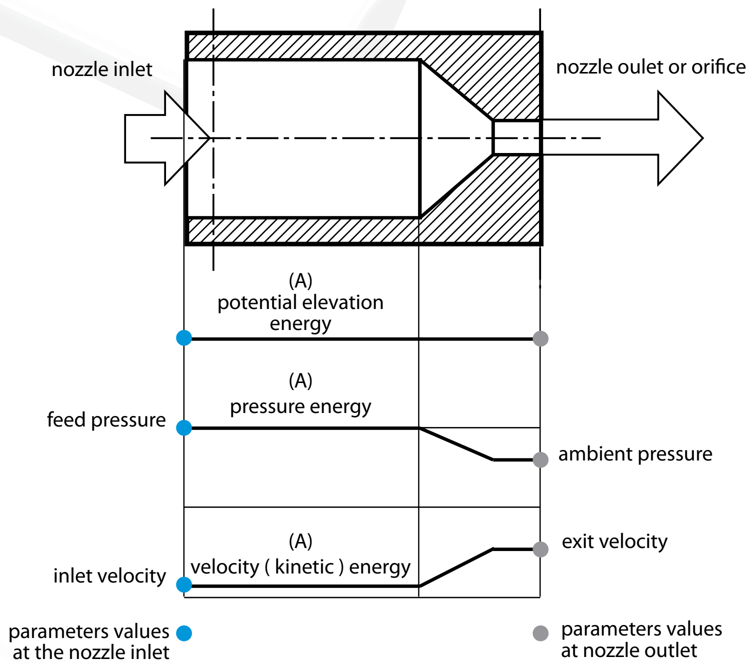
When we apply the formula at the entrance and at the outlet (the orifice) of a nozzle, and we neglect the influence of turbulence losses in between, we can easily see that.

- The potential energy variation can be neglected because of the limited dimensions of the nozzle, since the distance between the nozzle entrance and the nozzle orifice plays no role-
- The pressure energy variation is important, since the liquid pressure value falls abruptly from the pressure inside the feed pipe to the ambient pressure.
- The velocity energy variation is also consistent, since the liquid is ejected from the orifice at high speed.

In other words the pressure energy of the liquid flowing through the orifice is suddenly transformed in liquid drops velocity, which is exactly what a nozzle is designed to do.

This is shown from equation [3] at page 19, which allows the exit velocity from the nozzle to be calculated from the pressure inside the pipe (we actually consider the pressure difference between the inside of the pipe and the ambient pressure in this formula).

In other words all the energy still available at the nozzle is converted into velocity, or if you so prefer, you have a total pressure fall. The system designer shall therefore evaluate all the pressure drop between the pump outlet flange and the nozzle entrance in order to be sure that the nozzle feed pressure is sufficient to assure the desired capacity for the liquid being sprayed.



The choice of the right material for a nozzle is sometimes the most important one to do, since the nozzle operating life depends upon it.
There are several factors to influence or shorten the nozzle operating life, sometimes more than one at the same time, the most important being:

1. Wear from solid particles suspended into the liquid being sprayed.
2. Chemical corrosion from the liquid being sprayed.
3. Chemical corrosion from the ambience outside the nozzle
4. Exposure to high temperature.
5. Exposure to mechanical shocks

NOZZLE MATERIALS

NOZZLE MATERIALS *PNR material codes*

PNR has adopted a short code to identify construction materials for nozzles and nozzle parts.
Here below the most frequenty used materials.

A1	Free Cutting Steel	**E1**	TEFLON® (PTFE)	**L3**	NICROFER® 5923
A2	Carbon Steel	**E3**	DELRIN® (POM)	**L4**	STELLITE® 6
A8	Zinc Plated Mild Steel	**E6**	PERSPEX® (PMMA)	**L5**	HASTELLOY® B2
A9	Nickel Plated Mild Steel	**E7**	VITON® (FPM)	**L6**	HASTELLOY® C4
B2	AISI 304 Stainless Steel	**E8**	NBR- Sh 70 Rubber	**L61**	HASTELLOY® C22
B3	AISI 316 Stainless Steel	**E81**	SANTOPRENE® Rubber	**L62**	ULTIMET®
B31	AISI 316L Stainless Steel	**E82**	KLINGERITE®	**L7**	NICKEL 201
B4	AISI 321 Stainless Steel	**E83**	HYPALON®	**L8**	HASTELLOY® C276
B8	AISI 309 Stainless Steel	**E91**	Silicon	**L9**	SANICRO® 28 SS
B81	AISI 310 Stainless Steel	**F12**	Tungsten Carbide (TC)	**N1**	AISI 302 Stainless Steel
C1	AISI 420 St. Steel, hardened	**F2**	PIREX®	**P6**	ABS
C4	AISI 317 Stainless Steel	**F3**	Rubin	**P7**	FASIT OIL
C6	SAF 2205 Stainless Steel	**F4**	Zapphire	**P8**	EPDM ShA Rubber
D1	Polyvinylchloride (PVC)	**F5**	Ceramic	**P9**	STIROLUX® 637
D2	Polypropylene (PP)	**F6**	Silicon Carbide (SC)	**T1**	Brass
D3	Polyamide (PA)	**G1**	Cast Iron	**T3**	Copper
D5	Powder Charged PP	**H1**	Titanium	**T5**	Bronze
D6	Fiberglass Charged PP	**L1**	MONEL 400	**T8**	Nickel Plated Brass
D7	High Density Polyethylene	**L2**	INCOLOY® 825	**V1**	Aluminium
D8	Polyvinylidenefluoride (PVDF)	**L21**	INCONEL® 600	**V7**	Aluminium ENP

NOTE
The complete list of the Materials Codes may be requested to our Technical Service mentioning release code TGCE CODMAT.

MATERIAL STANDARDS

The following standards are mentioned with reference to materials identification

STANDARD ORGANIZATION		COUNTRY	STANDARD CODE
AFNOR	Association Française de Normalisation	France	NF
AISI	American Iron and Steel Institute	USA	AISI
ANSI	American National Standards Institute	USA	ANSI
ASTM	American Society for Testing and Materials	USA	ASTM
BSI	British Standards Institution	UK	BS
DIN	Deutsches Institut für Normung	Germany	DIN
DS/IT	Dansk Standards/Information Technology	Denmark	DS
ISO	International Organization for Standardization	International	ISO
JIS	Japanese Institute for Standard	Japan	JIS
UNI	Ente Nazionale di Unificazione	Italy	UNI

B1 AISI 303 STAINLESS STEEL

Chemical composition	**CR 17,50 NI 8.50 S 0,25**	**Coding correspondence**	
Type	Stainless Steel Austenitic	AISI	303
Hardening	Not possible	BS	303 S 21
Annealing	1050 /1100° C in water	DIN Wnr	1.4305
Welding	Possible with precautions	Euro	X10CrNiS18.09
Corrosion properties	Good resistance: Atmospheric exposure, food substances, organic chemicals. Low resistance: Chlorides, reducing acids and over 800° C	JIS	SUS 303
		NF	Z6CN 18-09
		SIS	2346
		UNI	XWCrNiS 1809

B3 AISI 316 STAINLESS STEEL

Chemical composition	**C 0,05 CR 17,0 NI 12,0 MO 2,25**	**Coding correspondence**	
Type	Stainless Steel Austenitic	AISI	316
Hardening	Not possible	BS	316 S 21
Annealing	1050 /1100° C in water	DIN Wnr	1.4401
Welding	Easy, using same steel electrodes	Euro	X6CrNiMo17122
Corrosion properties	Good resistance: Atmosphere, great number of salts, organic acids, foods Low resistance: Solutions of reducing acids temperatures over 500° C	JIS	SUS 316
		NF	Z6CND 17-11
		SIS	2347
		UNI	X5CrNiMo1712

B31 AISI 316L STAINLESS STEEL

Chemical composition	**C 0,03 CR 17,0 NI 13,0 MO 2,25**	**Coding correspondence**	
Type	Stainless Steel Austenitic	AISI	316 L
Hardening	Not possible	BS	316S12
Annealing	1050 /1100° C in water	DIN Wnr	1.4404
Welding	Easy, using same steel electrodes	Euro	X3CrNiMo1810
Corrosion properties	Good resistance: Atmosphere, great number of salts, organic acids, foods, salt water Low resistance: Solutions of reducing acids temperatures over 500° C	JIS	SUS 316L
		NF	Z2CND17-12
		SIS	2348
		UNI	X2CrNiMo 1712

C1 AISI 420 STAINLESS STEEL

Chemical composition	**C 0,20 CR 13,00**	**Coding correspondence**	
Type	Stainless Steel Martensitic	AISI	420
Hardening	980° - 1030° C in oil	BS	420 S 29
Annealing	750° - 800° C in air	DIN Wnr	1.4021
Welding	Possible with precautions	Euro	X20Cr13
Corrosion properties	Good resistance Drinkable water, steam, gasoline, oil, alcohol, ammonia.	JIS	SUS 420 J1
		NF	Z20C13
		SIS	2303
		UNI	X20Cr13

C2 AISI 416 STAINLESS STEEL

Chemical composition	**C 0,12 CR 12,50 S 0,22**	**Coding correspondence**	
Type	Stainless Steel Martensitic	AISI	416
Hardening	950° - 1100° C in oil	BS	416 S 21
Annealing	750° - 800° C.	DIN Wnr	---
Welding	Not possible	Euro	X120CrS13
Corrosion properties	Good resistance Drinkable water, steam, gasoline, oil, alcohol, ammonia.	JIS	SUS 416
		NF	Z12CF13
		SIS	---
		UNI	X12CrS13

D8 POLYVINYLIDENE FLUORIDE (PVDF)

Description	**HIGH-MOLECULAR WEIGHT, THE TOUGHEST OF THE FLUOROCARBON RESINS**	
Trade names & Suppliers	KYNAR	(Atochem North America Inc formerly Penwalt Corporation)
	SOLEF	(Solvay Polymer Corporation)
Physical and Mechanical Properties	Excellent resistance to abrasion and stress fatigue	
	Extremely pure, opaque white resin	
Thermal Properties	Useful in temperatures ranging from -73 / 149°C (-100 / 300°F). Heat deflection temperature is (80/90° C at 18,2 Bars (176 / 194° F at 264 psi).	
Chemical Compatibility	Excellent chemical resistance. Can be used with wet or dry halogens, most strong acids and bases, aliphatics, aromatics, alcohols and strong oxidizing agents. Not recommended for contact with ketones, esters, amines and some organic acids (fuming sulfuric acid)	

E1 POLYTETRAFLUOROETHYLENE (PTFE)		
Description	**FLUOROPLASTIC THAT HAVE SOME OR ALL OF THEIR HYDROGEN MOLECULES REPLACED BY FLUORINE**	
Trade names & Suppliers	TEFLON TFE, FEP and PFA	(Dupont, Polymer Products)
	NEOFLON	(Daikin)
	FLUON	(ICI Americas, Inc.)
	SST-2/SST-3	(Shamrock Technologies, Inc.)
Physical and Mechanical Properties	Low coefficient	
	Low adhesiveness	
	Buona resistenza agli agenti atmosferici	
	Good weatherability. Low resistance to creep and wear, unless reinforced with glass fibers, which results in superior resistance	
Thermal Properties	High and low temperature stability. Heat deflection temperatures range from 48/55° C at 18,2 bar (118-132° F at 264 psi).	
Chemical Compatibility	Chemically inert	
	Totally insoluble	

E3 ACETAL (ACETAL HOMOPOLYMERS AND COPOLYMERS)		
Description	**HIGHLY CRYSTALLINE RESINS BASED ON FORMALDEHYDE POLYMERIZATION TECHNOLOGY**	
Trade names & Suppliers	DELRIN	(Dupont, Polymer Products Corporation)
	CELCON	(Hoechst Celanese Corporation)
	ULTRAFORM	(BASF Corporation)
	RTP 800	(RTP Corporation)
	LUPITAL & TENAL	(Franklin Polymers, Inc.)
	FULTRON 404	(ICI Americas, Inc.)
Physical and Mechanical Properties	High tensile strength, rigidity and esilience	
	High fatigue endurance	
	Excellent dimensional stability	
	Low coefficient of friction	
	Outstanding abrasion and wear resistance	
	Excellent creep resistance	
Thermal Properties	Heat deflection temperatures range from 110 -136° C at 18,2 bars (230 - 270° F at 264 psi), higher if glass filled.	
Chemical Compatibility	Remains stable in long-term, high temperature water immersion. Excellent resistance to chemicals and solvents, but prolonged exposure to strong acids not recommended. Note: Suitable for close-tolerance high-performance parts. Available for machined parts, or may be injection molded.	

L6 HASTELLOY C4

PHYSICAL AND MECHANICAL PROPERTIES	CHEMICAL COMPOSITION	CORROSION RESISTANCE
R = 650/800 Mpa	C = 0.015 max	Very good against pitting and tensile-corrosion, specially in oxydizing atmosphere. Resistance in welded joints definitely better than C 276, lower than C22
Rp_{02} = 250/470 Mpa	Ni = 65	
HRB = 90	Cr = 16.0	
	Mo = 15.5	
	W = --	
	Fe = 3 max	
	Ti = 0.5	
	Co = 2 max	

APPLICATIONS
Recommended for applications with strongly oxidizing atmosphere.

L61 HASTELLOY C 22

PHYSICAL AND MECHANICAL PROPERTIES	CHEMICAL COMPOSITION	CORROSION RESISTANCE
R = 700/800 Mpa	C = 0.01 max	Excellent performances with oxydizing atmospheres as well as for pitting and tensile-corrosion conditions. Very good resistance in reducing atmospheres and for welded joints.
Rp_{02} = 360/420 Mpa	Ni = 56	
HRB = 93	Cr = 22	
	Mo = 13	
	W = 3	
	Fe = 3	
	Ti = --	
	Co = 2.5 max	

APPLICATIONS
Chemical industry (gas ducts, gas washing and treatment systems, phosphoric acid production) Heat exchangers, pumps, chlorination reactors.

L8 HASTELLOY C 276

PHYSICAL AND MECHANICAL PROPERTIES	CHEMICAL COMPOSITION	CORROSION RESISTANCE
R = 600/800 Mpa	C = 0.015 max	Very good in reducing and oxydizing atmospheres. Very good against pitting and tensile-corrosion. Acceptable resistance in welded joints. In cast parts excessive segregation, not eliminated by thermal treatment of annealing, makes it convenient to use C22 or C4 qualities.which assure better corrosion resistance and mechanical properties.
Rp_{02} = 300/370 Mpa	Ni = 57	
HRB = 90	Cr = 14.5/16.5	
	Mo = 15/17	
	W = ¾.5	
	Fe = /	
	V = 0.35 max	
	Co = 2.5 max	

APPLICATIONS
Chemical industry (air ducts, scrubbers, fans). Paper industry. Thermoelectric plants. Steel thermal treatments.

MATERIAL	TENSILE STRENGHT				CORROSION RESISTANCE
	$R_{p\ 0,2}$		R		
	20°C (68°F)	800°C (1408°F)	20°C (68°C)	800°C (1408°C)	
AISI 302	280	100	680	200	Good: sensitive to corrosion between grains for slow heating and cooling in the 450-900° C range temperature.
AISI 303	280	100	680	200	Discrete.
AISI 304/304L	270	90	600	100	Good, especially for 304L. 304 sensitive to corrosion between grains like AISI 302.
AISI 309	250	100	640	220	Good. Sensitive to corrosion between grains like AISI 302.
AISI 310	310	170	650	270	Good. (> 304 - 304L). Sensitive to corrosion between grains like AISI 302.
AISI 316/316L	270	110	560	220	Very high, especially for 316L.
AISI 321	210	100	540	140	Good.
AISI 347	280	120	620	200	Good.
AISI 416	620	70	750	90	Good in medium corrosive ambient (atmosphere, water gasoline, alcohol, N1-13, foods). Not in high corrosive.
BRASS	110-150	---	360-410	---	Good, especially when nickel plated.
BRONZE	100-300	---	200-600	---	Discrete, especially with sea water.
CAST IRON	≤ 500	V	100-800	V	
NICKEL ALLOYS	100-1000	V	300-1300	V	Very high also for high temperature. To use in the temperature range 800-1200° C.
PLASTICS	---	---	20-200	---	Good, also for erosion. Generally they are attacked with oxidizers like nitric acid, halogens, ect.
PTFE	---	---	30-40	---	Very high, except for elementary state of alkaline metals and to compounds containing fluorine at high temp
DUPLEX STEEL	>AISI 3..	>AISI 3..	>AISI 3..	>AISI 3..	Very high, also with high temperature and also for pitting.
TITANIUM alloy	195-850	V	300-900	V	Very high in oxidizing ambient. Very low in reducing ambient and with compounds containing fluorine.

Legend:
$R_{p\ 0,2}$ = 0,2% YIELD STRENGHT [MPa]
R = ULTIMATE TENSILE STRENGHT [MPa]
V = To verify time by time

PIPING

PIPING

The following table report the data of pipes according to ANSI B36.19 that is one of the most used standards that regulate welded stainless steel pipes:

DN	NPS	OD [mm]	SCHEDULE							
			5S		10S		40S/STD		80S/XS	
			t [mm]	m [kg/m]	t [mm]	m [kg/m]	t [mm]	m [kg/m]	t [mm]	m [kg/m]
6	1/8	10,3	N/A	N/A	1.24	0.28	1.73	0.37	2.41	0.48
8	1/4	13,7	N/A	N/A	1.65	0.50	2.24	0.64	3.02	0.81
10	3/8	17,2	N/A	N/A	1.65	0.64	2.31	0.86	3.20	1.12
15	1/2	21,3	1.65	0.81	2.11	1.01	2.77	1.28	3.73	1.64
20	3/4	26,7	1.65	1.03	2.11	1.30	2.87	1.71	3.91	2.23
25	1	33,4	1.65	1.31	2.77	2.12	3.38	2.54	4.55	3.28
32	1¼	42,2	1.65	1.67	2.77	2.73	3.56	3.44	4.85	4.53
40	1½	48,3	1.65	1.92	2.77	3.15	3.68	4.11	5.08	5.49
50	2	60,3	1.65	2.42	2.77	3.99	3.91	5.51	5.54	7.59
65	2½	73,0	2.11	3.74	3.05	5.34	5.16	8.75	7.01	11.6
80	3	88,9	2.11	4.58	3.05	6.55	5.49	11.5	7.62	15.5
90	3½	101,6	2.11	5.25	3.05	7.52	5.74	13.8	8.08	18.9
100	4	114,3	2.11	5.92	3.05	8.49	6.02	16.3	8.56	22.6
125	5	141,3	2.77	9.60	3.40	11.7	6.55	22.1	9.53	31.4
150	6	168,3	2.77	11.5	3.40	14.0	7.11	28.7	10.97	43.2
200	8	219,1	2.77	15.0	3.76	20.2	8.18	43.1	12.70	65.6
250	10	273,0	3.40	22.9	4.19	28.2	9.27	61.1	12.70	82.7
300	12	323,9	3.96	31.7	4.57	36.5	9.53	74.9	12.70	98.8
350	14	355,6	3.96	34.8	4.78	41.9	N/A	N/A	N/A	N/A
400	16	406,4	4.19	42.1	4.78	48.0	N/A	N/A	N/A	N/A
450	18	457	4.19	47.4	4.78	54.1	N/A	N/A	N/A	N/A
500	20	508	4.78	60.2	5.54	69.6	N/A	N/A	N/A	N/A
550	22	559	4.78	66.2	5.54	76.7	N/A	N/A	N/A	N/A
600	24	610	5.54	83.7	6.35	95.9	N/A	N/A	N/A	N/A

Where:

DN = Nominal diameter NPD = Nominal Pipe Size OD = Outside Diameter t = Wall Thickness m = Specific Weight

The following **Specific Pressure Drops (Y)** are normally used in the good engineering practice:
(where Y=ΔP/L   ΔP: Pressur Drop and L: Pipe Lenght)

Not boiling water	Y = 0.2÷0.5 bar/100 m	for pump discharge (0.7 bar/100 m max, if P > 50 bar)
	Y < 0.110 bar/100 m	for pump suction
Boiling water	Y = 0.04÷0.05 bar/100 m	for pump suction (velocity = 0.3÷0.9 m/s)

For pipe sizing the Velocity (V) is also used.
In the following table are shown the typical liquid velocities in steel pipes.

LIQUID	LINE TYPE	**Specific Pressure Drops** vs **Velocity** [m/s]		
		0 < V < 2	3 < V < 10	10 < V < 20
NOT BOILING WATER	Pump suction Pump discharge (long) Discharge leads (short) Boiler feed Drains Sloped sewer	0.3 ÷ 0.6 0.6 ÷ 0.9 1.2 ÷ 2.7 1.2 ÷ 2.7 0.9 ÷ 1.2 -	0.6 ÷ 1.2 0.9 ÷ 1.5 1.5 ÷ 3.7 1.5 ÷ 3.7 0.9 ÷ 1.5 0.9 ÷ 1.5	0.9 ÷ 1.8 1.2 ÷ 2.1 2.4 ÷ 4.2 2.4 ÷ 4.2 - 1.2 ÷ 2.1
HYDROCARBON LIQUIDS (normal viscosity)	Pump suction Discharge heather (long) Discharge leads (short) Drains	0.5 ÷ 0.8 0.8 ÷ 1.1 1.2 ÷ 2.7 0.9 ÷ 1.2	0.6 ÷ 1.2 0.9 ÷ 1.5 1.5 ÷ 3.7 0.9 ÷ 1.5	0.9 ÷ 1.8 1.2 ÷ 2.1 2.4 ÷ 4.6 -
MEDIUM VISCOSITY OIL	Pump suction Discharge (short) Drains	- - 0.3	0.5 ÷ 0.9 0.1 ÷ 0.2 0.9 ÷ 1.5	0.8 ÷ 1.5 0.1 ÷ 0.3 1.2 ÷ 1.8
OTHER WATER	Cooling tower, Chilled water, Sea water and generally fouling water (long pipes) (*)	0.6 ÷ 0.9	0.9 ÷ 1.5	1.2 ÷ 2.1

Note: (*)
In this case Cameron method has to be used with C=1
Y = 0.05 ÷ 0.12 bar/100 m for principal manifold
Y = 0.12 ÷ 0.23 bar/100 m for secondary manifold

Some fixed pressure drop values indications:

- for gate valves (fully open) consider a pressure drop of 5 meters
- for normal bends consider a pressure drop of 5 meters
- for a check valve consider a pressure drop of 15 meters

In the succeeding tables we show the velocity and specific pressure drop for several flow rates and pipe diameters.

SPECIFIC PRESSURE DROPS FOR WATER FLOW IN CLEAN STEEL PIPE SCH. 10S

Q [l/m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]
	1/8”		1/4”													
1	0,350	0,370	0,200	0,090	3/8”		1/2”									
2	0,705	1,340	0,395	0,331	0,223	0,082	0,145	0,029	3/4”							
3	1,060	2,890	0,593	0,673	0,333	0,176	0,217	0,061	0,125	0,016	1”					
4	1,410	4,940	0,788	1,150	0,444	0,291	0,290	0,101	0,167	0,027	0,110	0,010				
5	1,760	7,460	0,985	1,750	0,556	0,424	0,362	0,149	0,209	0,040	0,137	0,014				
6			1,180	2,460	0,667	0,594	0,434	0,207	0,251	0,054	0,165	0,019	1 1/4”			
8			1,580	4,060	0,892	1,020	0,579	0,351	0,335	0,091	0,219	0,033	0,126	0,009	1 1/2”	
10					1,110	1,530	0,724	0,534	0,418	0,136	0,274	0,049	0,158	0,012	0,116	0,006
15					1,670	3,250	1,090	1,130	0,627	0,284	0,411	0,099	0,236	0,026	0,174	0,012
20	2”				2,230	5,600	1,450	1,900	0,836	0,481	0,549	0,168	0,315	0,043	0,233	0,021
30	0,212	0,013	2 1/2”				2,170	4,130	1,250	1,020	0,823	0,353	0,473	0,092	0,348	0,043
40	0,283	0,022	0,190	0,007			2,900	7,180	1,670	1,760	1,100	0,606	0,631	0,155	0,465	0,073
50	0,354	0,032	0,237	0,012					2,090	2,700	1,370	0,911	0,789	0,233	0,581	0,108
60	0,424	0,044	0,284	0,017					2,510	3,810	1,650	1,290	0,943	0,321	0,697	0,150
70	0,495	0,079	0,332	0,022	3”				2,930	5,120	1,920	1,720	1,11	0,434	0,814	0,199
80	0,566	0,074	0,379	0,028	0,248	0,010	3 1/2”				2,190	2,210	1,26	0,554	0,925	0,253
90	0,636	0,093	0,427	0,035	0,279	0,013	0,209	0,006			2,470	2,770	1,42	0,692	1,040	0,319
100	0,707	0,114	0,474	0,043	0,310	0,015	0,232	0,007	4”		2,740	3,400	1,58	0,843	1,160	0,392
150	1,060	0,238	0,711	0,090	0,464	0,031	0,349	0,016	0,272	0,008	4,110	7,440	2,36	1,81	1,740	0,828
200	1,410	0,414	0,948	0,153	0,619	0,053	0,466	0,027	0,362	0,014			3,15	3,14	2,330	1,450
250	1,760	0,625	1,190	0,233	0,774	0,080	0,581	0,040	0,453	0,021	5”				2,900	2,200
300	2,120	0,889	1,420	0,324	0,930	0,112	0,698	0,055	0,543	0,030	0,352	0,011			3,480	3,070
350	2,470	1,190	1,660	0,438	1,080	0,150	0,815	0,074	0,634	0,040	0,411	0,014	6”		4,070	4,160
400	2,830	1,550	1,900	0,563	1,240	0,195	0,935	0,096	0,724	0,051	0,469	0,018	0,341	0,007	4,650	5,380
450	3,180	1,930	2,130	0,707	1,390	0,242	1,050	0,120	0,815	0,063	0,528	0,022	0,366	0,009	5,230	6,790
500	3,540	2,380	2,370	0,867	1,550	0,298	1,170	0,147	0,902	0,076	0,587	0,027	0,407	0,011		
550	3,880	2,870	2,610	1,040	1,700	0,354	1,280	0,174	0,991	0,092	0,645	0,032	0,447	0,013		
600	4,240	3,390	2,840	1,220	1,860	0,418	1,400	0,204	1,090	0,110	0,704	0,037	0,488	0,015		
650	4,590	5,560	3,080	1,420	2,010	0,486	1,510	0,239	1,180	0,127	0,762	0,043	0,529	0,017		
700	4,950	4,550	3,320	1,650	2,170	0,560	1,630	0,275	1,270	0,146	0,821	0,050	0,569	0,020		
750	5,300	5,200	3,560	1,880	2,320	0,637	1,750	0,314	1,360	0,164	0,879	0,057	0,610	0,023		
800			3,790	2,130	2,480	0,721	1,860	0,354	1,450	0,185	0,936	0,064	0,651	0,025	8”	
850			4,030	2,390	2,630	0,805	1,980	0,395	1,540	0,209	1,000	0,072	0,692	0,028	0,403	0,007
900					2,790	0,901	2,090	0,438	1,630	0,232	1,050	0,008	0,732	0,032	0,427	0,008
950					2,940	1,000	2,210	0,486	1,720	0,258	1,120	0,087	0,773	0,036	0,451	0,010
1000					3,100	1,110	2,320	0,534	1,810	0,284	1,170	0,096	0,814	0,039	0,474	0,011
1100					3,410	1,290	2,560	0,643	1,990	0,341	1,290	0,116	0,895	0,047	0,522	0,012
1200					3,720	1 ,580	2,800	0,763	2,170	0,403	1,410	0,135	0,974	0,055	0,569	0,015
1300							3,030	0,890	2,360	0,473	1,530	0,157	1,060	0,063	0,616	0,017
1400							3,260	1,020	2,540	0,544	1,640	0,183	1,140	0,072	0,664	0,019
1500							3,490	1,170	2,720	0,617	1,76	0,208	1,220	0,083	0,712	0,022
1600							3,720	1,330	2,890	0,697	1,880	0,234	1,300	0,093	0,758	0,025
1700	10”						3,950	1,490	3,080	0,784	1,990	0,260	1,380	0,104	0,806	0,028
1800	0,546	0,010							3,260	0,875	2,110	0,290	1,470	0,116	0,854	0,032
1900	0,575	0,012							3,440	0,965	2,230	0,323	1,550	0,129	0,901	0,034
2000	0,606	0,012							3,617	1,060	2,340	0,356	1,630	0,143	0,946	0,037
2200	0,667	0,015							3,980	1,280	2,580	0,429	1,790	0,172	1,050	0,045
2400	0,727	0,017	12”								2,820	0,507	1,950	0,200	1,140	0,053
2600	0,788	0,021	0,563	0,009							3,050	0,589	2,110	0,234	1,230	0,061
2800	0,848	0,023	0,606	0,010	14”						3,280	0,676	2,280	0,268	1,330	0,070
3000	0,909	0,026	0,649	0,011	0,532	0,007					3,520	0,773	2,440	0,306	1,420	0,080
3500	1,060	0,035	0,760	0,015	0,620	0,009					4,110	1,05	2,850	0,416	1,660	0,108
4000	1,210	0,045	0,866	0,020	0,709	0,012	16”				4,690	1,35	3,250	0,532	1,900	0,139
4500	1,360	0,056	0,976	0,025	0,798	0,015	0,606	0,007					3,660	0,674	2,130	0,173
5000	1,520	0,069	1,080	0,029	0,886	0,018	0,674	0,009					4,070	0,822	2,370	0,212
6000	1,810	0,097	1,290	0,042	1,070	0,026	0,808	0,013	18”				4,880	1,160	2,850	0,301
7000	2,120	0,130	1,510	0,055	1,240	0,035	0,940	0,017	0,741	0,010			5,690	1,580	3,310	0,403
8000	2,420	0,168	1,730	0,072	1,420	0,045	1,080	0,022	0,847	0,012			6,510	2,050	3,790	0,525
9000	2,730	0,210	1,950	0,091	1,600	0,056	1,210	0,027	0,954	0,015					4,270	0,659
10000	3,030	0,257	2,170	0,111	1,770	0,067	1,350	0,033	1,050	0,019					4,740	0,801

Legend: **Q:** Water Flow Rate (Lpm), **V:** Velocity (m/s), **Y:** Specific Pressure Drops (bar/100m)
Water at ambient temperature in straight pipe

SPECIFIC PRESSURE DROPS FOR WATER FLOW IN CLEAN STEEL PIPE SCH. 40S

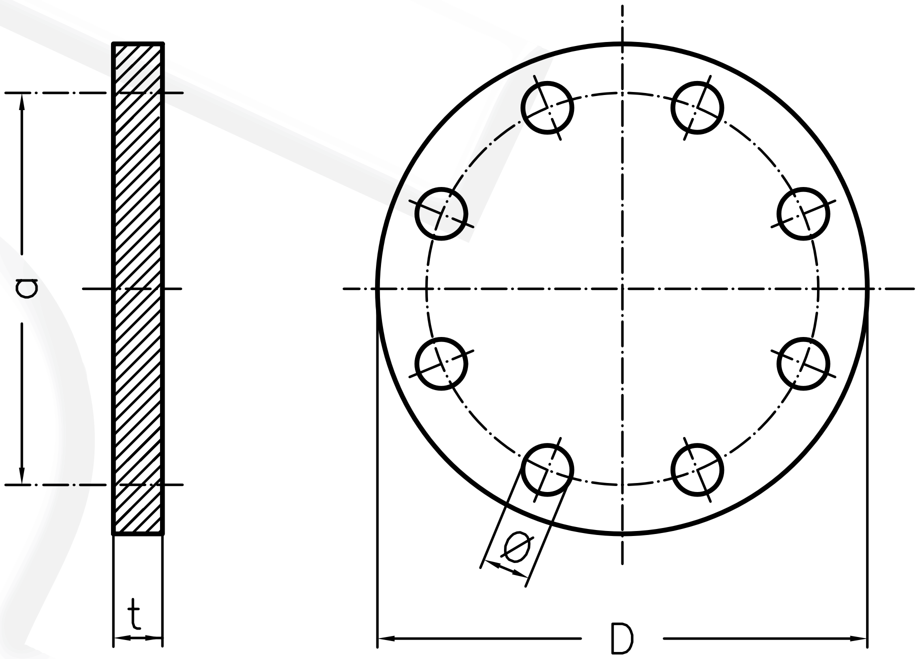
Q [l/m]	V [m/s]	Y [bar/100m]	V [m/s]	P [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]	V [m/s]	Y [bar/100m]
	1/8"		1/4"															
1	0,458	0,726	0,251	0,170	3/8"		1/2"											
2	0,918	2,590	0,501	0,600	0,272	0,136	0,170	0,044	3/4"									
3	1,380	5,590	0,752	1,220	0,407	0,29	0,255	0,091	0,144	0,023	1"							
4	1,840	9,570	1,000	2,090	0,543	0,48	0,340	0,151	0,192	0,038	0,120	0,012						
5	2,290	14,450	1,250	3,180	0,679	0,70	0,425	0,223	0,241	0,057	0,150	0,017						
6			1,500	4,460	0,815	0,980	0,510	0,309	0,289	0,077	0,180	0,024	1 1/4"					
8			2,010	7,360	1,090	1,690	0,680	0,524	0,385	0,129	0,240	0,041	0,138	0,011	1 1/2"			
10					1,360	2,520	0,850	0,798	0,481	0,193	0,300	0,061	0,172	0,015	0,127	0,008		
15					2,040	5,370	1,280	1,690	0,722	0,403	0,450	0,124	0,258	0,032	0,19	0,015		
20	2"				2,720	9,240	1,700	2,840	0,962	0,683	0,600	0,210	0,344	0,054	0,254	0,026		
30	0,231	0,016	2 1/2"				2,550	6,170	1,440	1,450	0,900	0,442	0,517	0,114	0,38	0,053		
40	0,308	0,027	0,216	0,010			3,400	10,720	1,920	2,500	1,200	0,758	0,689	0,193	0,507	0,091		
50	0,385	0,039	0,270	0,017					2,410	3,830	1,500	1,140	0,861	0,29	0,634	0,135		
60	0,462	0,055	0,324	0,023					2,890	5,410	1,800	1,610	1,03	0,400	0,761	0,187		
70	0,539	0,098	0,378	0,031	3"				3,370	7,270	2,100	2,150	1,210	0,541	0,888	0,248		
80	0,616	0,092	0,432	0,039	0,28	0,014	3 1/2"				2,400	2,760	1,380	0,690	1,010	0,315		
90	0,693	0,115	0,486	0,048	0,315	0,017	0,235	0,008			2,700	3,470	1,550	0,862	1,140	0,397		
100	0,770	0,141	0,540	0,059	0,35	0,02	0,261	0,010	4"		3,000	4,250	1,720	1,050	1,270	0,488		
150	1,150	0,295	0,810	0,125	0,524	0,042	0,392	0,021	0,304	0,011	4,500	9,300	2,580	2,260	1,900	1,030		
200	1,540	0,512	1,080	0,212	0,699	0,072	0,523	0,036	0,405	0,019			3,440	3,910	2,540	1,810		
250	1,920	0,773	1,350	0,322	0,874	0,108	0,653	0,053	0,507	0,028	5"				3,170	2,740		
300	2,310	1,100	1,620	0,449	1,05	0,152	0,784	0,074	0,608	0,04	0,387	0,014			3,800	3,820		
350	2,690	1,470	1,890	0,606	1,22	0,203	0,915	0,099	0,710	0,053	0,452	0,018	6"		4,440	5,180		
400	3,080	1,920	2,160	0,780	1,4	0,264	1,050	0,128	0,811	0,068	0,516	0,023	0,375	0,009	5,070	6,690		
450	3,460	2,390	2,430	0,979	1,57	0,328	1,180	0,161	0,912	0,084	0,581	0,028	0,402	0,012	5,710	8,450		
500	3,850	2,950	2,700	1,200	1,75	0,403	1,310	0,196	1,010	0,101	0,646	0,034	0,447	0,014				
550	4,230	3,550	2,970	1,440	1,92	0,479	1,440	0,232	1,110	0,122	0,710	0,041	0,491	0,016				
600	4,620	4,200	3,240	1,690	2,100	0,566	1,570	0,273	1,220	0,146	0,775	0,047	0,536	0,019				
650	5,000	6,880	3,510	1,970	2,270	0,658	1,700	0,319	1,320	0,169	0,839	0,055	0,581	0,022				
700	5,390	5,630	3,780	2,280	2,450	0,759	1,830	0,368	1,420	0,194	0,904	0,063	0,625	0,025				
750	5,77	6,440	4,050	2,600	2,620	0,863	1,960	0,42	1,520	0,218	0,968	0,072	0,67	0,029				
800			4,320	2,950	2,800	0,977	2,090	0,473	1,620	0,246	1,030	0,081	0,715	0,032	8"			
850			4,590	3,310	2,970	1,090	2,220	0,528	1,720	0,277	1,100	0,091	0,76	0,036	0,439	0,009		
900					3,150	1,220	2,350	0,585	1,820	0,308	1,160	0,100	0,804	0,041	0,465	0,01		
950					3,320	1,350	2,48	0,649	1,930	0,342	1,230	0,111	0,849	0,045	0,491	0,012		
1000					3,500	1,500	2,61	0,714	2,030	0,377	1,290	0,122	0,894	0,049	0,516	0,013		
1100					3,850	1,750	2,870	0,860	2,230	0,452	1,420	0,147	0,983	0,059	0,568	0,015		
1200					4,200	2,140	3,140	1,020	2,430	0,534	1,550	0,172	1,070	0,069	0,620	0,018		
1300							3,400	1,190	2,640	0,627	1,680	0,200	1,160	0,08	0,671	0,021		
1400							3,660	1,370	2,840	0,722	1,810	0,232	1,250	0,091	0,723	0,024		
1500							3,920	1,560	3,040	0,818	1,940	0,264	1,340	0,105	0,775	0,027		
1600							4,180	1,780	3,240	0,924	2,070	0,297	1,430	0,118	0,826	0,031		
1700	10"						4,440	1,990	3,450	1,040	2,190	0,331	1,520	0,132	0,878	0,035		
1800	0,590	0,012							3,650	1,160	2,320	0,369	1,610	0,147	0,930	0,039		
1900	0,622	0,014							3,850	1,280	2,450	0,41	1,700	0,163	0,981	0,042		
2000	0,655	0,015							40,500	1,410	2,580	0,452	1,790	0,181	1,030	0,046		
2200	0,721	0,018							4,460	1,700	2,840	0,545	1,970	0,217	1,140	0,056		
2400	0,786	0,021	12"								3,100	0,645	2,140	0,253	1,240	0,065		
2600	0,852	0,025	0,600	0,01							3,360	0,749	2,320	0,296	1,340	0,076		
2800	0,917	0,028	0,646	0,012	14"						3,610	0,859	2,500	0,339	1,450	0,087		
3000	0,983	0,032	0,692	0,013	0,573	0,008					3,870	0,982	2,68	0,387	1,550	0,099		
3500	1,150	0,043	0,810	0,018	0,668	0,011					4,520	1,330	3,130	0,526	1,810	0,134		
4000	1,310	0,055	0,923	0,023	0,764	0,014	16"				5,160	1,720	3,570	0,673	2,070	0,172		
4500	1,470	0,068	1,040	0,029	0,860	0,018	0,658	0,009					4,020	0,853	2,320	0,214		
5000	1,640	0,084	1,150	0,034	0,955	0,022	0,731	0,011					4,470	1,040	2,580	0,262		
6000	1,960	0,118	1,380	0,049	1,150	0,031	0,877	0,016	18"				5,360	1,470	3,100	0,373		
7000	2,290	0,158	1,610	0,065	1,340	0,042	1,020	0,021	0,808	0,012			6,250	2,000	3,610	0,499		
8000	2,620	0,204	1,840	0,085	1,530	0,054	1,170	0,027	0,924	0,015			7,150	2,590	4,130	0,65		
9000	2,950	0,256	2,080	0,107	1,720	0,067	1,310	0,033	1,040	0,019					4,650	0,816		
10000	3,280	0,313	2,310	0,130	1,910	0,081	1,460	0,041	1,150	0,023					5,160	0,992		

Legend: **Q:** Water Flow Rate (Lpm), **V:** Velocity (m/s), **Y:** Specific Pressure Drops (bar/100m)
Water at ambient temperature in straight pipe

PNR

Blind flanges to DIN 2527

DN	ND 6 *(DIN 2527)*						ND 10 *(DIN 2527)*						ND 16 *(DIN 2527)*					
	Flange			Holes			Dimensions			Holes			Dimensions			Holes		
	D	t	W	N	Ø	a	D	t	W	N	Ø	a	D	t	W	N	Ø	a
10	75	12	0,38	4	11	50	90	14	0,63	4	14	60	90	14	0,63	4	14	60
15	80	12	0,44	4	11	55	95	14	0.71	4	14	65	95	14	0,71	4	14	65
20	90	14	0,65	4	11	65	105	16	1,01	4	14	75	105	16	1,01	4	14	75
25	100	14	0,82	4	11	75	115	16	1.22	4	14	85	115	16	1,22	4	14	85
32	120	14	1,17	4	14	90	140	16	1.80	4	18	100	140	16	1,80	4	18	100
40	130	14	1,39	4	14	100	150	16	2,09	4	18	110	150	16	2,09	4	18	110
50	140	14	1,62	4	14	110	165	18	2.87	4	18	125	165	18	2,87	4	18	125
65	160	14	2,14	4	14	130	185	18	3.65	4	18	145	185	18	3.65	4	18	145
80	190	16	3,43	4	18	150	200	20	4.61	4	18	160	200	20	4.61	8	18	160
100	210	16	4,22	4	18	170	220	20	5.65	8	18	180	220	20	5,65	8	18	180
125	240	18	6,11	8	18	200	250	22	8,12	8	18	210	250	22	8,12	8	18	210
150	265	18	7,51	8	18	225	285	22	10.50	8	22	240	285	22	10,50	8	22	240
175	295	20	10,20	8	18	255	315	24	14,10	8	22	270	315	24	14,10	8	22	270
200	320	20	12,30	8	18	280	340	24	16.50	8	22	295	340	24	16,20	12	22	295
250	375	22	18,50	12	18	335	395	26	24.10	12	22	350	405	28	25,10	12	25	355
300	440	22	25,50	12	22	395	445	26	30.80	12	22	400	460	28	35,20	12	25	410
350	490	22	31,80	12	22	445	505	26	39.60	16	22	460	520	30	48,20	16	25	470
400	540	22	38,50	16	22	495	565	26	49.60	16	25	515	580	32	63,50	16	30	525
450	595	22	47,00	16	22	550	615	26	58.60	20	25	565	640	32	77,20	20	30	585
500	645	24	60,40	20	22	600	670	28	75.30	20	25	620	715	34	102,0	20	33	650
	PN 6 *(UNI 6091)*						**PN 10 *(UNI 6092)***						**PN 16 *(UNI 6093)***					



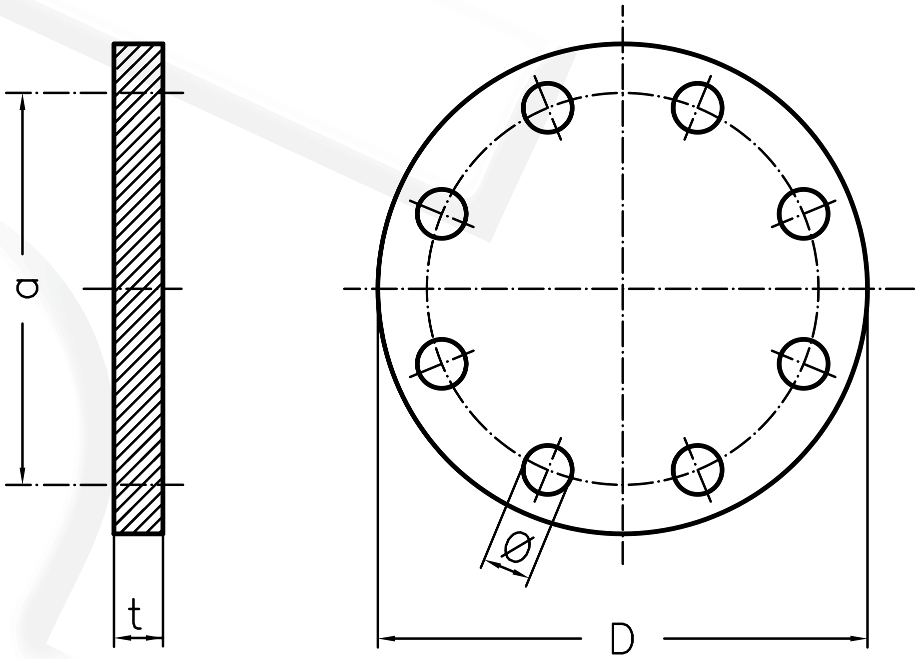
Legenda:
DN: Nominal Diameter
D: Flange External Diameter
t: Flange Thickness
W: Flange Weight
N: Hole Number
Ø: Hole Diameter
a: Hole axis

Flanges to ANSI norms

DN	ANSI 150 lb					
	Flange			Holes		
	D	t	W	N	Ø	a
1/2"	88,9	11,1	0,8	4	15,9	60,3
3/4"	98,4	12,7	0,9	6	15,9	69,8
1"	107,9	14,3	1,0	4	15,9	79,4
1 1/4"	117,5	15,9	1,3	4	15,9	88,9
1 1/2"	127,0	17,5	1,4	4	15,9	98,4
2"	152,4	19,0	1,8	4	19,0	120,6
2 1/2"	177,8	22,2	3,2	4	19,0	139,7
3"	190,5	23,8	4,1	4	19,0	152,4
3 1/2"	215,9	23,8	5,9	8	19,0	177,8
4"	228.6	23,8	7,7	8	19,0	190,5
5"	254.0	23,8	9,1	8	22,2	215,9
6"	279,4	25,4	11,8	8	22,2	241,3
8"	342,9	28,6	20,4	8	22,2	298,4
10"	406,4	30,2	31,8	12	25,4	361,9
12"	482,6	31,7	50,0	12	25,4	431,8
14"	533,4	34,9	60,0	12	28,6	476,2
16"	596,9	36,5	77,0	16	28,6	539,7
18"	635,0	39,7	95,0	16	31,7	577,8
20"	698,5	42,9	123,0	20	31,7	635,0
22"	749,3	46,0	151,0	20	34,9	692,1

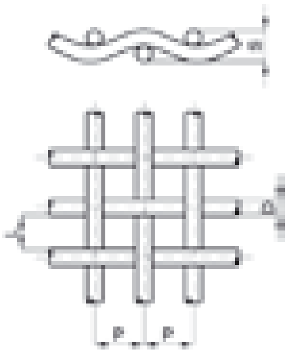
DN	ANSI 300 lb					
	Dimensions			Holes		
	D	t	W	N	Ø	a
1/2"	95,2	14,3	1,0	4	15,9	66,7
3/4"	117,5	15,9	1,4	4	19,0	82,5
1"	123,8	17,5	1,8	4	19,0	88,9
1 1/4"	133,3	19,0	2,7	4	19,0	98,4
1 1/2"	155,6	20,6	3,2	4	22,0	114,3
2"	165,1	22,2	3,6	8	19,0	127,0
2 1/2"	190,5	25,4	5,4	8	22,2	149,2
3"	209,5	28,6	7,3	8	22,2	168,3
3 1/2"	228,6	30,2	9,5	8	22,2	184,1
4"	254,0	31,7	12,2	8	22,2	200,0
5"	279,4	34,9	15,9	8	22,2	234,9
6"	317,5	36,5	22,7	12	22,2	269,9
8"	381,0	41,3	37,0	12	25,4	330,2
10"	444,5	47,6	58,0	16	28,6	387,3
12"	520,7	50,8	84,0	16	31,7	450,8
14"	584,2	54,0	107,0	20	31,7	514,3
16"	647,7	57,1	139,0	20	34,9	571,5
18"	711,2	60,3	390,0	24	34,9	628,6
20"	774,7	63,5	223,0	24	34,9	685,8
22"	838,2	66,7	270,0	24	41,3	742,9

DN	ANSI 400 lb					
	Dimensions			Holes		
	D	t	W	N	Ø	a
1/2"	95,2	14,3	1,0	4	15,9	66,7
3/4"	117,5	15,9	1,4	4	19,0	82,5
1"	123,8	17,5	1,8	4	19,0	88,9
1 1/4"	133,3	20,6	2,7	4	19,0	98,4
1 1/2"	155,6	22,2	3,6	4	22,2	114,3
2"	165,1	25,4	4,5	8	19,0	127,0
2 1/2"	190,S	28,6	6,8	8	22,2	149,2
3"	209,S	31,7	9,1	8	22,2	168,3
3 1/2"	228,6	34,9	13,2	8	25,4	184,1
4"	254,0	34,9	15,0	8	25,4	200,0
5"	279,4	38,1	20,0	8	25,4	234,9
6"	317,5	41,3	27,7	12	25,4	269,9
8"	381,0	47,6	45,0	12	28,6	330,2
10"	444,5	54,0	70,0	16	31,7	387,3
12"	520,7	57,1	103	16	34,9	450,8
14"	584,2	60,3	141	20	34,9	514,3
16"	647,7	63,5	181	20	38,1	571,5
18"	711,2	66,7	228	24	38,1	628,6
20"	774,7	69,8	282	24	41,3	685,8
22"	838,2	73,0	311	24	44,4	742,9



Legend:
DN: Nominal Diameter
D: Flange External Diameter
t: Flange Thickness
W: Flange Weight
N: Hole Number
Ø: Hole Diameter
a: Hole axis

PIPING *Sieve size conversion chart*



Sieves are used both for determining the particle size distribution of a granular material and to filter solid particles in a liquid. Normally the sieve is made with a fabric whose characteristic dimensions are:
L is the Opening Width (free passage)
D is the Diameter of the wire
P is the Pitch of the wire
S is the Thickness of the fabric
To classify particle sizes, there is some Sieve Series according to specific standards; the most known are: Tyler Sieve Series, US Sieve Series, UK Sieve Series,…
The Tyler mesh size indicates exactly the number of openings per linear inch of mesh

L [µm]	TYLER Sieve [Mesh No]	ASTM E11 Sieve [Mesh No]	BS 410 Sieve [Mesh No]	DIN 4188 Sieve [mm]
5	2500		2500	0.005
10	1250		1250	0.010
15	800		800	0.015
20	625	635	625	0.020
22				0.022
25	500	500	500	0.025
28				0.028
32	n/a	450	440	0.032
36				0.036
38	400	400	400	
40				0.040
45	325	325	350	0.045
50				0.050
53	270	270	300	
56				0.056
63	250	230	240	0.063
71				0.071
75	200	200	200	
80				0.080
90	170	170	170	0.090
100				0.100
106	150	140	150	
112				0.112
125	115	120	120	0.125
140				0.140
150	100	100	100	
160				0.160
180	80	80	85	0.180
200				0.200

In the german standard (DIN norm 4188) the Opening Width (L) is given in millimeters.

L [µm]	TYLER Sieve [Mesh No]	ASTM E11 Sieve [Mesh No]	BS 410 Sieve [Mesh No]	DIN 4188 Sieve [mm]
212	65	70	72	
250	60	60	60	0.250
280				0.280
300	48	50	52	
315				0.315
355	42	45	44	0.355
400				0.400
425	35	40	36	
450				0.450
500	32	35	30	0.500
560				0.560
600	28	30	25	
630				0.630
710	24	25	22	0.710
800				0.800
850	20	20	18	
900				0.900
1000	16	18	16	1.000
1120				1.120
1180	14	16	14	
1250				1.250
1400	12	14	12	1.400
1600				1.600
1700	10	12	10	
1800				1.800
2000	9	10	8	2.000
2240				2.240
2360	8	8	7	
2500				2.500
2800	7	7	6	2.800
3150				3.150
3350	6	6	5	
3550				3.550
4000	5	5	4	4.000
4500				4.500
4750	4	4	3.5	
5000				5.000
5600	3.5	3.5	3	
6700	3	0.265 in	1	
8000	2.5	5/16 in	n/a	

Applicable standards are:
ISO 565 (1987)
DIN 4188 (1977)
ISO 3310 (1999)
BS 410 (1986)
ASTM E 11-70 (1995)
AFNOR NFX11-501 (1987)

Legend: Q: Water Flow Rate, V: Velocity, P: Pressure drop
Pressure drop in bar per 100 meters of straight pipe (water at ambient temperature)

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Besides its main range of nozzles for industrial applications, PNR manufactures a wide range of complementary products and systems to optimize the use of spray jets and fluids control in most of the modern industrial processes

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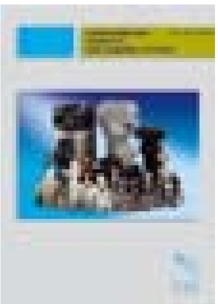

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