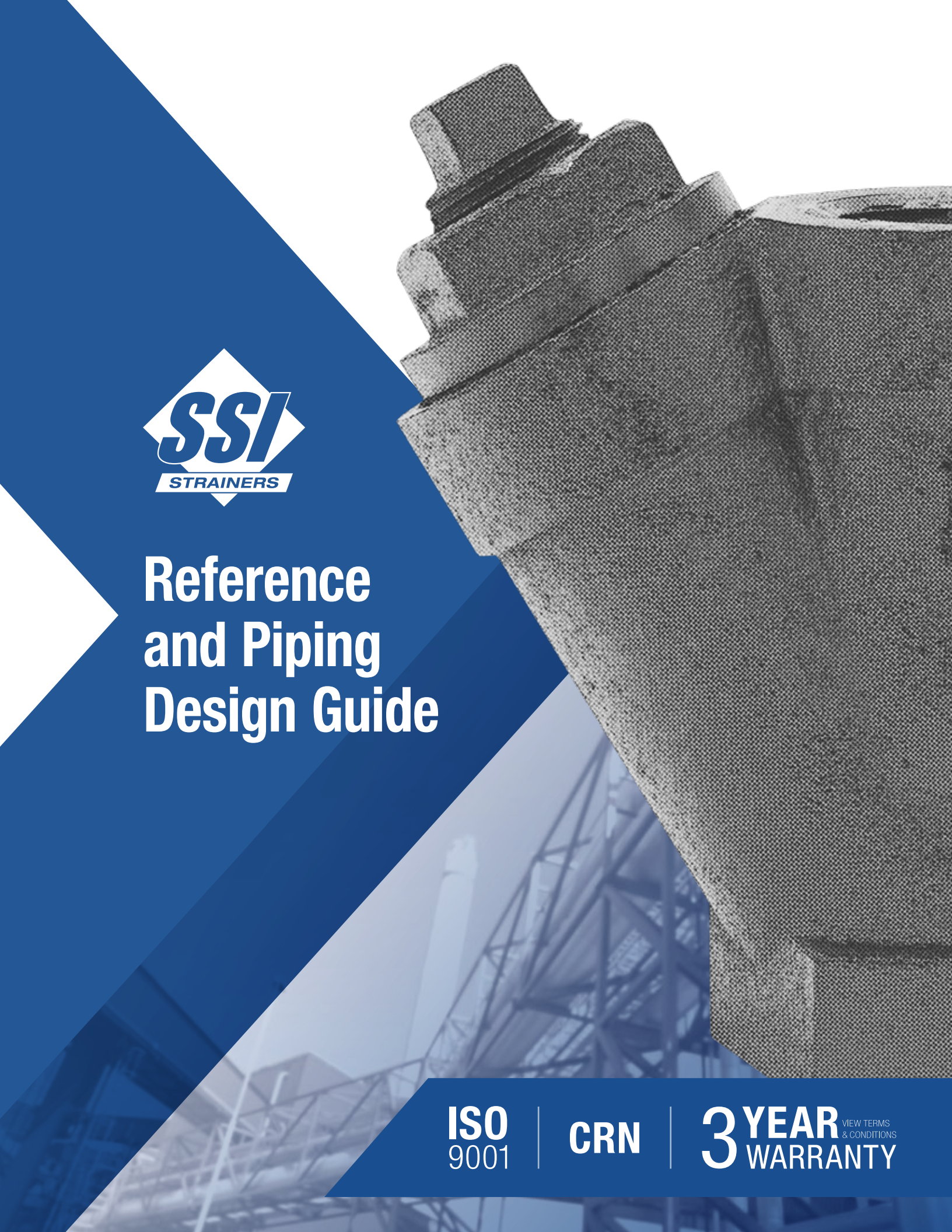

SSI STRAINERS

Reference and Piping Design Guide

ISO 9001 | CRN | 3 YEAR WARRANTY VIEW TERMS & CONDITIONS

Table of Contents

Guide for the Selection, Installation and Maintenance of Pipeline Strainers

Preface

Piping and Flange Compatibilities

Experience has proven the need for strainers in the protection of pumps, compressors, turbines, meters, automatic valves, sprinkler heads, burner nozzles, steam traps and other pipeline equipment.

This guide has been established as a technical reference for project engineers and managers responsible for specifying and using pipeline strainers. While strainers remain a relatively low cost item, when specified properly, the protection they provide is invaluable. It is the intent of this guide to provide the background and information necessary to make knowledgeable and sound engineering decisions in the specification of pipeline strainers.

The Pipeline Strainer Section of the Fluid Controls Institute, Inc. acknowledges and appreciates the assistance of those people who have made the creation and updating of this technical resource possible the horizontal position with the lower disc edge opening in the downstream direction.

Chapter 1

Definition

A pipeline strainer is a device which provides a means of mechanically removing solids from a flowing fluid by utilizing a perforated, mesh or wedge wire straining element. The most common range of strainer particle retention is 1 inch to 40 microns (.00156 inch).

Purpose

Strainers are employed in pipelines to protect downstream mechanical equipment such as condensers, heat exchangers, pumps, compressors, meters, spray nozzles, turbines, steam traps, etc. from the detrimental effect of sediment, rust, pipe scale or other extraneous debris.

Types of Strainers

Two frequently specified strainers are the “Y” strainer and the basket strainer. While there is primarily one type of “Y” strainer (Fig. 1A), there are several variations of basket strainers (Figs. 1B through 1E).

Figure 1A

Figure 1B

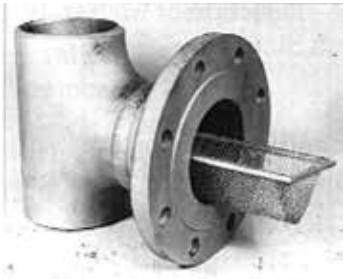

Figure 1C

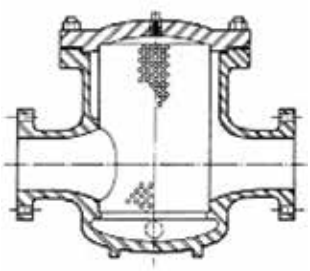

Figure 1D

Figure 1E

A “Y” strainer in vertical piping must be placed with its screen in the downward position to trap the sediment in the debris collection chamber.

Tee type strainers, suction diffusers and several variations of basket strainers can also be used in a right angle flow application (Fig. 3).

“Y” strainers and most variations of basket strainers can be self-cleaning. With the addition of a blowdown valve and some modification of the straining element of a basket strainer, the element can be flushed out by opening and closing the blowdown valve. This can be done without flow shut down or disassembling any piping.

In sizes above 4”, a single basket strainer will generally, create less pressure drop than a “Y” type. Basket strainers are normally installed in a horizontal pipe with the cover over the basket at the top. Cleaning of the strainer is generally simple and no draining is required. Cover flanges for basket strainers are relatively easy to remove and servicing is simplified. Replacement of covers on “Y”-type strainers is facilitated by some manufacturers through the use of studs, rather than bolts, which help to align the cover during the replacement operations. Hinged covers and screen locking devices can also make servicing easier.

Figure 3

There seems to be a general misconception among engineers and contractors concerning “Y” strainers and basket strainers used in steam service. In many instances, basket and “Y” strainers will perform comparably in steam service. It is essential in ordering strainers for steam service that the manufacturer be so advised. As mentioned above, the housings may be furnished without a bottom, allowing the accumulated debris to be blown out by opening the blowdown valve (Fig. 4).

“Y” strainers, on the other hand, are readily available for working pressures up to 6,000 psi and higher. In addition to “Y” and basket types, other strainers are available such as duplex/twin, geometric, washdown/back-flushing, automatic self cleaning, plate or expanded cross section type, scraper, and magnetic screen types. Descriptions of these as well as miscellaneous options available with them, follow.

Duplex/Twin Strainers

For applications where continuous operation is required and the line cannot be disassembled for cleanout, duplex or twin basket strainers can be used. Refer also to Automatic Strainers for continuous service applications. Examples are fuel oil strainers for industrial or marine oil burners, lubricating lines on board ships, cooling towers, continuously running chemical operations, and many industrial water intake and service lines.

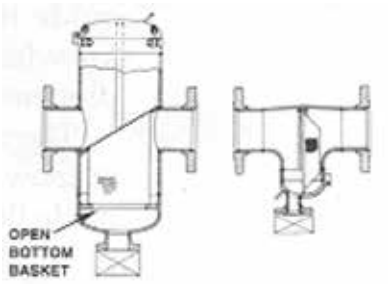

Figure 4

When one basket becomes full, the flow is switched to the other basket. The first basket is removed, cleaned and replaced. These strainers are frequently furnished with an interlocking chain-drive mechanism so the two valves work in unison (one basket compartment opens while the other is being valved off). This prevents accidental shutoff of the line.

This type strainer can be furnished with individual globe valves instead of gate valves. Globe valves give more positive shutoff, but since these strainers are not normally used for high pressures they are generally not needed. The globe- valve-type duplex strainer is usually more expensive than the gate-valve type.

Twin strainers, two single basket strainers connected in parallel with individual control valves are also available (Fig. 8). Where continuous operations is required, however, a duplex strainer is generally preferred. It occupies less space and is a “one-piece unit”. However, because of the more circuitous path the liquid must take through a duplex strainer, pressure drop is higher than through the equivalent size single basket strainer.

Figure 8

Figure 9A

Geometric (Temporary) Strainers

(Fig. 9A) Where cost is of prime importance, a geometric strainer may be installed between flanges in a pipe line. The design considerations with these types of strainers are:

1) They have a lower net open area than basket strainers.
2) The pipe line must be disassembled to inspect, clean or remove these strainers.
3) Structural strength can be difficult to achieve, particularly in larger sizes, and in the case of wire mesh.

While these strainers were once called temporary or startup strainers, more frequently than not, they are now left in the line during operation. As with all types of strainers, periodic maintenance must be carried out to ensure efficient operation.

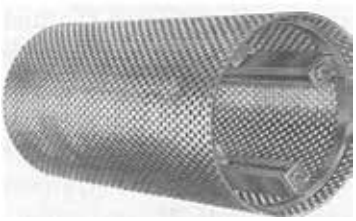

Figure 15

Magnetic Strainers

(Fig. 15) An effective solution to the problem of excessive and premature wear of plump seals and wear rings has been the magnetic screen assembly. A standard strainer is fitted with magnets which are removable for cleaning. These magnets are so spaced and arranged as to create a magnetic field around the interior of the screen and attract fine ferrous particle which could damage downstream equipment.

Engineers have specified this type of strainer in pilot jobs and, after evaluation, have standardized this specification for all pump strainers. Magnets can be incorporated in almost any of the “Y”, basket or geometric type strainers.

Special Application Strainers

A) High Differential Strainers

There is an increasing demand for strainers with screens which can withstand full line pressure when clogged. While the types of strainers already discussed can be structurally enhanced to withstand fairly high pressures (Fig. 16A and 16B), cases where extremely high differentials exist may call for special design. These screens are frequently constructed of very heavy wire mesh or welded to ensure complete structural integrity. A few manufacturers can supply these strainers over a wide range of pressure requirements.

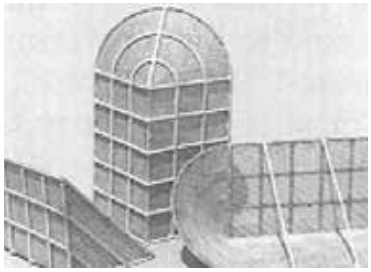

Figure 16A

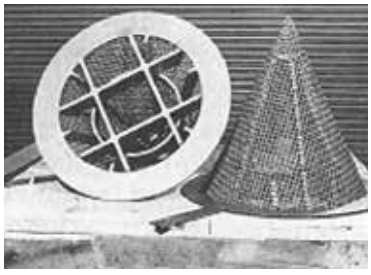

Figure 16B

B) Micronic Strainers

Strainers are available with extremely fine wire mesh which will remove particles as fine as 5 microns. These strainers, though expensive, are more economical than the disposable cartridge-type filters in that the straining elements can be cleaned and reused. Corrosion resistance is also better in most cases. Baskets must be supplied with a gasket, “O” ring, or close tolerance metal-to-metal seal to eliminate bypassing. Oil separation can be accomplished with cotton or fiber-filled screens. Water can be separated from gasoline using a fine mesh. Bronze or stainless steel wool-packed straining elements also serve certain filter requirements.

C) High Capacity (Volume) Basket Strainers

These strainers are designed for viscous fluids, gasoline and fuel oil service where fine straining has to be combined with a large basket which will not clog after extended periods. A gasketed seat or close tolerance metal-to-metal fit for the baskets insures that no bypassing of fine particles will occur.

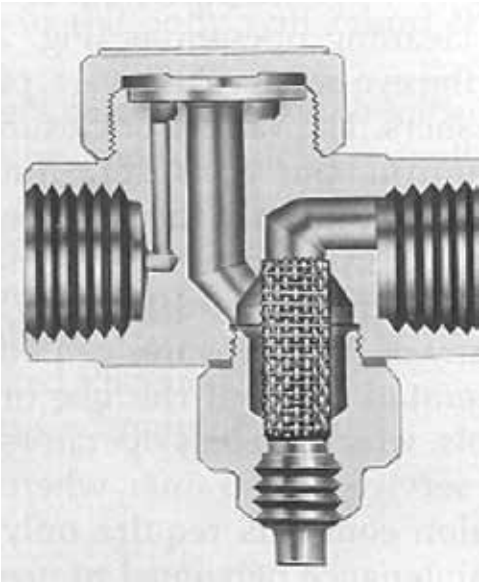

Figure 17

Figure 17

Quite frequently line sizes are reduced following a strainer prior to temperature control valves or heating and cooling coils (Fig. 19). A reducing strainer can eliminate joints, reduce pressure loss, and still provide the same offset produced by the reducer. Of course, the reducer is also eliminated.

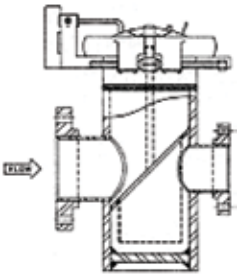

Figure 19

Figure 20

Miscellaneous Strainer Options

Strainers can be incorporated into a piping system in a variety of ways. Mechanical equipment can incorporate a strainer in the body. This can be economical and can reduce pipe connections and labor (Fig. 17).

In some cases, a strainer is required at the inlet of a pump or meter which is extremely close to the ground. An offset strainer (Fig. 18) with a high inlet and low outlet will satisfy this need. Other designs may use a tee type basket strainer (Fig. 3) in an angle flow application.

Special processes may warrant special strainer housings. Steel or stainless steel strainers may be fitted with a fabricated or cast outer jacket with connections for the introduction of steam or other heating or cooling medium (Fig. 20). These types of strainers are used in applications mainly in process piping where the liquid handled must be maintained at other than ambient temperatures.

In addition to special process needs, there may be special maintenance needs. Simplifying the handling of strainers during cleanings or inspections reduces maintenance costs. Strainers are available with many types of quick-opening covers to reduce the length of time and labor involved in cleaning operations (Fig. 21). Among these are swing eye bolts, yoke covers, pinwheel covers and “C” washers. The variety of closures are too numerous to mention, but consideration should be given to them where reduction of downtime is important. Additionally, many of these closures can be operated without the use of tools, which enables operators to service the strainer where Union contracts require only maintenance personnel to use tools.

Figure 21

Chapter 2

End Connections

Strainers are available in a variety of end connections. Iron strainers are most commonly furnished in either threaded or flanged ends. Steel, stainless steel and bronze are supplied in any of the types discussed below. The four most common groups of end connections are listed and described below.

Threaded

Usually a tapered female pipe thread, although male connections are also available.

Flanged

ANSI (American National Standards Institute) and MSS (Manufacturer’s Standardization Society) standard flange ratings 25, 125, 150, 250, 300, 400, 600, 900, 1500 and 2500 pounds can be supplied. Ring-type joints (male and female), and tongue and groove joints are also available. The U.S. Navy also has some flange standards which are quite different from the commercial standards. Among these are B-176, B177, and MIL-F-20042C.

Weld Ends

Butt weld end strainers are generally available in all sizes, and although many forms of end preparations can be used, the standard 37-1/2" beveled end is most common. ANSI B16.25 illustrates the various types of weld joint preparations available. It is very important that the purchaser specify the bore of pipe being used so that the manufacturer can provide a matching bore in the strainer. Socket weld end strainers are usually available in sizes through 3", and again, it is important to specify the bore of the pipe used. In ordering weld end strainers of any type, consider whether you desire a welded blowdown connection.

Special Ends

Grooved ends are available on many strainers, and a detail of this end should be supplied to the manufacturer. Other special ends such as “O” ring and union ends are also available on special order, and complete details should be furnished. Most “Y”-type and certain other types of small strainers are designed according to the fitting standards for full pressure ratings and therefore can be subjected to higher working pressures at lower temperatures. It should be clearly understood, however, that most of the larger types and many of the smaller strainers are designed for the working pressure requested and should not be operated above that pressure without consulting the manufacturer. It is important to note that the flange rating is not necessarily the same as the pressure rating of the vessel. A fabricated carbon steel strainer, for example, may be operated at 40 psig at 500°F, designed for 100 psig at 650°F, and have 150-lb ANSI flanges. The maximum safe pressure at any temperature (650°F and below) for this vessel is 100 psig, even though the flange can be taken to 170 psig at 500°F.

It is important, at the time of initial design, to specify working pressure, working temperature, design pressure, design temperature, required flange rating and any operating conditions affecting vessel loading.

Chapter 3

Materials of Construction

Strainer components can include a body, flanges, cover, perforated plate, mesh, wedge wire, gasket and cover fasteners. Listed below are some materials of construction for these components.

Housing/Body	
Description	**ASTM Specification**
Iron Castings	A 126, A 278
Ductile Iron Castings	A 395, A 536
Iron-Austenitic Castings	A 436
Carbon Steel Castings	A 216
Carbon Steel Castings	A 27
Carbon Steel Pipe	A 53, A 106
Carbon Steel Plate	A 20, A 285, A 515, A 516
Carbon Steel Forgings	A 105
Carbon Moly Castings	A 217, A 352
Chrome Moly Forgings	A 182
Stainless Steel Castings	A 743, A 744, A 351
Chrome Moly Plate	A 387
Chrome Moly Pipe	A 335
Stainless Steel Pipe	A 312
Stainless Steel Plate	A 240
Stainless Steel Forgings	A 182
Aluminum Castings	B 26
Bronze Castings	B 61, B 62
Monel	B 164, B 127
Nickel 200 Plate	B 160, B 162
Hastelloy B Castings	A 494
Hastelloy B Plate	B 333
Hastelloy C Plate	B 575
Hastelloy C Pipe	B 619
Titanium Pipe	B 337
Titanium Castings	B 367
Perf. Plate/ Mesh/Wedge Wire	
Carbon Steel	S.S. (Various Grades Available)
Monel	Hastelloy B
Hastelloy C	Alloy 20
Nickel	Brass
Copper	Galvanized Steel
Incoloy	Inconel
Titanium	Aluminum
Gaskets	
Red Rubber	Compressed Nonasbestos
Teflon	Buna-N, O Ring
Neoprene	S.S. – Jacketed
Graphite	S.S. – Spiral Wound
Fasteners	
Carbon Steel	Alloy Steel
Silicon Bronze	304 S.S.
316 S.S.	Monel

Chapter 4

Corrosion Resistance – Selection of Materials

Almost every strainer operating in a pipe line is subject to some degree of corrosion or erosion. It is therefore very important that corrosion/erosion resistance is considered when selecting materials and/or coatings. The selection of the material or coating used is also usually based on economic considerations and should be made by the customer and/or consulting engineer after some discussion with the strainer manufacturer.

It is important that the type of fluid, the pressure and temperature conditions, type of adjacent piping, desired service life, and the customer's prior experience with similar fluid conditions be known. Corrosion resistance charts offer some assistance in the selection of materials or coatings. (See Corrosion Data Survey – Metals Solution, 6th Edition, NACE). Electrolytic corrosion is also a consideration in some services and the manufacturer should be advised.

Sometimes the inclusion of magnesium or zinc consumable bars in the body will retard this action. Most types of strainers can be lined with various coatings to retard corrosion, and some of these are listed below:

- Vinyl
- Rubber
- Baked Phenolic
- Neoprene
- Asphalt
- Vinyl
- Vinyl
- Rubber
- Baked Phenolic
- Penton (Plating: Zinc, Cadmium, Nickel, Galvanizing, etc.)

Chapter 5

Perforations and Mesh Sizing

An extremely important consideration in the selection of a strainer is the size of the perforations, mesh or wire opening used in the making of the straining element. A tendency exists to select smaller hole than those actually needed, leading to too-frequent cleaning, excessive pressure drops, and screens constructed of thinner metal which will withstand less pressure differential.

Generally, stainless steel perforated metal can only be obtained in a thickness which is one gage thickness less than the diameter of the punched holes. Carbon steel and brass can be obtained in approximately the same thickness as the hole diameter. These limitations are important considerations. For example, a strainer made with stainless steel plate perforated with 1/64" diameter holes in a 16" line would be impractical, as the plate would be about 17" in diameter and only 0.014" thick, and would have a very low maximum allowable differential pressure.

The most common way to accomplish fine straining in large strainers is by mesh lining a larger hole, heavier gage perforated plate. The following table illustrates available perforations, mesh, and wedge wire and their respective straining capability. The main criteria for choosing hole and mesh size is the size and quantity of particles which can pass through downstream equipment without causing damage.

Reference & Piping Design

Perforated Metal**	
Hole Diameter x Hole Spacing	Percent Open Area
0.020 x 0.043	20
0.027 x 0.066	17
*0.033 x 0.077	20
*0.045 x 0.086	28
*0.057 x 0.121	25
*0.062 x 3/32	41
*0.094 x 5/32	33
0.100 x 5/32	37
*1/8 x 3/16	40
*5/32 x 3/16	63
3/16 x 1/4	51
*1/4 x 3/8	40
5/16 x 7/16	47
3/8 x 1/2	51
7/16 x 19/32	49
1/2 x 11/16	48
5/8 x 13/16	54
3/4 x 1	51
1 x 1-3/8	48

* These are standards as they appear in the Designers, Specifiers and Buyers Handbook for Perforated Metals published by the Industrial Perforators Association.

** Perforated plate listed is for staggered pattern only.

Wedge Wire		
Opening	Micron	% Open
0.003"	75	–
0.005"	127	7.7
0.010"	254	14.3
0.015"	381	25
0.020"	500	25
0.031"	775	34
0.034"	864	20
0.062"	1550	51
0.063"	1600	50
0.094"	2350	44
0.125"	3175	66
0.156"	3962	71

Mesh				
Mesh (Openings (Inches)	Wire Diameter (Inches)	Opening		Percent Open Area
		Inches	Micron	
2	0.063	0.437	11100	76.4
2	0.092	0.407	10360	66.6
3	0.063	0.270	6860	65.6
4	0.47	0.208	5160	65.9
4	0.063	0.187	4750	56.0
5	0.041	0.159	4040	63.2
6	0.035	0.132	3350	62.7
7	0.035	0.108	2740	57.2
8	0.028	0.097	2460	60.2
10	0.025	0.075	1910	56.3
11	0.018	0.073	1850	64.5
12	0.023	0.060	1520	51.8
14	0.020	0.051	1300	51.0
16	0.018	0.044	1130	50.7
18	0.017	0.038	980	48.3
20	0.016	0.034	872	46.2
30	0.013	0.020	513	37.1
40	0.010	0.015	384	36.0
50	0.009	0.011	282	30.3
60	0.007	0.009	231	33.9
80	0.005	0.0075	180	36.0
24 x 115	0.0056	–	–	–
100	0.0045	0.0055	141	30.3
120	0.0037	0.0046	118	30.1
30 x 160	–	0.0046	118	–
150	0.0026	0.0041	105	37.4
40 x 200	–	0.0033	85	–
170	0.0024	0.0035	79	35.1
30 x 260	–	0.0029	75	–
200	0.0021	0.0029	74	33.6
250	0.0016	0.0024	62	36.0
50 x 250	0.0024	–	62	–
28 x 480	–	0.0023	59	–
300	0.0015	0.0018	46	29.7
325	0.0014	0.0017	44	30.0
400	0.0010	0.0015	39	36.0
80 x 700	–	0.0012	40	–
125 x 600	–	–	30	–
165 x 800	–	–	28	–
165 x 1400	–	–	17	–
200 x 1400	–	–	10	–
250 x 1400	–	–	83	–
25 x 2300	–	–	53	–
5 x 2400	–	–	4	–
400 x 2800	–	–	3	–

Chapter 6

Capacity

The capacity ratio, or open area ratio (OAR) of a strainer influences such operating characteristics as the length of time it can operate without cleaning and the created pressure loss. The ratio/OAR is the relationship between internal cross sectional area (flow area) of the pipe and the open flow area of the material which makes up the straining element.

A 100% OAR, or 1-to-1 ratio would give an unrestricted flow area equal to that of the pipe while the element was clean. As clogging occurs, however, flow would be inhibited. A 200% OAR, or 2-to-1 ratio would provide full flow, after the element became 50% clogged. A 250% OAR is a good standard for general heating and air conditioning service. However, larger OAR's or ratios would be appropriate for flow in which much debris is expected to be strained or where very viscous fluids are being handled.

When considering the OAR of a straining element, there are two accepted methods of analysis used by various specifying agencies and manufacturers. One method maintains a "line of sight" reasoning and uses the multiple of the open areas for elements in series. In this method, a 60% open area material in series with a 40% open area material has a resultant combined open area of 24% (i.e. as in accordance with military standards). An alternative method allows the open area of the more restrictive element in series to be used. This would be 40% for the example above (i.e. as in accordance with Underwriter Laboratories' Standards). The method used influences the estimated operating pressure drop, as well as design decisions such as sizing.

As an example, fuel oils are generally strained to a fine degree to protect small orifices in burner nozzles. This requires a fine woven mesh be used in series with a reinforcing perforated plate. Due to the fact that the perforated plate may have a 50% open area and the mesh 30%, the resultant combined open area may be considered to be only 15% if there is not flow path other than line of sight through the two elements in series. This, of course, would mean that to have a OAR of 250%, a high capacity, large bodied strainer is required

This same strainer using only the perforated plate would have an OAR more than three times as great. So, it may be seen that in any given strainer, the OAR may be varied by using various perforations or meshes having different open areas. Thus, it is essential to specify not only the OAR desired, but the straining element opening size and the method for calculating OAR

Chapter 7

Pressure Loss

Because strainers are made with various dimensions and configurations, most reputable manufacturers have tested and published pressure drop results.

Most pump installations designed for reasonable velocities will permit approximately a 2-psi drop across the strainer. When a screen becomes clogged, the pressure drop varies with the clogging pattern experienced and the type of strainer being used. While some manufacturers speculate as to the change in head loss at different percentages of clogging, it should be recognized that this type of testing is very difficult to relate to actual line performance. This is because of differences in strainer clogging characteristics — a 1/4" perforated basket two-thirds full of 1/2" stones will be less affected than a small amount of fine leaves on a large 100-mesh basket. If large amounts of solids are expected, use a strainer with a high net open area as discussed in Chapter 6.

As a strainer becomes clogged to the point where the OAR of the strainer approaches the pipe area, the pressure drop across the strainer increases very rapidly and unpredictably. It is at this point, therefore that it is recommended the strainer be cleaned. Otherwise, a large differential pressure will develop. The maximum differential pressure a strainer can withstand varies widely with strainer type, line size and material used. Always consult the manufacturer for maximum differential pressure a straining element can withstand.

From the foregoing discussion, it is obvious that periodic cleaning is essential in any strainer installation. Once the rate of clogging is established, a cleaning schedule can be set up. Pressure gauges on each side of the strainer can be valuable to determine when the strainer requires cleaning. Differential pressure switches can be set up to operate warning lights or alarms if so desired.

Some manufacturers have related their strainers' pressure drop to equivalent feet of pipe at various turbulent flow rates, and this can simplify the computation of head loss for an entire system. However, varying field conditions and fluid properties can affect the accuracy of general type pressure drop estimations. Further, operating viscous fluids under laminar flow conditions requires analysis different from that for fluids under turbulent conditions. Accordingly, the manufacturer should always be consulted for the most specific and accurate estimated pressure loss.

Chapter 8

Specifications and Manufacturer Testing

Needless to say, the more information provided to the manufacturer when ordering strainers, the better the chance of obtaining a strainer which is appropriately suited for a particular job. It is for this reason that considerable space is devoted to the preparation of specifications.

Specification

To allow the manufacturer to make selection or recommendations for a particular strainer, as much as possible, the following information should be provided:

Physical characteristics

- Pipe size and schedule.
- Strainer type requires.
- End connections.
- Material (body, screen, studs, gaskets).
- Pressure rating (design/operating — including shock).
- Temperature rating (design, operating, minimum).
- Straining element opening size.
- Capacity:
  a) Net effective open area required.
  b) Method of net open area calculation.
- Special requirements (hinged cover, vent tapping, jacketed, etc.).
- Applicable specifications (military specifications, special nondestructive tests or other QC Requirements).
- For automatic self-cleaning strainers, specify the following:
  a) Voltage and frequency of power supply;
  b) Air supply pressure if available;
  c) Type of controls desired;
  d) Type of motor, switch & control panel enclosure required.

Flow Data

Liquid

- Description of fluid.
- Rate of flow - gallons per minute (gpm) or pounds per hour (lbs/hr).
- Viscosity – SSU.
- Specific gravity/density.
- Temperature.
- Concentration (if acid or other corrosive).

Gas

- Description of fluid.
- Rate of flow - gallons per minute (gpm) or pounds per hour (lbs/hr).
- Viscosity – SSU.
- Specific gravity/density.
- Temperature.
- Concentration (if acid or other corrosive).

Steam

- Flow-pounds per hour.
- Temperature.
- Pressure.
- Density.
- State of flow.

Solids to be Removed

Specify the nature and relative size of the sediment. Parts per million (ppm) or percent by volume or cubic inches per hour or percent by weight can also be specified.

NOTE: If strainer is to be steam jacketed, the following information for the heat transfer fluid or steam must be given

- Type of fluid.
- Rate of flow
- Temperature.
- Pressure.
- Type and size connections desired.
- Material for jacket construction.
- Whether strainer end flanges are oversized to match jacketed pipe.

Allowable Pressure Drop (psi)

- Clean.
- 50% clogged.

NOTE: Operating pressure drop is a function of operating conditions, fluid characteristics and strainer geometry. Consequently, if specifying a strainer type and geometry, a desired pressure drop may not be obtainable if fluid parameters are fixed. The “trade-off” relationship between fluid conditions, strainer geometry and operating pressure drop establishes what compromises must be made.

Available Types of Manufacturer Testing

A) Hydrostatic

Most common test – usually 1-1/2 times working pressure to determine that a strainer body, cover gaskets, etc., are sound.

B) Radiographic Examination

To determine if the casting or welded joint has any slag or sand inclusions, gas pockets or subsurface defects. This type of test is quite expensive and usually specified only for high pressure strainers.

C) Magnetic Particle

A reasonably low cost examination to reveal relatively shallow subsurface cracks, gas pockets, etc. Iron dust is sprinkled on the surface of the casting/weld and a magnetic force is induced electrically, causing the dust to align over defects and cracks showing their location and size. Can be used only on iron and steel.

D) Dye Penetrant

Equivalent to magnetic particle testing, except used mainly with nonmagnetic castings/welds to reveal surface defects, cracks, depressions, etc.

E) Air Test

Either under water or with part covered with soap solution. This is a more stringent test for porosity and gasket leakage than hydrostatic, and leaks often are more obvious. Sometimes not done, due to relative danger involved.

F) Hydrostatic Burst Test

Sometimes done to establish manufacturer's maximum working pressure rating, or at the request of purchaser.

G) Shock

Usually a government requirement where strainers will remain operative or intact in the event of a near- proximity explosion. Test normally conducted on a machine where weighted hammer strikes plate on which strainer is mounted.

H) Vibration

Normally a government requirement where strainers must withstand a vibration test which involves a number of frequencies. This usually simulates shipboard vibrations, earthquake, etc.

I) Surge Test

A strainer is pressurized with water and a quick-opening valve on the outlet flange is rapidly opened to determine that no damage is sustained by the basket. Normally, a military requirement.

J) Helium Leak Test

A very stringent test where the strainer is pressurized with helium and leaks are checked with sensitive instruments. A maximum leak rate is usually specified. Used mostly for nuclear plants for radioactive water piping.

K) Ferroxyl

A test to detect free iron in stainless steel strainers where the iron would contaminate the product.

NOTE: Many tests by their very nature can be more or less stringent. Acceptance standards should be included in any inquiry calling for such tests. Naturally, the more stringent the test requirements, the more costly the ultimate strainer becomes.

Chapter 9

Shock-Hydraulic and Thermal

Any liquid being transmitted in a pipe line possesses a certain amount of energy (weight times velocity). A rapid change in velocity results in a momentary shock wave. In the case of a quick-closing valve, the energy of the flowing fluid must be used up in some way, and the resulting shock, or "water hammer", is clearly audible. A pressure wave, in some cases, travels at over 3,000 feet per second and traverses the pipeline in one direction, then the other, until it dissipates. A theoretical figure of 54 psi for each foot per second that is stopped by the valve may be used. A 12 foot per second velocity could produce a shock wave having a peak of 648 psi; therefore, consideration should be given to the shock and non- shock rating of the strainer.

No attempt will be made here to go into the highly technical field of hydraulic shock, and it is covered briefly to point out that even if your system can produce only a specific head, if the possibility of shock is present, tremendous overpressures may result.

Commonly known is the phenomenon of pouring hot tea into a glass and watching the glass crack. This is an example of thermal shock. Rapid changes of temperature in piping systems can have the same effect, and in selecting strainers consideration must be given to this possibility.

In improperly trapped steam lines, condensate can collect in low points and subsequently become a slug of water traveling at high velocity down the line. Almost all strainers cause a change in direction of flow due to their configuration, and the result can be obvious if the strainer cannot absorb this type of shock. In considering this situation, it is important to remember that steam velocities of 4,000 to 20,000 feet per minute are quite common.

Chapter 10

Conclusion

Strainers are no longer confined to a simple cast body with a wire mesh screen, but are a technical, highly refined, carefully designed piece of equipment.

Sometimes they operate at 1,500ºF and 10,000 psig or at cryogenic temperatures. They are modified with steam jackets, cover lifting davits, magnets, motorized cleaning devices and automatic vent valves. They are supplied with screwed, flanged, socket weld, butt weld, ring joint and silver brazing end connections.

Accordingly, the implementation of a strainer needs to be well thought out and engineered. While it is good practice to use a strainer to protect downstream equipment, it is very important to carefully consider the options available. Choosing the correct strainer can save money not only by protecting equipment, but also by keeping operations and maintenance costs at a minimum.

List of Figures

Flange Standards – Cast Iron & Bronze

125 lb. Cast Iron | ANSI Standard B16.1															
Pipe Size	**½**	**¾**	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**3½**	**4**	**5**	**6**	**8**	**10**	**12**
Diameter of Flange	–	–	4.25	4.63	5.00	6.00	7.00	7.50	8.50	9.00	10.00	11.00	13.50	16.00	19.00
Thickness of Flange (min)[a]	–	–	0.44	0.50	0.56	0.63	0.69	0.75	0.81	0.94	0.94	1.00	1.13	1.19	1.25
Diameter of Bolt Circle	–	–	3.13	3.50	3.88	4.75	5.50	6.00	7.00	7.50	8.50	9.50	11.75	14.25	17.00
Number of Bolts	–	–	4.00	4.00	4.00	4.00	4.00	4.00	8.00	8.00	8.00	8.00	8.00	12.00	12.00
Diameter of Bolts	–	–	0.50	0.50	0.50	0.63	0.63	0.63	0.63	0.63	0.75	0.75	0.75	0.88	0.88

250 lb. Cast Iron | ANSI Standard B16.1															
Pipe Size	**½**	**¾**	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**3½**	**4**	**5**	**6**	**8**	**10**	**12**
Diameter of Flange	–	–	4.88	5.25	6.13	6.50	7.50	8.25	9.00	10.00	11.00	12.50	15.00	17.50	20.50
Thickness of Flange (min)[b]	–	–	0.69	0.75	0.81	0.88	1.00	1.13	1.19	1.25	1.38	1.44	1.63	1.88	2.00
Diameter of Raised Face	–	–	2.69	3.06	3.56	4.19	4.94	5.69	6.31	6.94	8.31	9.69	11.94	14.06	16.44
Diameter of Bolt Circle	–	–	3.50	3.88	4.50	5.00	5.88	6.63	7.25	7.88	9.25	10.63	13.00	15.25	17.75
Number of Bolts	–	–	4.00	4.00	4.00	8.00	8.00	8.00	8.00	8.00	8.00	12.00	12.00	16.00	16.00
Diameter of Bolts	–	–	0.63	0.63	0.75	0.63	0.75	0.75	0.75	0.75	0.75	0.75	0.88	1.00	1.13

150 lb. Bronze | ANSI Standard B16.24															
Pipe Size	**½**	**¾**	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**3½**	**4**	**5**	**6**	**8**	**10**	**12**
Diameter of Flange	3.50	3.88	4.25	4.63	5.00	6.00	7.00	7.50	8.50	9.00	10.00	11.00	13.50	16.00	19.00
Thickness of Flange (min)[c]	0.31	0.34	0.38	0.41	0.44	0.50	0.56	0.63	0.69	0.69	0.75	0.81	0.94	1.00	1.06
Diameter of Bolt Circle	2.38	2.75	3.13	3.50	3.88	4.75	5.50	6.00	7.00	7.50	8.50	9.50	11.75	14.25	17.00
Number of Bolts	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	8.00	8.00	8.00	8.00	8.00	12.00	12.00
Diameter of Bolts	0.50	0.50	0.50	0.50	0.50	0.63	0.63	0.63	0.63	0.63	0.75	0.75	0.75	0.88	0.88

300 lb. Bronze | ANSI Standard B16.24															
Pipe Size	**½**	**¾**	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**3½**	**4**	**5**	**6**	**8**	**10**	**12**
Diameter of Flange	3.75	4.63	4.88	5.25	6.50	6.50	7.50	8.25	9.00	10.00	11.00	12.50	15.00	–	–
Thickness of Flange (min)[d]	0.50	0.53	0.59	0.63	0.69	0.75	0.81	0.91	0.97	1.06	1.13	1.19	1.38	–	–
Diameter of Bolt Circle	2.63	3.25	3.50	3.88	4.50	5.00	5.88	6.63	7.25	7.88	9.25	10.63	13.00	–	–
Number of Bolts	4.00	4.00	4.00	4.00	4.00	8.00	8.00	8.00	8.00	8.00	8.00	12.00	12.00	–	–
Diameter of Bolts	0.50	0.63	0.63	0.63	0.75	0.63	0.75	0.75	0.75	0.75	0.75	0.75	0.88	–	–

[a] 125 lb. cast iron flanges have plain faces | [b] 250 lb. cast iron flanges have a 1/16" raised face which is included in the flange thickness dimensions | [c] 150 lb. bronze flanges have plain faces with two concentric gasket-retaining grooves between the port and the bolt holes
[d] 300 lb. bronze flanges have plain faces with two concentric gasket-retaining grooves between the port and the bolt holes

Flange Standards – Steel

150 lb. Steel | ANSI Standard B16.5															
Pipe Size	**½**	**¾**	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**3½**	**4**	**5**	**6**	**8**	**10**	**12**
Diameter of Flange	–	–	4.00	4.63	5.00	6.00	7.00	7.50	8.50	9.00	10.00	11.00	13.50	16.00	19.00
Thickness of Flange (min)[e]	–	–	0.44	0.50	0.56	0.63	0.69	0.75	0.81	0.94	0.94	1.00	1.13	1.19	1.25
Diameter of Raised Face	–	–	2.00	2.50	2.88	3.63	4.13	5.00	5.50	6.19	7.31	8.50	10.63	12.75	15.00
Diameter of Bolt Circle	–	–	3.13	3.50	3.88	4.75	5.50	6.00	7.00	7.50	8.50	9.50	11.75	14.25	17.00
Number of Bolts	–	–	4.00	4.00	4.00	4.00	4.00	4.00	8.00	8.00	8.00	8.00	8.00	12.00	12.00
Diameter of Bolts	–	–	0.50	0.50	0.50	0.63	0.63	0.63	0.63	0.63	0.75	0.75	0.75	0.88	0.88

300 lb. Steel | ANSI Standard B16.5															
Pipe Size	**½**	**¾**	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**3½**	**4**	**5**	**6**	**8**	**10**	**12**
Diameter of Flange	–	–	4.88	5.25	6.13	6.50	7.50	8.25	9.00	10.00	11.00	12.50	15.00	17.50	20.50
Thickness of Flange (min)[f]	–	–	0.69	0.75	0.81	0.88	1.00	1.13	1.19	1.25	1.38	1.44	1.63	1.88	2.00
Diameter of Raised Face	–	–	2.00	2.50	2.88	3.63	4.13	5.00	5.50	6.19	7.31	8.50	10.63	12.75	15.00
Diameter of Bolt Circle	–	–	3.50	3.88	4.50	5.00	5.88	6.63	7.25	7.88	9.25	10.63	13.00	15.25	17.75
Number of Bolts	–	–	4.00	4.00	4.00	8.00	8.00	8.00	8.00	8.00	8.00	12.00	12.00	16.00	16.00
Diameter of Bolts	–	0.63	0.63	0.75	0.63	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.88	1.00	1.38

400 lb. Steel | ANSI Standard B16.5															
Pipe Size	**½**	**¾**	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**3½**	**4**	**5**	**6**	**8**	**10**	**12**
Diameter of Flange	3.75	4.63	4.88	5.25	6.13	6.50	7.50	8.25	9.00	10.00	11.00	12.50	15.00	17.50	20.50
Thickness of Flange (min)[g]	0.56	0.63	1.06	1.19	0.88	1.00	1.13	1.25	1.38	1.38	1.50	1.63	1.88	2.13	2.25
Diameter of Raised Face	0.03	1.69	2.00	2.50	2.88	3.63	4.13	5.00	5.50	6.19	7.31	8.50	10.63	12.75	15.00
Diameter of Bolt Circle	2.63	3.25	3.50	3.88	4.50	5.00	5.88	6.63	7.25	7.88	9.25	10.63	13.00	15.25	17.75
Number of Bolts	4.00	4.00	4.00	4.00	4.00	8.00	8.00	8.00	8.00	8.00	8.00	12.00	12.00	16.00	16.00
Diameter of Bolts	0.50	0.63	0.63	0.63	0.75	0.63	0.75	0.75	0.88	0.88	0.88	0.88	1.00	1.13	1.25

600 lb. Steel | ANSI Standard B16.5															
Pipe Size	**½**	**¾**	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**3½**	**4**	**5**	**6**	**8**	**10**	**12**
Diameter of Flange	3.75	4.63	4.88	5.25	6.13	6.50	7.50	8.25	9.00	10.75	13.00	14.00	16.50	20.00	22.00
Thickness of Flange (min)[h]	0.56	0.63	0.69	0.81	0.88	1.00	1.13	1.25	1.38	1.50	1.75	1.88	2.19	2.50	2.63
Diameter of Raised Face	1.38	1.69	2.00	2.50	2.88	3.63	4.13	5.00	5.50	6.19	7.31	8.50	10.63	12.75	15.00
Diameter of Bolt Circle	2.63	3.25	3.50	3.88	4.50	5.00	5.88	6.63	7.25	8.50	10.50	11.50	13.75	17.00	19.25
Number of Bolts	4.00	4.00	4.00	4.00	4.00	8.00	8.00	8.00	8.00	8.00	8.00	12.00	12.00	16.00	20.00
Diameter of Bolts	0.50	0.63	0.63	0.63	0.75	0.63	0.75	0.75	0.88	0.88	1.00	1.00	1.13	1.25	1.25

[e] 150 lb. steel flanges have a 1/16" raised face which is included in the flange thickness dimensions | [f] 300 lb. steel flanges have a 1/16" raised face which is included in the flange thickness dimensions | [g] 400 lb. steel flanges have a 1/4" raised face which is included in the flange thickness dimensions
[h] 600 lb. steel flanges have a 1/4" raised face which is included in the flange thickness dimensions

Pipe Data Tables

Pipe Size (in)	Outside Dia. (in)	Weight Class	C.S. Sched	S.S. Sched	Wall Thk. (in)	Inside Dia. (in)	Circum. Ext. (in)	Circum. Int. (in)	Flow Area (sq in)	Pipe Weight (lbs/ft)	Water Weight (lbs/ft)	Water Gallons (per ft)	Section Modulus
		–	–	10S	0.049	0.307		0.96	0.074	0.19	0.032	0.004	0.00437
1/8	0.405	STD	40	40S	0.068	0.269	1.27	0.85	0.057	0.24	0.025	0.003	0.00523
		XS	80	80S	0.095	0.215		0.68	0.036	0.31	0.016	0.002	0.00602
		–	–	10S	0.065	0.410		1.29	0.132	0.33	0.057	0.007	0.01032
1/4	0.540	STD	40	40S	0.088	0.364	1.70	1.14	0.104	0.42	0.045	0.005	0.01227
		XS	80	80S	0.119	0.302		0.95	0.072	0.54	0.031	0.004	0.01395
		–	–	10S	0.065	0.545		1.71	0.233	0.42	0.101	0.012	0.01736
3/8	0.675	STD	40	40S	0.091	0.493	2.12	1.55	0.191	0.57	0.083	0.010	0.0216
		XS	80	80S	0.126	0.423		1.33	0.141	0.74	0.061	0.007	0.0255
		–	–	5S	0.065	0.710		2.23	0.396	0.54	0.172	0.021	0.0285
		–	–	10S	0.083	0.674		2.12	0.357	0.67	0.155	0.019	0.0341
1/2	0.840	STD	40	40S	0.109	0.622	2.64	1.95	0.304	0.85	0.132	0.016	0.0407
		XS	80	80S	0.147	0.546		1.72	0.234	1.09	0.102	0.012	0.0478
		–	160	–	0.187	0.466		1.46	0.171	1.31	0.074	0.009	0.0527
		XXS	–	–	0.294	0.252		0.79	0.050	1.71	0.022	0.003	0.0577
		–	–	5S	0.065	0.920		2.89	0.665	0.69	0.288	0.035	0.0467
		–	–	10S	0.083	0.884		2.78	0.614	0.86	0.266	0.032	0.0566
3/4	1.050	STD	40	40S	0.113	0.824	3.30	2.59	0.533	1.13	0.231	0.028	0.0706
		XS	80	80S	0.154	0.742		2.33	0.433	1.47	0.188	0.022	0.0853
		–	160	–	0.219	0.612		1.92	0.296	1.94	0.128	0.015	0.1004
		XXS	–	–	0.308	0.434		1.36	0.148	2.44	0.064	0.008	0.1103
		–	–	5S	0.065	1.185		3.72	1.103	0.87	0.478	0.057	0.0760
		–	–	10S	0.109	1.097		3.45	0.945	1.40	0.409	0.049	0.1151
1	1.315	STD	40	40S	0.133	1.049	4.13	3.30	0.864	1.68	0.375	0.045	0.1328
		XS	80	80S	0.179	0.957		3.01	0.719	2.17	0.312	0.037	0.1606
		–	160	–	0.250	0.815		2.56	0.522	2.84	0.230	0.027	0.1903
		XXS	–	–	0.358	0.599		1.88	0.282	3.66	0.122	0.015	0.2136
		–	–	5S	0.065	1.530		4.81	1.839	1.11	0.797	0.096	0.1250
		–	–	10S	0.109	1.442		4.53	1.633	1.81	0.708	0.085	0.1934
1¼	1.660	STD	40	40S	0.140	1.380	5.22	4.34	1.495	2.27	0.649	0.078	0.2346
		XS	80	80S	0.191	1.278		4.02	1.283	3.00	0.555	0.067	0.2913
		–	160	–	0.250	1.160		3.64	1.057	3.76	0.458	0.055	0.3421
		XXS	–	–	0.382	0.896		2.81	0.630	5.21	0.273	0.033	0.4110
		–	–	5S	0.065	1.770		5.56	2.461	1.28	1.066	0.128	0.1662
		–	–	10S	0.109	1.682		5.28	2.222	2.09	0.963	0.115	0.2598
1½	1.900	STD	40	40S	0.145	1.610	5.97	5.06	2.036	2.72	0.882	0.106	0.3262
		XS	80	80S	0.200	1.500		4.71	1.767	3.63	0.765	0.092	0.4118
		–	160	–	0.281	1.338		4.20	1.406	4.86	0.608	0.073	0.5078
		XXS	–	–	0.400	1.100		3.46	0.950	6.41	0.420	0.049	0.5977
		–	–	5S	0.065	2.245		7.05	3.958	1.61	1.72	0.206	0.2652
		–	–	10S	0.109	2.157		6.78	3.654	2.64	1.58	0.190	0.4204
2	2.375	STD	40	40S	0.154	2.067	7.46	6.49	3.355	3.65	1.45	0.174	0.5606
		XS	80	80S	0.218	1.939		6.09	2.953	5.02	1.28	0.153	0.7309
		–	160	–	0.344	1.687		5.30	2.241	7.46	0.97	0.116	0.9790
		XXS	–	–	0.436	1.503		4.72	1.774	9.03	0.77	0.092	1.1040
		–	–	5S	0.083	2.709		8.51	5.764	2.48	2.50	0.299	0.4939
		–	–	10S	0.120	2.635		8.28	5.453	3.53	2.36	0.283	0.6868
2½	2.875	STD	40	40S	0.203	2.469	9.03	7.76	4.788	5.79	2.07	0.249	1.064
		XS	80	80S	0.276	2.323		7.30	4.238	7.66	1.87	0.220	1.339
		–	160	–	0.375	2.125		6.68	3.546	10.01	1.54	0.184	1.638
		XXS	–	–	0.552	1.771		5.56	2.464	13.69	1.07	0.128	1.997

Pipe Data Tables Continued

Pipe Size (in)	Outside Dia. (in)	Weight Class	C.S. Sched	S.S. Sched	Wall Thk. (in)	Inside Dia. (in)	Circum. Ext. (in)	Circum. Int. (in)	Flow Area (sq in)	Pipe Weight (lbs/ft)	Water Weight (lbs/ft)	Water Gallons (per ft)	Section Modulus
		–	–	5S	0.083	3.334		10.47	8.730	3.03	3.78	0.454	.744
		–	–	10S	0.120	3.260		10.24	8.347	4.33	3.62	0.434	1.041
3	3.500	STD	40	40S	0.216	3.068	11.00	9.64	7.393	7.58	3.20	0.384	1.724
		XS	80	80S	0.300	2.900		9.11	6.605	10.25	2.86	0.343	2.225
		–	160	–	0.438	2.624		8.24	5.408	14.32	2.35	0.281	2.876
		XXS	–	–	0.600	2.300		7.23	4.155	18.58	1.80	0.216	3.424
		–	–	5S	0.083	4.334		13.62	14.75	3.92	6.39	0.766	1.249
		–	–	10S	0.120	4.260		13.38	14.25	5.61	6.18	0.740	1.761
		STD	40	40S	0.237	4.026		12.65	12.73	10.79	5.50	0.661	3.214
4	4.500	XS	80	80S	0.337	3.826	14.14	12.02	11.50	14.98	4.98	0.597	4.271
		–	120	–	0.438	3.624		11.39	10.31	19.00	4.47	0.536	5.178
		–	160	–	0.531	3.438		10.80	9.28	22.51	4.02	0.482	5.898
		XXS	–	–	0.674	3.152		9.90	7.80	27.54	3.38	0.405	6.791
		–	–	5S	0.109	5.345		16.79	22.44	6.36	9.72	1.17	2.498
		–	–	10S	0.134	5.295		16.63	22.02	7.77	9.54	1.14	3.029
		STD	40	40S	0.258	5.047		15.86	20.01	14.62	8.67	1.04	5.451
5	5.563	XS	80	80S	0.375	4.813	17.48	15.12	18.19	20.78	7.88	0.945	7.431
		–	120	–	0.500	4.563		14.34	16.35	27.04	7.09	0.849	9.250
		–	160	–	0.625	4.313		13.55	14.61	32.96	6.33	0.759	10.796
		XXS	–	–	0.750	4.063		12.76	12.97	38.55	5.61	0.674	12.090
		–	–	5S	0.109	6.407		20.13	32.24	7.60	13.97	1.68	3.576
		–	–	10S	0.134	6.357		19.97	31.74	9.29	13.75	1.65	4.346
		STD	40	40S	0.280	6.065		19.05	28.89	18.97	12.51	1.50	8.496
6	6.625	XS	80	80S	0.432	5.761	20.81	18.10	26.07	28.57	11.29	1.35	12.22
		–	120	–	0.562	5.501		17.28	23.77	36.39	10.30	1.24	14.98
		–	160	–	0.719	5.187		16.30	21.15	45.35	9.16	1.10	17.81
		XXS	–	–	0.864	4.897		15.38	18.84	53.16	8.16	0.978	20.02
		–	–	5S	0.109	8.407		26.41	55.51	9.93	24.06	2.88	6.131
		–	–	10S	0.148	8.329		26.17	54.48	13.40	23.61	2.83	8.212
		–	20	–	0.250	8.125		25.53	51.85	22.36	22.47	2.69	13.39
		–	30	–	0.277	8.071		25.36	51.16	24.70	22.17	2.66	14.69
		STD	40	40S	0.322	7.981		25.07	50.03	28.55	21.70	2.60	16.81
		–	60	–	0.406	7.813		24.55	47.94	35.64	20.77	2.49	20.58
8	8.625	XS	80	80S	0.500	7.625	27.10	23.95	45.66	43.39	19.78	2.37	24.51
		–	100	–	0.594	7.437		23.36	43.46	50.95	18.83	2.26	28.14
		–	120	–	0.719	7.187		22.58	40.59	60.71	17.59	2.11	32.58
		–	140	–	0.812	7.001		21.99	38.50	67.76	16.68	2.00	35.65
		XXS	–	–	0.875	6.875		21.60	37.12	72.42	16.10	1.93	37.56
		–	160	–	0.906	6.813		21.40	36.46	74.69	15.80	1.89	38.48
		–	–	5S	0.134	10.482		32.93	86.29	15.19	37.39	4.48	11.71
		–	–	10S	0.165	10.420		32.74	85.28	18.65	36.95	4.43	14.30
		–	20	–	0.250	10.250		32.20	82.52	28.04	35.76	4.29	21.15
		–	30	–	0.307	10.136		31.84	80.69	34.24	34.96	4.19	25.57
		STD	40	40S	0.365	10.020		31.48	78.86	40.48	34.20	4.10	29.90
10	10.750	XS	60	80S	0.500	9.750	33.77	30.63	74.66	54.74	32.35	3.88	39.43
		–	80	–	0.594	9.562		30.04	71.84	64.43	31.13	3.73	45.54
		–	100	–	0.719	9.312		29.25	68.13	77.03	29.53	3.54	53.22
		–	120	–	0.844	9.062		28.47	64.53	89.29	27.96	3.35	60.32
		XXS	140	–	1.000	8.750		27.49	60.13	104.13	26.06	3.12	68.43
		–	160	–	1.125	8.500		26.70	56.75	115.64	24.59	2.95	74.29

Pipe Data Tables Continued

Pipe Size (in)	Outside Dia. (in)	Weight Class	C.S. Sched	S.S. Sched	Wall Thk. (in)	Inside Dia. (in)	Circum. Ext. (in)	Circum. Int. (in)	Flow Area (sq in)	Pipe Weight (lbs/ft)	Water Weight (lbs/ft)	Water Gallons (per ft)	Section Modulus
		–	–	5S	0.156	12.438		39.08	121.50	20.98	52.65	6.31	19.2
		–	–	10S	0.180	12.390		38.92	120.57	24.17	52.25	6.26	22.0
		–	20	–	0.250	12.250		38.48	117.86	33.38	51.07	6.12	30.2
		–	30	–	0.330	12.090		37.98	114.80	43.77	49.74	5.96	39.0
		STD	–	40S	0.375	12.000		37.70	113.10	49.56	49.00	5.88	43.8
		–	40	–	0.406	11.938		37.50	111.93	53.52	48.50	5.81	47.1
12	12.750	XS	–	80S	0.500	11.750	40.06	36.91	108.43	65.42	46.92	5.63	56.7
		–	60	–	0.562	11.626		36.52	106.16	73.15	46.00	5.51	62.8
		–	80	–	0.688	11.374		35.73	101.64	88.63	44.04	5.28	74.6
		–	100	–	0.844	11.062		34.75	96.14	107.32	41.66	4.99	88.1
		XXS	120	–	1.000	10.750		33.77	90.76	125.49	39.33	4.71	100.7
		–	140	–	1.125	10.500		32.99	86.59	139.67	37.52	4.50	109.9
		–	160	–	1.312	10.126		31.81	80.53	160.27	34.89	4.18	122.6
		–	–	5S	0.156	13.688		43.00	147.15	23.07	63.77	7.64	23.2
		–	–	10S	0.188	13.624		42.80	145.78	27.73	63.17	7.57	27.8
		–	10	–	0.250	13.500		42.41	143.14	36.71	62.03	7.44	36.6
		–	20	–	0.312	13.376		42.02	140.52	45.61	60.89	7.30	45.0
		STD	30	–	0.375	13.250		41.63	137.88	54.57	59.75	7.16	53.2
		–	40	–	0.438	13.124		41.23	135.28	63.44	58.64	7.03	61.3
14	14.000	XS	–	–	0.500	13.000	43.98	40.84	132.73	72.09	57.46	6.90	69.1
		–	60	–	0.594	12.812		40.25	128.96	85.05	55.86	6.70	80.3
		–	80	–	0.750	12.500		39.27	122.72	106.13	53.18	6.37	98.2
		–	100	–	0.938	12.124		38.09	115.49	130.85	50.04	6.00	117.8
		–	120	–	1.094	11.812		37.11	109.62	150.79	47.45	5.69	132.8
		–	140	–	1.250	11.500		36.13	103.87	170.28	45.01	5.40	146.8
		–	160	–	1.406	11.188		35.15	98.31	189.11	42.60	5.11	159.6
		–	–	5S	0.165	15.670		49.23	192.85	27.90	83.57	10.02	32.2
		–	–	10S	0.188	15.624		49.08	191.72	31.75	83.08	9.96	36.5
		–	10	–	0.250	15.500		48.69	188.69	42.05	81.74	9.80	48.0
		–	20	–	0.312	15.376		48.31	185.69	52.27	80.50	9.65	59.2
		STD	30	–	0.375	15.250		47.91	182.65	82.58	79.12	9.49	70.3
		XS	40	–	0.500	15.000		47.12	176.72	82.77	76.58	9.18	91.5
16	16.000	–	60	–	0.656	14.688	50.27	46.14	169.44	107.50	73.42	8.80	116.6
		–	80	–	0.844	14.312		44.96	160.92	136.61	69.73	8.36	144.5
		–	100	–	1.031	13.938		43.79	152.58	164.82	66.12	7.93	170.5
		–	120	–	1.219	13.562		42.61	144.50	192.43	62.62	7.50	194.5
		–	140	–	1.438	13.124		41.23	135.28	233.64	58.64	7.03	220.0
		–	160	–	1.594	12.812		40.26	128.96	245.25	55.83	6.70	236.7
		–	–	5S	0.165	17.67		55.51	245.22	31.43	106.26	12.74	40.8
		–	–	10S	0.188	17.62		55.37	243.95	35.76	105.71	12.67	46.4
		–	10	–	0.250	17.50		54.98	240.53	47.39	104.21	12.49	61.1
		–	20	–	0.312	17.38		54.59	237.13	58.94	102.77	12.32	75.5
		STD	–	–	0.375	17.25		54.19	233.71	70.59	101.18	12.14	89.6
		–	30	–	0.438	17.12		53.80	230.30	82.15	99.84	11.96	103.4
		XS	–	–	0.500	17.00		53.41	226.98	93.45	98.27	11.79	117.0
18	18.000	–	40	–	0.562	16.88	56.55	53.02	223.68	104.87	96.93	11.62	130.1
		–	60	–	0.750	16.50		51.84	213.83	138.17	92.57	11.11	168.3
		–	80	–	0.938	16.12		50.66	204.24	170.92	88.50	10.61	203.8
		–	100	–	1.156	15.69		49.29	193.30	207.96	83.76	10.04	242.3
		–	120	–	1.375	15.25		47.91	182.66	244.14	79.07	9.49	277.6
		–	140	–	1.562	14.88		46.73	173.80	274.22	75.32	9.03	305.5
		–	160	–	1.781	14.44		45.36	163.72	308.50	70.88	8.50	335.6

Pipe Data Tables Continued

Pipe Size (in)	Outside Dia. (in)	Weight Class	C.S. Sched	S.S. Sched	Wall Thk. (in)	Inside Dia. (in)	Circum. Ext. (in)	Circum. Int. (in)	Flow Area (sq in)	Pipe Weight (lbs/ft)	Water Weight (lbs/ft)	Water Gallons (per ft)	Section Modulus
20	20.000	–	–	5S	0.188	19.62	62.83	61.65	302.46	39.78	131.06	15.71	57.4
		–	–	10S	0.218	19.56		61.46	300.61	46.06	130.27	15.62	66.3
		–	10	–	0.250	19.50		61.26	298.65	52.73	129.42	15.51	75.6
		–	20	–	0.375	19.25		60.48	290.04	78.60	125.67	15.12	111.3
		STD	30	–	0.500	19.00		59.69	283.53	104.13	122.87	14.73	145.7
		XS	40	–	0.594	18.81		59.10	278.00	123.11	120.46	14.44	170.4
		–	60	–	0.812	18.38		57.73	265.21	166.40	114.92	13.78	225.7
		–	80	–	1.031	17.94		56.35	252.72	208.87	109.51	13.13	277.1
		–	100	–	1.281	17.44		54.78	238.83	256.10	103.39	12.41	331.5
		–	120	–	1.500	17.00		53.41	226.98	296.37	98.35	11.79	375.5
		–	140	–	1.750	16.50		51.84	213.82	341.09	92.66	11.11	421.7
		–	160	–	1.969	16.06		50.46	202.67	379.17	87.74	10.53	458.5
22	22.000	–	–	5S	0.188	21.62	69.12	67.93	367.25	43.80	159.14	19.08	69.7
		–	–	10S	0.218	21.56		67.75	365.21	50.71	158.26	18.97	80.4
		–	10	–	0.250	21.50		67.54	363.05	58.07	157.32	18.86	91.8
		STD	20	–	0.375	21.25		66.76	354.66	86.61	153.68	18.42	135.4
		XS	30	–	0.500	21.00		65.97	346.36	114.81	150.09	17.99	117.5
		–	60	–	0.875	20.25		63.62	322.06	197.41	139.56	16.73	295.0
		–	80	–	1.125	19.75		62.05	306.35	250.81	132.76	15.91	366.4
		–	100	–	1.375	19.25		60.48	291.04	302.88	126.12	15.12	432.6
		–	120	–	1.625	18.75		58.90	276.12	353.61	119.65	14.34	493.8
		–	140	–	1.875	18.25		57.33	261.59	403.00	113.36	13.59	550.3
		–	160	–	2.125	17.75		55.76	247.45	451.06	107.23	12.85	602.4
24	24.000	–	–	5S	0.218	23.56	75.40	74.03	436.10	55	188.98	22.65	96.0
		–	10	10S	0.250	23.50		73.83	433.74	63	187.95	22.53	109.6
		STD	20	–	0.375	23.25		73.04	424.56	95	183.95	22.05	161.9
		XS	–	–	0.500	23.00		72.26	415.48	125	179.87	21.58	212.5
		–	30	–	0.562	22.88		71.86	411.00	141	178.09	21.35	237.0
		–	40	–	0.688	22.62		71.08	402.07	171	174.23	20.88	285.1
		–	60	–	0.969	22.06		69.31	382.35	238	165.52	19.86	387.7
		–	80	–	1.219	21.56		67.74	365.22	297	158.26	18.97	472.8
		–	100	–	1.531	20.94		65.78	344.32	367	149.06	17.89	570.8
		–	120	–	1.812	20.38		64.01	326.08	430	141.17	16.94	652.1
		–	140	–	2.062	19.88		62.44	310.28	483	134.45	16.12	718.9
		–	160	–	2.344	19.31		60.67	292.98	542	126.84	15.22	787.9
30	30.000	–	–	5S	0.250	29.50	94.25	92.68	683.49	79	296.18	35.51	172.3
		–	10	10S	0.312	29.38		92.29	677.71	99	293.70	35.21	213.8
		STD	–	–	0.375	29.25		91.89	671.96	119	291.18	34.91	255.3
		XS	20	–	0.500	29.00		91.11	660.52	158	286.22	34.31	336.1
		–	30	–	0.625	28.75		90.32	649.18	196	281.31	33.72	414.9

Conversion Tables

Liquid Weights & Measures		
To Convert	To	Multiply By
Gallons	Liters	3.7853
Gallons	Cu. Inches	231
Gallons	Cu. Feet	0.1337
Gallons	Cu. Meters	0.00379
Gallons	Lbs. of Water	8.339
Liters	Gallons	0.26418
Liters	Cu. Inches	61.025
Liters	Cu. Feet	0.0353
Liters	Cu. Meters	0.001
Liters	Lbs. of Water	2.202
Cu. Inches	Gallons	0.00433
Cu. Inches	Liters	0.01639
Cu. Inches	Cu. Feet	0.00058
Cu. Inches	Cu. Meters	0.000016
Cu. Inches	Lbs. of Water	0.0362
Cu. Feet	Gallons	7.48052
Cu. Feet	Liters	28.316
Cu. Feet	Cu. Inches	1728
Cu. Feet	Cu. Meters	0.0283
Cu. Feet	Lbs. of Water	62.371
Cu. Meters	Gallons	264.17
Cu. Meters	Liters	999.972
Cu. Meters	Cu. Inches	61023.74
Cu. Meters	Cu. Feet	35.3145
Cu. Meters	Lbs. of Water	2202.61
Lbs. of Water	Gallons	0.11992
Lbs. of Water	Liters	0.45419
Lbs. of Water	Cu. Inches	27.643
Lbs. of Water	Cu. Feet	0.01603
Lbs. of Water	Cu. Meters	0.000454
Lineal Measures		
Inches	mm	25.4
Inches	cm	2.54
Inches	Meters	0.0254
Feet	cm	30.48
Feet	Meters	0.3048
mm	Inches	0.03937
mm	Feet	0.00328
cm	Inches	0.3937
cm	Feet	0.03281
Meters	Feet	3.28
Area		
Sq. Inches	Sq. Feet	0.006944
Sq. Inches	Sq. cm	6.4516
Sq. Feet	Sq. Inches	144
Sq. Feet	Sq. cm	929.03
Sq. Feet	Sq. Meters	0.0929
Sq. cm	Sq. Inches	0.155
Sq. cm	Sq. Feet	0.00108
Sq. cm	Sq. Meters	0.0001
Sq. Meter	Sq. Inches	1550
Sq. Meter	Sq. Feet	10.76

Pressure & Head		
To Convert	To	Multiply By
Lbs .per Sq .In.	Lbs. per Sq. Ft.	144
Lbs. per Sq. In.	Atmospheres	0.06805
Lbs. per Sq. In.	Ins. of Water	27.728
Lbs. per Sq. In.	Ft. of Water	2.3106
Lbs. per Sq. In.	Ins. of Mercury	2.03602
Lbs. per Sq. In.	mm of Mercury	51.715
Lbs. per Sq. In.	Bar	0.06895
Lbs. per Sq. In.	kg per Sq. cm	0.070307
Lbs. per Sq. In.	kg per Sq. M	703.070
Lbs. per Sq. Ft.	Lbs. per Sq. In.	0.0069445
Lbs. per Sq. Ft.	Atmospheres	0.000473
Lbs. per Sq. Ft.	Ins. of Water	0.1926
Lbs. per Sq. Ft.	Ft. of Water	0.01605
Lbs. per Sq. Ft.	Ins. of Mercury	0.014139
Lbs. per Sq. Ft.	mm of Mercury	0.35913
Lbs. per Sq. Ft.	Bar	0.000479
Lbs. per Sq. Ft.	kg per Sq. cm	0.000488
Lbs. per Sq. Ft.	kg per Sq. M	4.88241
Atmospheres	Lbs. per Sq. In.	14.696
Atmospheres	Lbs. per Sq. Ft.	2116.22
Atmospheres	Ins. of Water	407.484
Atmospheres	Ft. of Water	33.957
Atmospheres	Ins. of Mercury	29.921
Atmospheres	mm of Mercury	760
Atmospheres	Bar	1.01325
Atmospheres	kg per Sq. cm	1.0332
Atmospheres	kg per Sq. M	10332.27
Ins. of Water	Lbs. per Sq. In.	0.03609
Ins. of Water	Lbs. per Sq. Ft.	5.1972
Ins. of Water	Atmospheres	0.002454
Ins.of Water	Ft. of Water	0.08333
Ins. of Water	Ins. of Mercury	0.07343
Ins. of Water	mm of Mercury	1.8651
Ins. of Water	Bar	0.00249
Ins. of Water	kg per Sq. cm	0.00253
Ins. of Water	kg per Sq. M	25.375
Ft. of Water	Lbs. per Sq. In.	0.432781
Ft. of Water	Lbs. per Sq. Ft.	63.3205
Ft. of Water	Atmospheres	0.029449
Ft. of Water	Ins. of Water	12
Ft. of Water	Ins. of Mercury	0.88115
Ft. of Water	mm of Mercury	22.3813
Ft. of Water	Bar	0.029839
Ft. of Water	kg per Sq. cm	0.03043
Ft. of Water	kg per Sq. M	304.275

Pressure & Head		
To Convert	To	Multiply By
Ins. of Mercury	Lbs. per Sq. In.	0.491154
Ins. of Mercury	Lbs. per Sq. Ft.	70.7262
Ins. of Mercury	Atmospheres	0.033421
Ins. of Mercury	Ins. of Water	13.6185
Ins. of Mercury	Ft. of Water	1.1349
Ins. of Mercury	mm of Mercury	25.40005
Ins. of Mercury	Bar	0.033864
Ins. of Mercury	kg per Sq. cm	0.03453
Ins. of Mercury	kg per Sq. M	345.316
mm of Mercury	Lbs. per Sq. In.	0.019337
mm of Mercury	Lbs. per Sq. Ft.	2.7845
mm of Mercury	Atmospheres	0.001316
mm of Mercury	Ins. of Water	0.53616
mm of Mercury	Ft. of Water	0.04468
mm of Mercury	Ins. of Mercury	0.03937
mm of Mercury	Bar	0.00133
mm of Mercury	kg per Sq. cm	0.00136
mm of Mercury	kg per Sq. M	13.59509
kg per Sq. cm	Lbs. per Sq. In.	14.2233
kg per Sq. cm	Lbs. per Sq. Ft.	2048.155
kg per Sq. cm	Atmospheres	0.96784
kg per Sq. cm	Ins. of Water	394.38
kg per Sq. cm	Ft. of Water	32.865
kg per Sq. cm	Ins. of Mercury	28.959
kg per Sq. cm	mm of Mercury	735.559
kg per Sq. cm	Bar	0.98067
kg per Sq. cm	kg per Sq. M	10000

Temperature

To convert Fahrenheit to Celsius:

$$\frac{°F - 32}{1.8}$$

To convert Celsius to Fahrenheit:

(1.8 x °C) + 32

Velocity

1 Ft per Sec. = **0.3048 M Per Sec.**

1 M per Sec. = **3.2808 Ft. per Sec.**

All weights and measures of water are base on temperature of 60°F | Temperature of Water and Mercury is 68°F and 32°F respectively

Pressure to Vaccum

Gage Indicated		Absolute Pressure		
PSIG	Inches of Hg	PSIA	Inches of Hg	Torricelli
-14.70000	29.92000	0.0	0.0	0.0
-14.69998	29.91996	0.00002	0.00004	0.001
-14.69996	29.91992	0.00004	0.00008	0.002
-14.69994	29.91988	0.00006	0.00012	0.003
-14.69992	29.91984	0.00008	0.00016	0.004
-14.69990	29.91980	0.00010	0.00020	0.005
-14.69981	29.91961	0.00019	0.00039	0.010
-14.69961	29.91921	0.00039	0.00079	0.020
-14.69942	29.91882	0.00058	0.00118	0.030
-14.69923	29.91843	0.00077	0.00157	0.040
-14.69903	29.91803	0.00097	0.00197	0.050
-14.69806	29.91606	0.00194	0.00394	0.100
-14.69613	29.91212	0.00387	0.00788	0.200
-14.69449	29.90818	0.00551	0.01182	0.300
-14.69226	29.90424	0.00774	0.01576	0.400
-14.69032	29.90030	0.00968	0.01970	0.500
-14.68066	29.88063	0.01934	0.03937	1.000
-14.66698	29.84126	0.03302	0.07874	2.000
-14.64197	29.80189	0.05803	0.11811	3.000
-14.62262	29.76252	0.07738	0.15748	4.000
-14.60329	29.72315	0.09671	0.19685	5.000
-14.50658	29.52630	0.19342	0.39370	10.000
-14.40980	29.32940	0.29020	0.59060	15.000
-14.31320	29.13260	0.38680	0.78740	20.000
-14.21840	28.93570	0.48160	0.98430	25.000
-14.20870	28.920	0.49130	1.000	25.400
-14.11970	28.740	0.58030	1.181	30.000
-13.75700	28.000	0.94330	1.920	48.770
-12.28300	25.000	2.41700	4.920	124.970
-10.31800	21.000	4.38200	8.920	226.570
-8.84400	18.000	5.85600	11.920	302.770
-7.37000	15.000	7.320	14.920	378.970
-5.89600	12.000	8.804	17.920	455.770
-4.91300	10.000	9.787	19.920	505.970
-3.93000	8.000	10.770	21.920	556.770
-2.94800	6.000	11.752	23.920	607.570
-1.96500	4.000	12.735	25.920	658.370
-0.98300	2.000	13.732	27.920	709.170
-0.49100	1.000	14.209	28.920	733.570
-0.24600	0.500	14.454	29.420	747.270
Atmospheric				
0.0	0.0	14.700	29.920	760.000
+ 0.30	–	15.000	30.540	775.720
+ 1.00	–	15.700	31.970	811.910
+ 2.00	–	16.700	34.000	863.630
+ 10.00	–	24.700	50.290	277.35

Weight of water per gallon is based on 7.48052 gallons per cubic foot | Specific gravity of water @ 60°F = 1.00

Properties of Water

Water Temp	Saturation Pressure	Weight	Weight Density	Specific Volume
Deg. F	PSIA	lbs/Gallon	lbs/Cu.Ft.	Cu.Ft./lb
32	0.0886	8.344	62.414	0.016022
40	0.1216	8.345	62.426	0.016019
50	0.1780	8.343	62.410	0.016023
60	0.2561	8.338	62.371	0.016033
70	0.3629	8.329	62.305	0.016050
80	0.5068	8.318	62.220	0.016072
90	0.6981	8.304	62.116	0.016099
100	0.9492	8.288	61.996	0.016130
110	1.2750	8.270	61.862	0.016165
120	1.6927	8.250	61.713	0.016204
130	2.2230	8.228	61.550	0.016247
140	2.8892	8.205	61.376	0.016293
150	3.7184	8.180	61.188	0.016343
160	4.7414	8.154	60.994	0.016395
170	5.9926	8.126	60.787	0.016451
180	7.5110	8.097	60.569	0.016510
190	9.340	8.067	60.343	0.016572
200	11.526	8.035	60.107	0.016637
210	14.123	8.002	59.862	0.016705
212	14.696	7.996	59.812	0.016719
220	17.186	7.969	59.613	0.016775
240	24.968	7.898	59.081	0.016926
260	35.427	7.823	58.517	0.017089
280	49.200	7.743	57.924	0.017264
300	67.005	7.661	57.307	0.01745
350	134.604	7.431	55.586	0.01799
400	247.259	7.172	53.648	0.01864
450	422.55	6.880	51.467	0.01943
500	680.86	6.543	48.948	0.02043
550	1045.43	6.143	45.956	0.02176
600	1543.2	5.655	42.301	0.02364
650	2208.4	4.999	37.397	0.02674
700	3094.3	3.651	27.307	0.03662

Steam Table

h = Total heat of steam, Btu per pound | v = Specific volume, cubic feet per pound

PSI (gage)	Temp °F (sat.)		Sat. Liquid	Sat. Vapor	Total Temperature °F												
					220	240	260	280	300	320	340	360	380	400	420	440	460
0	212	h	180.1	1150.4	1154.4	1164.2	1173.8	1183.3	1192.8	1202.3	1211.7	1221.1	1230.5	1239.9	1249.3	1258.8	1268.2
		v	0.0167	26.80	27.15	28.00	28.85	29.70	30.53	31.37	32.20	33.03	33.85	34.68	35.50	36.32	37.14
5	228	h	196.2	1156.3	–	1162.3	1172.2	1182.0	1191.6	1201.2	1210.8	1220.3	1229.7	1239.2	1248.7	1258.2	1267.6
		v	0.0168	20.089	–	20.48	21.11	21.74	22.36	22.98	23.60	24.21	24.82	25.43	26.04	26.65	27.25
10	240	h	208.4	1160.6	–	–	1170.7	1180.6	1190.5	1200.2	1209.8	1219.4	1229.0	1238.5	1248.1	1257.6	1267.1
		v	0.0169	16.303	–	–	16.819	17.330	17.836	18.337	18.834	19.329	19.821	20.31	20.80	21.29	21.77
15	250	h	218.8	1164.1	–	–	1169.1	1179.3	1189.3	1199.1	1208.9	1218.6	1228.3	1237.9	1247.5	1257.0	1266.6
		v	0.0170	13.746	–	–	13.957	14.390	14.816	15.238	15.657	16.072	16.485	16.897	17.306	17.714	18.121
20	259	h	227.9	1167.1	–	–	1167.5	1177.9	1188.1	1198.1	1208.0	1217.8	1227.5	1237.2	1246.8	1256A	1266.1
		v	0.0171	11.898	–	–	11.911	12.288	12.659	13.025	13.387	13.746	14.103	14.457	14.810	15.162	15.512
25	267	h	236.0	1169.7	–	–	–	1176.5	1186.8	1197.0	1207.0	1216.9	1226.7	1236.5	12462	1255.9	1265.5
		v	0.0171	10.498	–	–	–	10.711	11.040	11.364	11.684	12.001	12.315	12.628	12.938	13.247	13.555
30	274	h	243.4	1172.0	–	–	–	1175.0	1185.6	1195.9	1206.0	1216.0	1225.9	1235.8	1245.6	1255.3	1265.0
		v	0.0172	9.401	–	–	–	9.484	9.781	10.072	10.359	10.643	10.925	11.204	11.482	11.758	120033
40	287	h	256.3	1175.9	–	–	–	–	1183.0	1193.6	1204.0	1214.3	1224.4	1234.3	1244.3	1254.1	1263.9
		v	0.0173	7.787	–	–	–	–	7.947	8.192	8.432	8.668	8.902	9.134	9.364	9.592	9.819
50	298	h	267.5	1179.1	–	–	–	–	1180.3	1191.3	1202.0	1212.5	1222.7	1232.9	1242.9	1252.9	1262.8
		v	0.0174	6.655	–	–	–	–	6.676	6.889	7.096	7.300	7.501	7.700	7.896	8.091	8.285
60	308	h	277.4	1181.9	–	–	–	–	–	1188.9	1199.9	1210.6	1221.1	1231.4	1241.6	1251.7	1261.7
		v	0.0175	5.816	–	–	–	–	–	5.9321	6.116	6.296	6.473	6.648	6.820	6.991	7.161
70	316	h	286.4	1184.2	–	–	–	–	–	1186.4	1197.7	1208.7	1219.4	1229.9	1240.2	1250.4	1260.6
		v	0.0176	5.168	–	–	–	–	–	5.200	5.366	5.528	5.687	5.843	5.997	6.150	6.301
80	324	h	294.6	1186.2	–	–	–	–	–	–	1195.5	1206.7	1217.7	1228.3	1238.8	1249.2	1259.4
		v	0.0177	4.652	–	–	–	–	–	–	4.773	4.921	5.065	5.207	5.347	5.485	5.621
90	331	h	302.1	1188.1	–	–	–	–	–	–	1193.2	1204.7	1215.9	1226.7	1237.4	1247.9	1258.2
		v	0.0178	4.232	–	–	–	–	–	–	4.292	4.429	4.562	4.693	4.821	4.947	5.071
100	338	h	309.1	1189.7	–	–	–	–	–	–	1190.8	1202.7	1214.1	1225.2	1236.0	1246.6	1257.1
		v	0.0178	3.882	–	–	–	–	–	–	3.895	4.022	4.146	4.267	4.385	4.502	4.617
125	353	h	324.8	1193.0	–	–	–	–	–	–	–	1197.3	1209.4	1211.1	1232.3	1243.3	1254.1
		v	0.0180	3.220	–	–	–	–	–	–	–	3.258	3.365	3.468	3.569	3.667	3.764
150	366	h	338.5	1195.6	–	–	–	–	–	–	–	–	1204.5	1216.7	1228.4	1239.8	1251.0
		v	0.0182	2.752	–	–	–	–	–	–	–	–	2.818	2.910	2.998	3.085	3.169
175	378	h	350.8	1197.6	–	–	–	–	–	–	–	–	1199.3	1212.2	1224.5	1236.3	1247.8
		v	0.0183	2.404	–	–	–	–	–	–	–	–	2.414	2.498	2.577	2.655	2.730
200	388	h	361.9	1199.3	–	–	–	–	–	–	–	–	–	1207.4	1220.3	1232.6	1244.5
		v	0.0185	2.134	–	–	–	–	–	–	–	–	–	2.180	2.253	2.324	2.393
225	397	h	372.1	1200.6	–	–	–	–	–	–	–	–	–	1202.5	1216.0	1228.8	1241.1
		v	0.0186	1.9183	–	–	–	–	–	–	–	–	–	1.9276	1.9964	2.062	2.126
250	406	h	381.6	1201.7	–	–	–	–	–	–	–	–	–	–	1211.5	1224.9	1237.6
		v	0.0187	1.7422	–	–	–	–	–	–	–	–	–	–	1.7870	1.8488	1.9081
275	414	h	390.5	1202.6	–	–	–	–	–	–	–	–	–	–	1206.8	1220.8	1234.0
		v	0.0188	1.5954	–	–	–	–	–	–	–	–	–	–	1.6130	1.6717	1.7277
300	422	h	398.8	1203.2	–	–	–	–	–	–	–	–	–	–	–	1216.5	1230.3
		v	0.0190	1.4711	–	–	–	–	–	–	–	–	–	–	–	1.5222	1.5755
350	436	h	414.1	1204.1	–	–	–	–	–	–	–	–	–	–	–	1207.5	1222.4
		v	0.0192	1.2720	–	–	–	–	–	–	–	–	–	–	–	1.2831	1.3326
400	448	h	428.1	1204.6	–	–	–	–	–	–	–	–	–	–	–	–	1214.0
		v	0.0194	1.1194	–	–	–	–	–	–	–	–	–	–	–	–	1.1468
450	460	h	440.9	1204.6	–	–	–	–	–	–	–	–	–	–	–	–	–
		v	0.0196	0.9985	–	–	–	–	–	–	–	–	–	–	–	–	–
500	470	h	452.9	1204.2	–	–	–	–	–	–	–	–	–	–	–	–	–
		v	0.0198	0.9004	–	–	–	–	–	–	–	–	–	–	–	–	–
550	480	h	464.1	1203.7	–	–	–	–	–	–	–	–	–	–	–	–	–
		v	0.0200	0.8191	–	–	–	–	–	–	–	–	–	–	–	–	–
600	489	h	474.7	1203.0													
		v	0.0202	0.7503													

Steam Table Continued

h = Total heat of steam, Btu per pound | v = Specific volume, cubic feet per pound

PSI (gage)	Temp °F (sat.)		Total Temperature °F														
			480	500	520	540	560	580	600	620	640	660	680	700	720	740	750
0	212	h	1277.6	1287.1	1296.6	1306.2	1315.7	1325.3	1334.8	1344.5	1354.2	1363.8	1373.5	1383.2	1393.0	1402.8	1407.7
		v	37.96	38.78	39.60	40.41	41.23	42.04	42.86	43.68	44.49	45.31	46.12	46.94	47.75	48.56	48.97
5	228	h	1277.1	1286.6	1296.2	1305.7	1315.3	1324.8	1334.4	1344.1	1353.8	1363.5	1373.2	1382.9	1392.7	1402.6	1407.5
		v	27.86	28.46	29.06	29.67	30.27	30.87	31.47	32.07	32.67	33.27	33.87	34.47	35.07	35.67	35.96
10	240	h	1276.6	1286.2	1295.8	1305.3	1314.9	1324.5	1334.1	1343.8	1353.5	1363.2	1372.9	1382.6	1392.5	1402.3	1407.2
		v	22.26	22.74	23.22	23.71	24.19	24.68	25.16	25.64	26.12	26.60	27.08	27.56	28.04	28.52	28.76
15	250	h	1276.2	1285.7	1295.3	1304.9	1314.5	1324.2	1333.8	1343.5	1353.2	1362.9	1372.6	1382.4	1392.3	1402.1	1407.0
		v	18.528	18.933	19.337	19.741	20.144	20.547	20.95	21.35	21.75	22.15	22.56	22.96	23.36	23.76	23.96
20	259	h	1275.7	1285.3	1294.9	1304.5	1314.1	1323.8	1333.5	1343.2	1352.9	1362.6	1372.3	1382.1	1391.9	1401.8	1406.7
		v	15.862	16.210	16.558	16.905	17.251	17.597	17.943	18.288	18.633	18.977	19.322	19.666	20.01	20.35	20.52
25	267	h	1275.2	1284.8	1294.5	1304.1	1313.8	1323.4	1333.1	1342.8	1352.5	1362.3	1372.1	1381.9	1391.7	1401.6	1406.5
		v	13.862	14.168	14.473	14.778	15.082	15.385	15.688	15.990	16.293	16.595	16.896	17.198	17.499	17.8001	7.951
30	274	h	1274.7	1284.4	1294.0	1303.7	1313.4	1323.1	1332.8	1342.5	1352.2	1362.0	1371.8	1381.6	1391.5	1401.4	1406.3
		v	12.307	12.580	12.852	13.123	13.394	13.665	13.935	14.204	14.473	14.742	15.011	15.279	15.547	15.815	15.949
40	287	h	1273.7	1283.4	1293.2	1302.9	1312.6	1322.4	1332.1	1341.9	1351.7	1361.5	1371.3	1381.1	1391.0	1400.9	1405.8
		v	10.044	10.269	10.493	10.717	10.940	11.162	11.384	11.605	11.826	12.047	12.268	12.488	12.708	12.927	13.037
50	298	h	1272.7	1282.5	1292.3	1302.1	1311.9	1321.7	1331.5	1341.3	1351.1	1360.9	1370.8	1380.6	1390.5	1400.4	1405.4
		v	8.478	8.670	8.861	9.051	9.240	9.429	9.618	9.806	9.993	10.181	10.368	10.555	10.741	10.928	11.021
60	308	h	1271.6	1281.5	1291.4	1301.3	1311.1	1321.0	1330.8	1340.6	1350.5	1360.3	1370.2	1380.1	1390.0	1399.9	1404.9
		v	7.329	7.496	7.663	7.829	7.994	8.159	8.323	8.486	8.649	8.812	8.975	9.138	9.300	9.462	9.543
70	316	h	1270.6	1280.6	1290.5	1300.5	1310.4	1320.2	1330.1	1340.0	1349.9	1359.8	1369.7	1379.6	1389.6	1399.5	1404.5
		v	6.450	6.599	6.747	6.894	7.041	7.187	7.332	7.477	7.622	7.766	7.910	8.054	8.198	8.341	8.413
80	324	h	1269.5	1279.6	1289.6	1299.6	1309.6	1319.5	1329.4	1339.4	1349.3	1359.3	1369.2	1379.1	1389.1	1399.0	1404.0
		v	5.756	5.891	6.024	6.156	6.288	6.419	6.550	6.680	6.810	6.940	7.069	7.199	7.327	7.456	7.520
90	331	h	1268.5	1278.6	1288.7	1298.8	1308.8	1318.8	1328.7	1338.7	1348.7	1358.6	1368.6	1378.5	1388.5	1398.5	1403.5
		v	5.195	5.317	5.439	5.559	5.679	5.799	5.918	6.036	6.154	6.272	6.389	6.506	6.623	6.740	6.798
100	338	h	1267.4	1277.7	1287.8	1297.9	1308.0	1318.0	1328.1	1338.1	1348.0	1358.0	1368.0	1378.0	1388.1	1398.1	1403.1
		v	4.730	4.843	4.955	5.066	5.176	5.285	5.394	5.503	5.611	5.719	5.827	5.934	6.041	6.148	6.201
125	353	h	1264.7	1275.2	1285.5	1295.8	1306.0	1316.2	1326.4	1336.5	1346.6	1356.6	1366.7	1376.8	1386.9	1397.0	1402.0
		v	3.860	3.954	4.047	4.140	4.232	4.323	4.413	4.503	4.593	4.683	4.772	4.861	4.949	5.038	5.082
150	366	h	1261.9	1272.6	1283.2	1293.6	1304.0	1314.3	1324.6	1334.8	1345.0	1355.2	1365.3	1375.4	1385.6	1395.8	1400.8
		v	3.252	3.334	3.414	3.494	3.573	3.652	3.730	3.807	3.884	3.960	4.037	4.113	4.188	4.264	4.301
175	378	h	1259.0	1270.0	1280.8	1291.4	1302.0	1312.4	1322.8	1333.2	1343.5	1353.7	1363.9	1374.2	1384.4	1394.6	1399.7
		v	2.804	2.877	2.948	3.019	3.089	3.157	3.226	3.294	3.361	3.429	3.495	3.562	3.628	3.694	3.727
200	388	h	1256.0	1267.3	1278.3	1289.2	1299.9	1310.5	1321.0	1331.4	1341.8	1352.2	1362.5	1372.8	1383.1	1393.3	1398.5
		v	2.460	2.525	2.590	2.653	2.716	2.777	2.839	2.900	2.960	3.019	3.079	3.139	3.198	3.256	3.286
225	397	h	1253.0	1264.5	1275.8	1286.9	1297.8	1308.5	1319.2	1329.8	1340.3	1350.7	1361.1	1371.5	1381.9	1392.2	1397.3
		v	2.187	2.247	2.306	2.364	2.421	2.477	2.533	2.587	2.642	2.696	2.750	2.804	2.857	2.910	2.936
250	406	h	1249.9	1261.7	1273.2	1284.5	1295.6	1306.5	1317.3	1328.0	1338.7	1349.2	1359.7	1370.2	1380.6	1391.0	1396.2
		v	1.9654	2.021	2,076	2.129	2.181	2.233	2.284	2.334	2.384	2.434	2.483	2.532	2.580	2.629	2.653
275	414	h	1246.6	1258.8	1270.6	1282.1	1293.4	1304.5	1315.5	1326.3	1337.0	1347.7	1358.3	1368.8	1379.3	1389.8	1395.0
		v	1.7816	1.8338	1.8846	1.9342	1.9829	2.031	2.078	2.125	2.171	2.217	2.262	2.307	2.352	2.396	2.418
300	422	h	1243.3	1255.8	1267.9	1279.7	1291.2	1302.5	1313.6	1324.5	1335.4	1346.1	1356.8	1367.4	1378.0	1388.6	1393.8
		v	1.6266	1.6759	1.7237	1.7703	1.8159	1.8607	1.9048	1.9483	1.9912	2.034	2.076	2.118	2.159	2.200	2.220
350	436	h	1236.4	1249.6	1262.4	1274.7	1286.6	1298.2	1309.7	1320.9	1332.0	1343.0	1353.9	1364.7	1375.4	1386.1	1391.4
		v	1.3795	1.4243	1.4675	1.5094	1.5501	1.5900	1.6291	1.6676	1.7056	1.7430	1.7801	1.8168	1.8531	1.8892	1.9071
400	448	h	1229.0	1243.2	1256.6	1269.4	1281.8	1293.9	1305.7	1317.2	1328.6	1339.8	1350.9	1361.9	1372.8	1383.6	1389.0
		v	1.1908	1.2325	1.2724	1.3108	1.3480	1.3842	1.4196	1.4544	1.4885	1.5222	1.5554	1.5883	1.6207	1.6529	1.6689
450	460	h	1221.2	1236.3	1250.5	1264.0	1276.9	1289.4	1301.6	1313.5	1325.1	1336.5	1347.8	1359.0	1370.1	1381.1	1386.5
		v	1.0416	1.0811	1.1186	1.1544	1.1889	1.2224	1.2550	1.2868	1.3180	1.3488	1.3789	1.4088	1.4382	1.4675	1.4819
500	470	h	1212.8	1229.0	1244.0	1258.3	1271.8	1284.8	1297.3	1309.6	1321.5	1333.2	1344.7	1356.1	1367.3	1378.4	1384.0
		v	0.9204	0.9584	0.9941	1.0280	1.0604	1.0917	1.1221	1.1516	1.1805	1.2088	1.2367	1.2641	1.2913	1.3180	1.3313
550	480	h	–	1221.4	1237.4	1252.4	1266.5	1280.0	1293.0	1305.6	1317.8	1329.8	1341.6	1353.2	1364.6	1375.8	1381.4
		v	–	0.8565	0.8909	0.9234	0.9542	0.9838	1.0124	1.0401	1.0671	1.0935	1.1195	1.1449	1.1700	1.1947	1.2070
600	489	h	–	1213.2	1230.3	1246.1	1261.0	1275.1	1288.5	1301.5	1314.1	1326.3	1338.3	1350.2	1361.8	1373.2	1378.9
		v	–	0.7703	0.8040	0.8353	0.8649	0.8931	0.9203	0.9465	0.9720	0.9968	1.0211	1.0450	1.0684	1.0916	1.1030

Terms & Conditions

1) **CANCELLATIONS & RESTOCKING POLICY:** Purchase orders once placed by Buyer and accepted by Seller can be cancelled only with Seller's written consent and upon terms which will save Seller from loss. No orders may be cancelled subsequent to delivery and/or shipment, whichever occurs first. As estimated actual damages, Buyer agrees to pay Seller the greater of Seller's actual costs incurred prior to cancellation plus a reasonable profit, or the following minimum cancellation charges: a) 20% of Order value if cancelled thirty (30) or more days prior to the original delivery/shipment date; b) 50% of the Order value if cancelled thereafter; or, c) 100% of the Order value of any non-standard items, which are items not built for stock or built to Buyer's specifications.

2) **RETURNED PRODUCT:** All sales are final; all custom products (non-stocking) are not subject to return, credit or refund. The return of obsolete and used Products shall not be permitted. The Purchaser shall not return Products without first obtaining Seller's written permission and shall be subject to a restocking charge. Products must be returned within 10 days after the date that written permission has been given. All transportation charges for any returned Products shall be paid by the Purchaser. Request to return Products must be accompanied by relevant customer order and Seller's invoice number(s). Final acceptance of returned Products is subject to examination and/or testing. Products will not be accepted for return or credit later than six (6) months after invoicing.

3) **PRICES:** Possession of price lists will not be accepted by the Seller as an obligation, or offer, to sell any goods listed therein. All prices contained in published price lists are subject to change without notice and supersede those of all previous lists. Prices quoted are based on current exchange rates; Seller reserves the right to adjust pricing to reflect the exchange rate in effect at the product receipt date to Seller's facility.

4) **LIQUIDATED DAMAGES:** Liquidated damages will not be accepted in the event of order placement.

5) **SALES TAXES, ETC.:** The Purchaser shall pay and be responsible for all provincial, local or federal sales, use or other taxes (including general sales or value added taxes) and customs duties now or hereinafter enacted which may be applicable to the sale of the Products or the importation of the Products to the destination specified by the Purchaser and which duties and taxes shall be the responsibility of the Purchaser.

6) **CREDIT APPROVAL:** Orders are accepted subject to satisfactory credit approval. Pending credit approval, delivery may be delayed without liability to Seller.

7) **TERMS OF PAYMENT:** The terms of payment for Products purchased pursuant to this Agreement are (I) upon acceptance of the purchase order a deposit in such amount as may be set out in the Seller's written acceptance notice and (II) the balance within 30 days from the date of invoice. Any invoice amount which is not paid when due shall bear interest at the rate of one and one-half (1 ½%) percent per month until paid in full.

   The Purchaser agrees that it will not have any rights of set off against or deduction from the purchase price for the Products payable by the Purchaser pursuant to this Agreement. The Purchaser grants to Seller a purchase money security interest in all Products delivered pursuant to this Agreement and all proceeds thereof (whether cash or non-cash and including, without limitation, accounts, instruments and chattel paper). Any failure by the Purchaser to pay the purchase price in full as provided in this Agreement shall constitute an event of default for purposes of said security interest. Upon the occurrence of any such default, Seller shall have all rights of a secured party after default under applicable law. Any repossession and removal of any Products shall be without prejudice to any of Seller's other remedies at law or in equity. The Purchaser agrees, without further consideration, at any time, to do or cause to be done, to execute and deliver, all such further acts and instruments (including, without limitation, financing statements approved for filing) as Seller may reasonably request in order to perfect Seller's security interest.

8) **DELIVERY DATE:** Seller will utilize reasonable best efforts to meet the delivery schedules stipulated in this Agreement. In the event the provisions of Section 14 hereof shall apply, the delivery date shall be extended by a number of days that is equal to the duration of the event or condition that is responsible for such delay.

9) **TITLE AND SHIPMENT:** All quotations and sales are FCA Loaded Truck ValvSource Warehouse (Inco Terms 2010) unless otherwise specified in writing and agreed by both parties. Seller's responsibility ceases upon delivery to carrier and title shall transfer and risk of loss shall be borne by Buyer at that point. Any expedited or other premium transportation charges requested by Buyer will be for the account of Buyer. Prices include domestic packing, blocked and strapped to open pallets and wrapped in Poly. No claims for price adjustments will be honored unless presented within six (6) months from date of invoice. All quotations are subject to change without notice and prior to sale of goods.

10) **INSPECTION BY PURCHASER:** All Products must be inspected by the Purchaser upon receipt and the Purchaser and Seller, collectively, agree to file appropriate claims with the carrier when there is evidence of shipping damage, either concealed or external. Claims for shortage or error in shipment or for damage other than shipping damage must be made within 5 days after receipt of shipment, failing which the Purchaser shall be deemed to have accepted the shipment.

11) **LIMITED WARRANTY:** Purchaser acknowledges that the Products are provided to the Purchaser subject only to the limited warranties provided by the manufacturer of the Products and are subject to all of the conditions, limitations and exclusions set out therein, all of which are hereby accepted by the Purchaser. The warranty exclusions include, without limitation, (I) any defects caused by faulty installation performed by Purchaser or third parties, (II) any damage caused by the contractors or tradesman of the Purchaser, (III) any damage caused by improper use or misuse, including exposure to excessive temperatures, moisture or cleaning agents and solvents and (IV) any damage caused during transportation or improper storage. Claims for warranty repairs and replacements must be made within the applicable time period described in the manufacturer's limited warranty. In no event shall Seller be liable for other than the repair or replacement of any defective Products. In no event shall Seller be liable for any damages, direct or indirect, special or consequential, including, without limitation, damages for lost profits, business interruption, or economic loss arising out of defects in the Products.

12) **EXCLUSION OF WARRANTIES:** Except as expressly set forth herein seller disclaims all warranties with regard to the products including, without limitation, all implied warranties of merchantability and fitness for a particular purpose.

13) **CATALOGUE AND OTHER PRINTED MATTER:** Seller's illustrations are representations of a certain size of each line of Product, but do not necessarily represent all sizes and materials in detail. Similarly, dimensions, weights and material information have been prepared with care, but their correctness is not guaranteed. Seller reserves the right to vary the designs and dimensions without notice.

14) **FORCE MAJEURE:** Any delay or failure of performance by Seller shall be excused if and to the extent caused, directly or indirectly, events beyond Seller's control including, without limitation, fire, flood earthquake, lightning, hurricane, explosion, accident or breakdown, acts of God, embargo, strike, labour dispute, labour trouble, lockout, shortage or control of power supply, shortage of supplies or raw materials, or any causes whether of the same kind as the causes enumerated before or not. Subject to any express provisions of this Agreement, any such causes of delay shall extend the time of performance by the length of delay occasioned thereby.

15) **NO WAIVER:** No waiver by Seller of any right hereunder or of any right granted in connection with a failure to perform or breach by the Purchaser shall be deemed as a waiver of any other right hereunder or of any right granted in connection with any other failure or breach by the Purchaser, whether of a similar nature or otherwise.

16) **NOTICE:** Any notice made under or in relation to this Agreement shall be sent to the addresses first above written or such other address as the intended recipient shall have previously designated by written notice, by postage prepaid registered mail or by telegram including telex, followed by a confirmation letter by postage prepaid and return receipt requested registered mail. The notice shall be deemed to be made on the fifth day following the date of mailing.

17) **ENTIRE AGREEMENT:** This Agreement contains the entire agreement and understanding of the parties hereto with respect to the subject matter of this Agreement, and supersedes all prior discussions, agreements, understandings of any and every nature, whether written or oral, between the parties with respect to the subject matter of this Agreement, and no condition, definition, warranty or representation other than those expressly provided for in this Agreement with respect to the subject matter of this Agreement shall be binding upon either party hereto.

18) **AMENDMENTS IN WRITING:** Any amendment, modification, change or alteration of this Agreement shall be made in writing which expressly refers to this Agreement and which is signed by a duly authorized officer or representative of each of the parties hereto.

19) **SEVERABILITY:** All provisions of this Agreement are severable and this Agreement shall be interpreted and enforced as if all completely invalid or unenforceable provisions were not contained herein. All partially valid and enforceable provisions shall be enforced to the extent they are valid and enforceable.

20) **NO AGENCY OR PARTNERSHIP:** Nothing herein contained shall be deemed or construed to constitute either party the agent or partner of the other. Neither party shall have any right, title or authority to enter into any contract, agreement or commitment on behalf of the other or to bind the other in any manner whatsoever.

21) **GOVERNING LAW:** This agreement shall be governed by and construed in accordance with the laws of the jurisdiction from which the products are shipped by the seller to the purchaser and the parties hereby attorn to the courts of such jurisdiction.

22) **ENUREMENT:** This Agreement shall enure to the benefit of and be binding upon the parties hereto and on their successors and permitted assigns.

23) **SELLER DEFINED:** For the purposes hereof, Seller means the Corporation listed as such on the front page of the Invoice or acceptance notice of which these terms and conditions of sale form a part.

Notes

Notes

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