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STA-RITE®

Commercial Pool/Spa Engineering Design Manual

STA-RITE®

Charts and Tables

Second Edition – January 2003

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POOL REQUIREMENTS

The pool designer must first consider the major requirements of those using the pool.

1. The population of area to be serviced by swimming facility?
2. The estimated potential bathing load?
3. What percentage of pool use time will be devoted to:
   (a) Competitive swimming and training?
   (To determine the length and minimum width)
   (b) Competitive diving and training?
   (To determine the minimum depths and type of diving equipment)
   (c) Recreational swimming?
   (Recreational requirements demand ample shallow area for relaxed water play)
   (d) Swimming instruction and water safety?
   (The swim coach or pool manager would have definite requirements governing the instruction area related to the classes to be taught)
   (e) Water polo?
   (Reflects planning of deep end and width of pool)
   (f) Precision swimming (water ballet)?
   (Area uses for this purpose should be considered in relation to the spectator positioning)
   (g) Skin diving and scuba instruction?
   (Governing minimum epths for diving area)

TOTAL 100%

A well planned pool will be developed around a combination of two or more of the above criteria considering them in their position of importance.

POOL SIZE – COMPETITION TYPE POOLS

Definite requirements have been established by NCAA governing the minimum length, width and depth of pools used for swimming competition.

These standards may conflict with the State Health Department regulations governing the pool being designed.

A decision must be made applicable to the Health Department and the purchasing organization with consideration to designing a pool complying with requirements for competitive dimensions and affording the maximum safety for the swimmers.

The following excerpts from the NCAA handbook reflect the preferred requirements to be considered in your preliminary planning: (See note, preceding page.)

Long Course Swimming – The racing course should be 164 feet, 1.50 in. (50 meters, 2.54 centimeters) in length by 75 feet, 1 inch (22.89m) in width, providing for eight 9-foot (2.74m) lanes with additional width outside lanes 1 and 8. A minimum water depth of 7 feet (2.13m) is desirable for competition. Optional markings: nine 8-foot (2.44m) lanes or ten 7-foot (2.13m) lanes.

Short Course Swimming – The racing course should be 75 feet, 1 inch (22.89m) in length by at least 60 feet (18.29m) in width, providing for not less that eight 7-foot (2.13m) lanes with additional width outside lanes 1 and 8. A minimum water depth of 7 feet (2.13m) is desirable for competition.

POOL SIZE – RECREATIONAL TYPE POOLS

Refer to National Spa and Pool Institute for guidelines in planning recreational type pools.

POOL SHAPES

The standard rectangle used for most competitive type swimming pools can be deviated from without changing its functional use by employing an Ell or Tee area, isolating the diving depths from the normal racing field. These combination pools can be designed to incorporate two different racing lengths.

When an appendage such as this is employed, the pool slopes should be laid out in the preliminary drawings to assure that the requirements for clearance from the deep end of the pool to the safety rope will allow adequate recreational area. Many State Health codes make the installation of an Ell or Tee shaped pool an impractical type of construction for parks and swim clubs where open swimming comprises a large quantity of their pools use time.

In pools not governed by competition requirements, those designed for recreation only, shapes are in no way a governing factor, and the ultimate design of the pool could be purely related to the architect's concept of what would be attractive to the property, taking into consideration the demand for pool safety and adequate supervision where lifeguards are to be employed.

Pool Design Requirements

LIFE GUARD CHAIRS

Life guard chairs must be installed allowing for the maximum coverage for supervision of both pool and deck.

MISCELLANEOUS EQUIPMENT REQUIRED

Provide cup anchors for facing lanes and safety ropes.

Racing lanes should be construted with continuous floats and equipped with tension adjusting devices.

Provide backstroke and false start indicator posts.

Depth markers should be installed on pool face, and distance markers incorporated into the deck including 220 and 440 yards, 200, 400 and 1500 meters.

Where water polo is to be played, goals should be provided with anchors in deck and markings indicating field of play.

Ample underwater and overhead lighting must be installed to comply with State and competition requirements.

Underwater observation areas equipped with an underwater speaker system affords advantages to the swimming and diving instructor. This underwater speaker system can also be used to supply music for synchronized swimming.

Starting blocks must be of an approved design and incorporated as part of the pool plan as anchors are required for their installation.

DECK AREA

Deck area considerations should include sufficient room for spectators, recreational sun bathing and dry swimming instruction.

Areas need to be provided for mechanical equipment installation, showers, change rooms and toilet facilities.

Provide drinking fountains in the pool deck area.

SPECIAL PURPOSE POOLS

Requirements may demand the planning of a special purpose pool incorporated with the designs for a large competitive swimming pool. Special purpose pools in this category would be wading pools, beginning swimming instruction pools and hydrotherapy pools. In most cases, these pools should operate independent of the main swimming pool.

Public Pool Calculations

HOW TO CALCULATE GALLONAGE

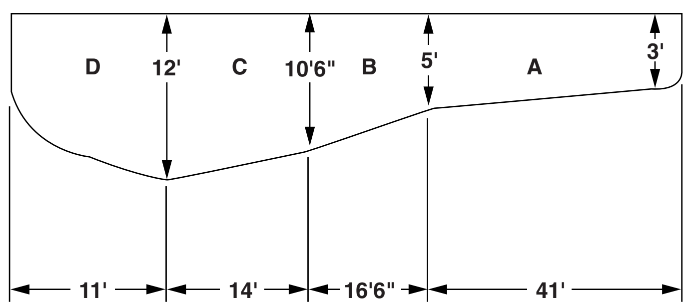
Pool gallonage content is calculated by geometric methods; first by measuring the width of the pool, then the length of the pool and arriving at an average depth. For example, one section of the pool slopes from 3 ft. through 5 ft. at a regular rate, the average depth would be half way between 3 ft. and 5 ft., or 3 + 5 ÷ 2 = 4 ft. The surface area of this section of the pool would be multiplied by 4 ft. and an answer in cubic feet would indicate the volume of the section. We know one cubic foot contains 7.5 gallons of water, therefore, we multiply the cu. ft. content by 7.5. This will give the gallonage content for this section. The pool should be divided into as many sections as possible, as this division will afford accuracy.

Example: A swimming pool 82'6" long by 42' wide, ranging in depth from 3 ft. to 12 ft. with three breakage slopes:

Area A = 41' X 42' = 1,722 sq. ft.

1,722' X (5' + 3' ÷ 2) = 6,888 cu. ft.

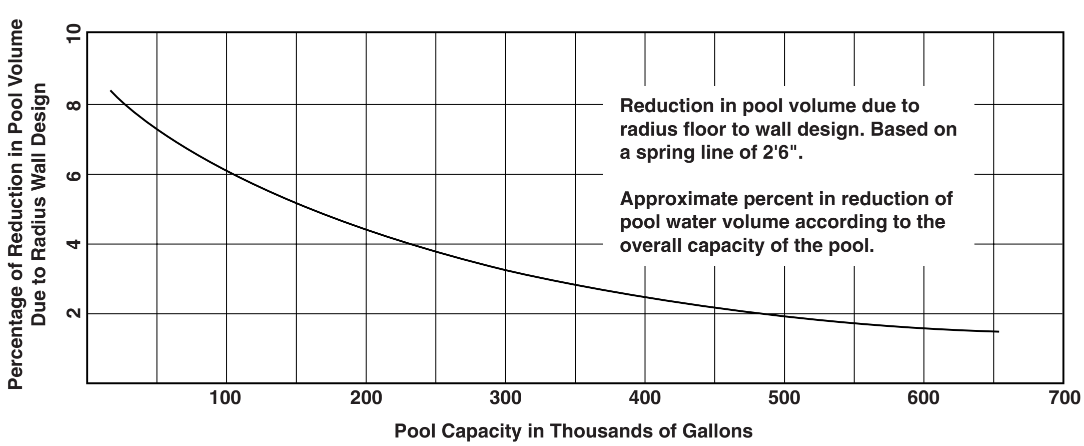
6,888 X 7.5 (gal. per cu. ft.) = 51,660 (gal. in Section A)



HOW TO CALCULATE RADII

We will divide the pool into four sections, as shown above, calculating area A, B, C, and D as shown above. You will notice no dedication for radii have been allowed. When all sections have been calculated, add and obtain total gallonage.

the curve below will enable you to deduct for the radii.



HOW TO CALCULATE MAXIMUM BATHING LOAD AND DISPLACEMENT OF BATHERS FOR PUBLIC POOLS

Bathing Load

One bather per 15 square feet of surface area (less than 5 feet deep).

One bather per 20 square feet of surface area (more than 5 feet deep).

Subtract 300 square feet from total square feet of area for each diving board.

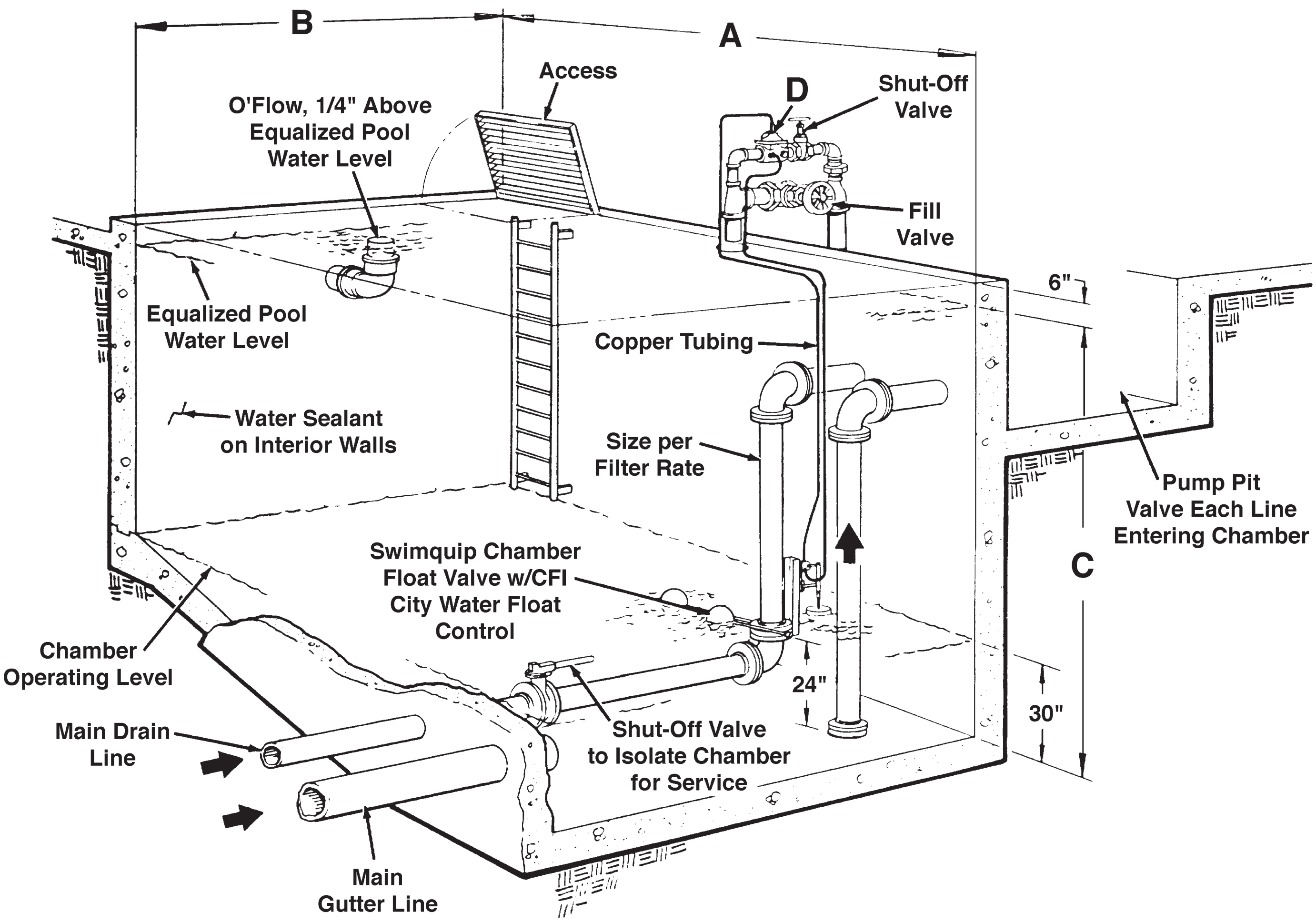
Example

1. Calculate surface square feet of area less than 5 feet deep.
2. Divide this figure by 15 for total number of swimmers.
3. Calculate surface square feet of area more than 5 feet deep.
4. Divide this by 20 for total number of swimmers.
5. Add results of No. 2 and No. 4.
6. Subtract 15 swimmers for each diving board.
7. The remainder is the total number of swimmers for that size pool.

Displacement of Bathers

8. Multiply the results of No. 2 by .75 (assuming the bathers in the shallow water are 75% submerged) and then by 2 (approximate displacement in cubic feet per bather).
9. Multiply the results of No. 4 by .9 (bathers in deep water 90% submerged) and then by 2.
10. Add results of No. 8 and No. 9 to give total bather displacement in cubic feet of water.

TYPICAL SURGE CAMBER INSTALLATION



SURGE CHAMBER SIZING

Bathing Load	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
Displacement (Gal.)	1500	2250	3000	3750	4500	5250	6000	6750	7500	8250	9000	9750	10500	11250	12000
Main Gutter (gpm)	150	225	300	375	450	525	600	675	750	825	900	975	1050	1125	1200
A – Chamber Length	8’	8’	8’	10’	10’	12’	12’	14’	15’	16’	18’	20’	20’	20’	20’
B – Chamber Width	6’	7’	8’	8’	10’	10’	10’	10’	10’	10’	10’	10’	10’	10’	10’
C – Chamber Depth	9’6”	11’0”	11’6”	11’6”	11’6”	11’6”	12’0”	12’0”	12’0”	12’6”	12’0”	12’0”	12’6”	13’6”	13’6”
D – C.W. Makeup (IPS)	1½”	1½”	2”	2”	2”	2½”	2½”	2½”	3”	3”	3”	3”	3”	3”	3”
E – Overflow	4”	4”	6”	6”	6”	6”	6”	6”	6”	8”	8”	8”	8”	8”	8”

Public Pool Calculations

SURGE CHAMBER DESIGN PROCEDURE

1. The design criteria in this reference sheet takes into account the maximum possible bathing load for any size pool and the surge chamber is sized to accommodate this full displacement, and yet, still maintain a gutter system which will continuously skim the pool surface. Of further importance, when there is no bathing load, the stored water in the surge chamber will return to the pool, thus maintaining a water level necessary to continue skimming of the surface water when the pool is not in use.

   The complete mechanism is fully automatic with butterfly-type valves which are self-adjusting to meet all varied load condition, and small debris will not cause them to malfunction.
2. In order to properly size the surge chamber, the maximum bathing load must be determined.
3. "Surge Chamber Sizing Chart" designates various bathing loads at the top of each column.
4. For proper operation, the elevation of the surge chamber must be established with proper relationship to water level in the pool, as illustrated in the drawing. Should the recirculating system be shut down, the water level between pool and surge chamber is equalized, at which time any excessive amount of water in the system will overflow to waste.

   Note: Should the top elevation of surge chamber be constructed below pool level, flooding would result should the circulating system be shut down.
5. The total chamber depth "C" has been established to insure continuous skimming of the pool even during peak bathing loads.
6. "GPM Through Main Gutter Line" is shown on the chart below. the flow rate through gutter line is based on a recovery time of 10 minutes, which is sufficient to avoid flooding the gutters. The main gutter line may be sized by using the chart at the bottom of this page. This chart is based on straight runs of pipe, utilizing a two (2) foot head. To properly utilize this chart, it will be necessary to add the loss through any fittings in the equivalent lengths of pipe. To arrive at these values, refer to other charts in this booklet.
7. For quiet chamber operation, install main gutter line at least 12' below chamber operating water level.

   Size the chamber suction line as well as the main outlet (main drain) line to handle the maximum design recirculation rate. Regardless of line size, install float valve as illustrated.

   Note: Always size the main gutter line for the maximum design flow rate or surge flow rate, whichever is greater.
8. The automatic fresh water make-up system maintains a proper pool level at all times. The air gap, as illustrated in the drawing, must be in conformity with local regulations.

   Set the CF1-A1 Float control valve with float in OFF position at chamber operating level. Allow 8" travel before actuation of ON position.

BATHING LOAD SELECTION

Pool Surface Area (Sq. Ft.)	Number of Bathers	
	Less Than 5' Deep Swimming Area	More Than 5' Deep Diving Area
1500	100	20
2000	133	27
2500	167	33
3000	200	40
3500	233	47
4000	267	53
4500	300	60
5000	333	67
5500	367	73
6000	400	80
6500	433	–
7000	467	–
7500	500	–
8000	533	–
8500	567	–
9000	600	–
9500	633	–
10000	667	–
10500	700	–
11000	733	–
11500	767	–
12000	800	–

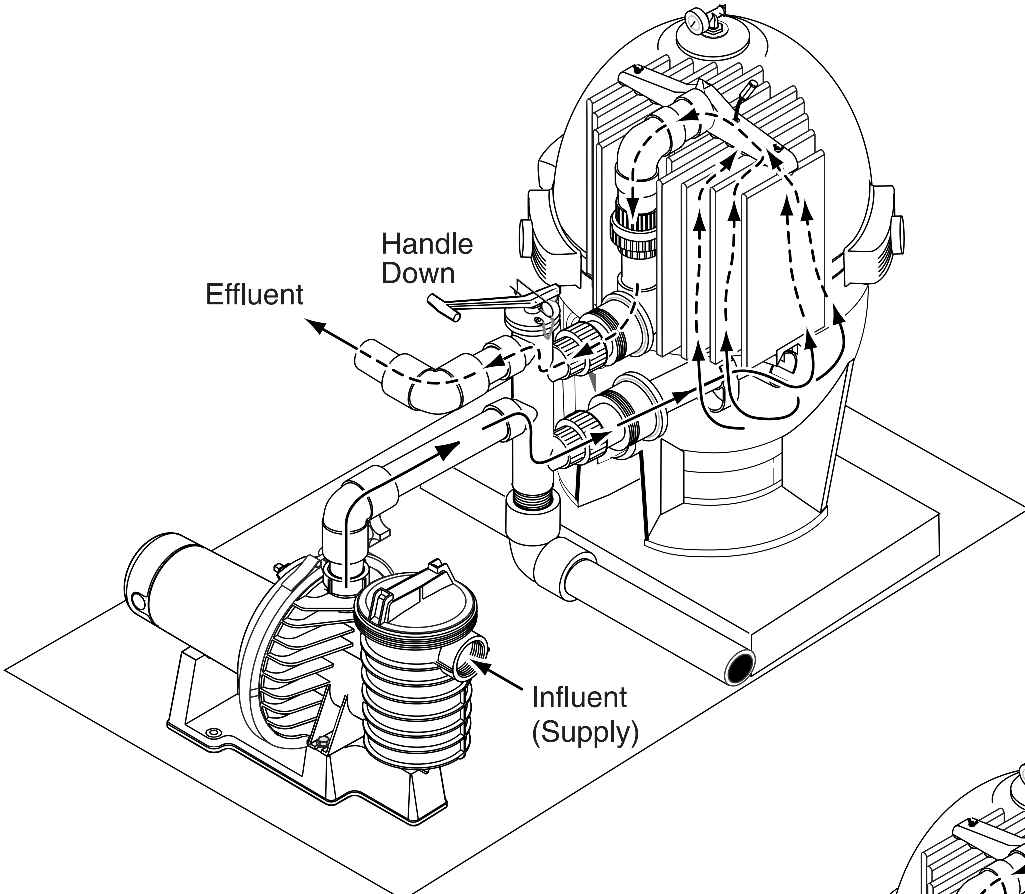
MAIN GUTTER LINE SIZING

Main Gutter	Length of Run From Pool To Chamber			
Line (IPS)	25 Ft.	50 Ft.	75 Ft.	100 Ft.
4"	165 gpm	130 gpm	110 gpm	100 gpm
6"	485 gpm	395 gpm	340 gpm	300 gpm
8"	1000 gpm	835 gpm	735 gpm	665 gpm
10"	1750 gpm	1500 gpm	1335 gpm	1210 gpm
12"	2690 gpm	2340 gpm	2110 gpm	1920 gpm

BASIC PRINCIPLES OF OPERATION

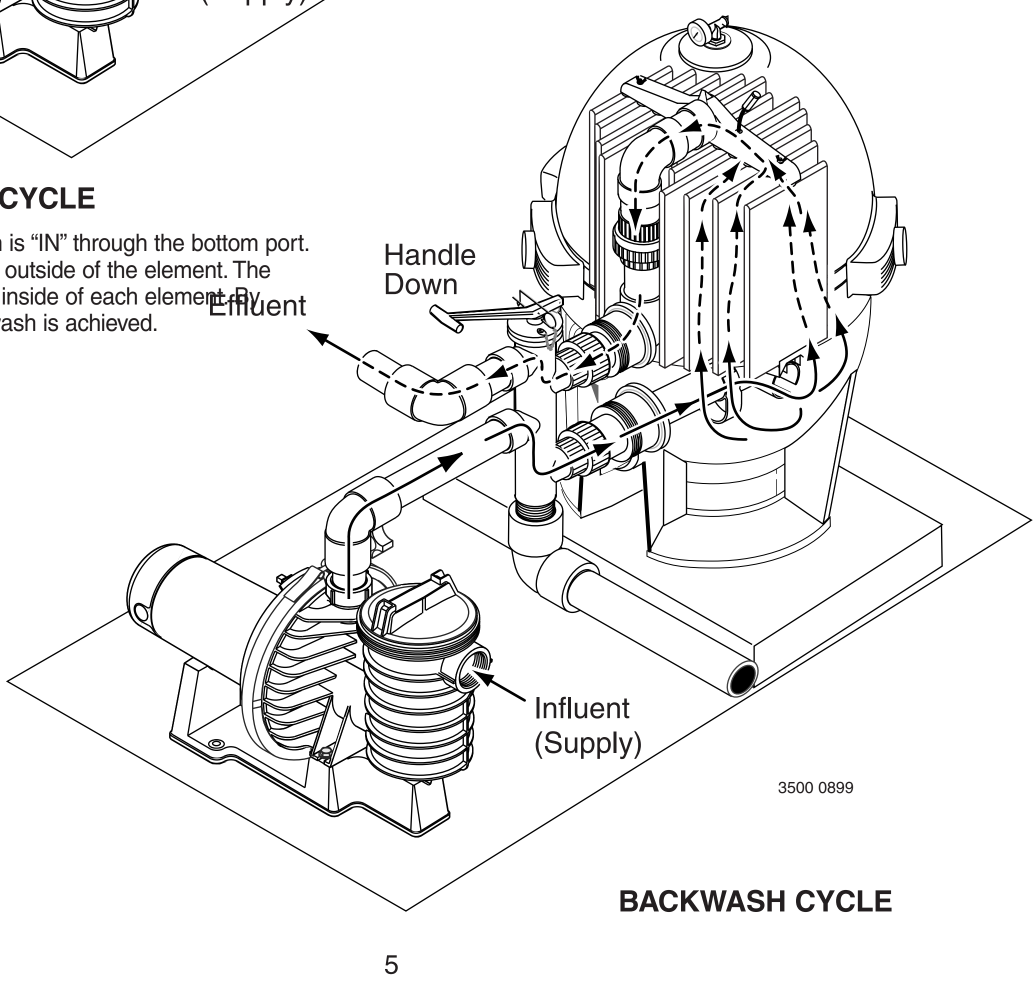
MODEL DEP VERTICAL D.E. FILTER

Liquid Flow Path During Filter and Backwash Cycles
Manual System with (Unitrol) Slide Vavle



FILTER CYCLE

In the filter cycle the flow direction is “IN” through the bottom port. Precoat, filter aid is applied to the outside of the element. The fluid flows from the outside to the inside of each element. By reversing the flow direction backwash is achieved.

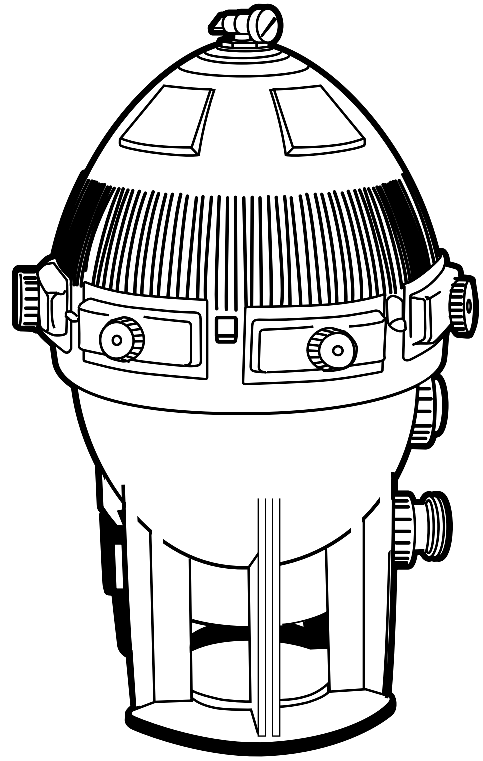


BACKWASH CYCLE

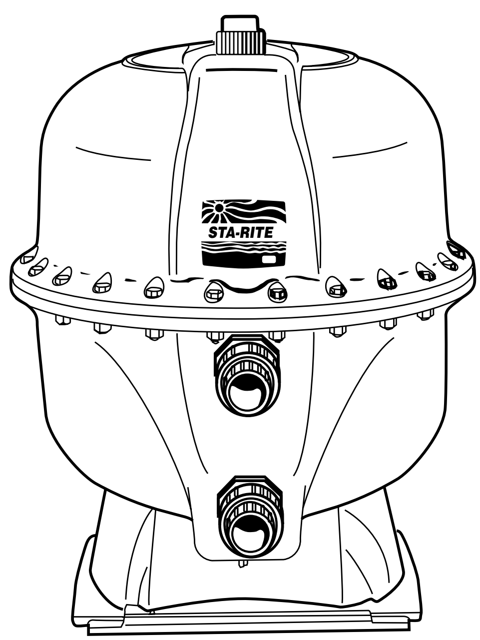
Diatomaceous Earth Filters

Model No.	No. of Units	Filter Area Sq. Ft.	Flow Rate 1.5 GPM	Flow Rate 2.0 GPM	Turnover Rate 6 Hours	Turnover Rate 8 Hours
PLD70	1	36	54	–	19,440	25,920
			–	72	25,920	34,560
S7MD60	1	60	90	–	32,400	43,200
			–	120	43,200	57,600
S7MD72	1	72	108	–	38,880	51,840
			–	144	51,840	69,120
DEPB83	1	83	125	–	45,000	60,000
			–	166	59,760	79,680
	2	166	249	–	89,640	119,520
			–	332	119,520	159,360
	3	249	373.5	–	143,280	179,280
			–	498	179,280	239,040
	4	332	498	–	179,280	239,040
			–	664	239,040	318,720
	5	415	622.5	–	224,100	298,800
			–	830	298,800	398,400
	6	498	747	–	268,920	358,560
			–	996	358,560	478,080
	7	581	871.5	–	313,740	418,320
			–	1162	418,320	557,760
	8	664	996	–	358,560	478,080
			–	1328	478,080	637,440

Note: Recommended flow rate – 1.5 GPM per sq. ft. of filter area.



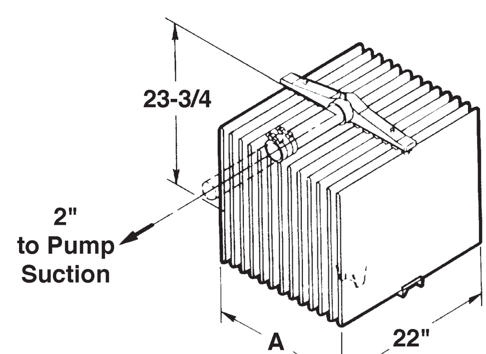
System 3
Model S7MD60 and Model S7MD72



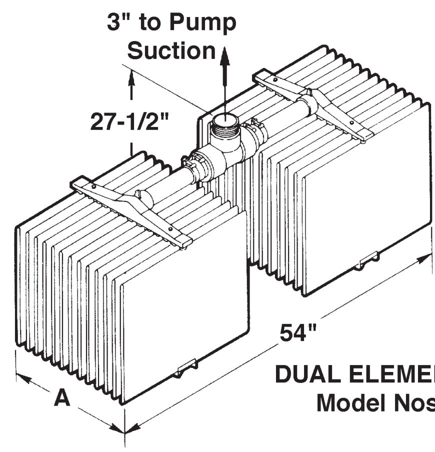
DEPB

ULTRA-VAC™ VACUUM D.E. RATES AND CAPACITIES

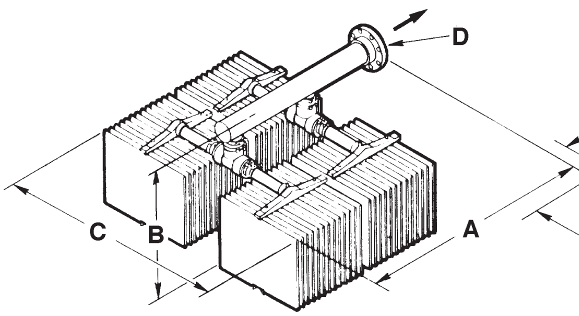
Part No.	U-V Model	Area	1 GPM Rate	1.5 GPM Rate	6 Hour Turnover		8 Hour Turnover	
					1.0 GPM	1.5 GPM	1.0 GPM	1.5 GPM
29830-0056	56	56	56	84	20,160	30,240	26,880	40,320
29830-0066	66	66	66	99	23,760	35,640	31,680	47,520
29830-0112	112	112	112	168	40,320	60,480	53,760	80,640
29830-0132	132	132	132	198	47,520	71,280	63,360	95,040
29830-0224	224	224	224	336	80,640	120,960	107,520	161,280
29830-0264	264	264	264	396	95,040	142,560	126,720	190,080
29830-0336	336	336	336	504	120,960	181,440	161,280	241,920
29830-0396	396	396	396	594	142,560	213,840	190,080	285,120
29830-0448	448	448	448	672	161,280	241,920	215,040	322,560
29830-0528	528	528	528	792	190,080	285,120	253,440	380,160
29830-0560	560	560	560	840	201,600	302,400	268,800	403,200
29830-0660	660	660	660	990	237,600	356,400	316,800	475,200
29830-0672	672	672	672	1008	241,920	362,880	322,560	483,840
29830-0792	792	792	792	1188	285,120	427,680	380,160	570,240
29830-0896	896	896	896	1344	322,560	483,840	430,080	645,120
29830-0924	924	924	924	1386	332,640	498,960	443,520	665,280
29830-1056	1056	1056	1056	1584	380,160	570,240	506,880	760,320
29830-1188	1188	1188	1188	1782	427,680	641,520	570,240	855,360
29830-1320	1320	1320	1320	1980	475,200	712,800	633,600	950,400
29830-1452	1452	1452	1452	2178	522,720	784,080	696,960	1,045,440
29830-1584	1584	1584	1584	2376	570,240	855,360	760,320	1,140,480



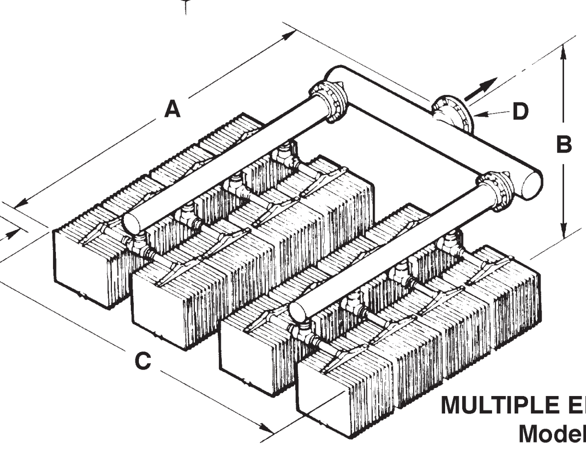
SINGLE ELEMENT ASSEMBLY
Model Nos. 56 & 66



DUAL ELEMENT ASSEMBLY
Model Nos. 112 & 132



MULTIPLE ELEMENT ASSEMBLIES
Models 224 Thru 792



MULTIPLE ELEMENT ASSEMBLIES
Models 896 Thru 1584

DIATOMACEOUS EARTH PRECOAT AND SLURRY FEED REQUIREMENTS

Diatomaceous earth filters divided into two basic classifications; pressure and vacuum type filters.

Flow rates vary depending upon the type of service, the anticipated loading and whether or not slurry feeding is to be included. For residential pools flow rates of between 2 and 2-1/2 gallons per minute per sq. ft. of filter area are obtainable.

Pressure type filters used on other than private pools operate at 2 gallon per minute flow rates, except where slurry feeding is used in which case to flow may be as high as 2-1/2 gallons per minute per sq. ft.

Vacuum type diatomite filters operate at a rate of 1-1/2 to 2 gpm per sq. ft. without slurry feed. Total flow is generally calculated on the basis of an 8 to 12 hour turnover for private pools and 6 to 8 hour turnover for public pools.

PRECOAT, VACUUM AND PRESSURE TYPE

The vacuum precoat vessel is plumbed to the suction side of the circulating pump. The precoat is drawn from the precoat pot under vacuum and introduced into the filter vessel under pressure (see Figure 4).

The pressure precoat vessel is plumbed between the circulating pump and the filter system. Fluid, under high pressure, is introduced into the top of the vessel and leaves through the connection located in the bottom of the vessel. The precoat is introduced directly into the filter face piping (see Figure 5).

Precoating with slurry tank, fill tank 1/4 full with fresh water and add the required amount of diatomaceous earth into the tank. Start agitator. Place filter into operation. Open the gate valve on the city water supply line connected to the injector. The solution will be drawn from the tank by the injector. When the tank is empty shut off the city water line, precoat is now complete (see Figure 6, Page 9).

Note: 1. The H-B/F must not be operated without a precoat.

2. Precoat must be prepared prior to starting circulating pump, as precoating must take place when the pump is started.

The precoat operation commences on the start of each filter cycle. The precoat is introduced by either a pressure or vacuum type precoat vessel.

The amount of precoat is determined by the total square footage of the filter unit. An example follows:

A filter containing 100 square feet of filter area, and not utilizing a slurry feeder, requries 15 pounds of D.E. per square foot of filter area, on the precoat charge.

Formula: 100 sq. ft. X .15 lbs. D.E. = 15 lbs. total precoat charge.

When feeding slurry, the amount per square foot of filter area is .1 lbs. per square foot of filter area on precoat charge.

VACUUM TYPE PRECOAT TANKS

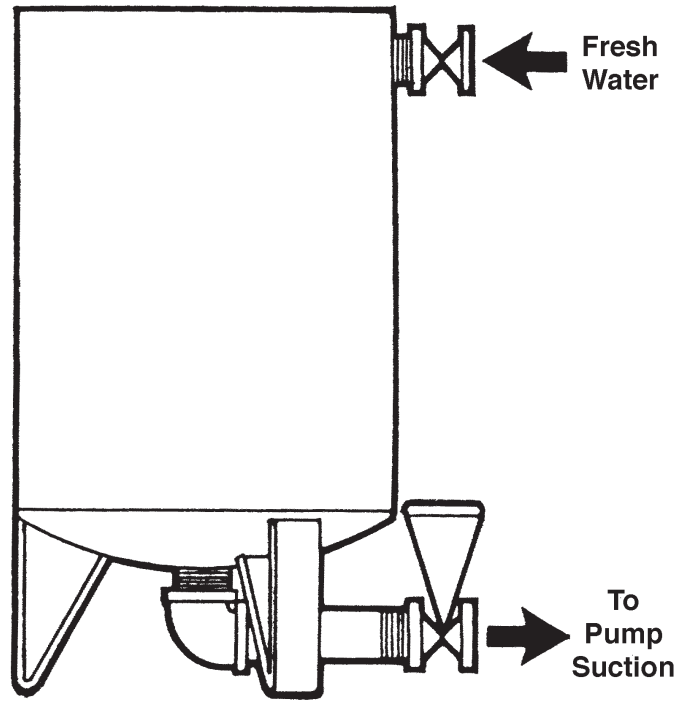


Figure 4

PRESSURE TYPE PRECOAT TANKS

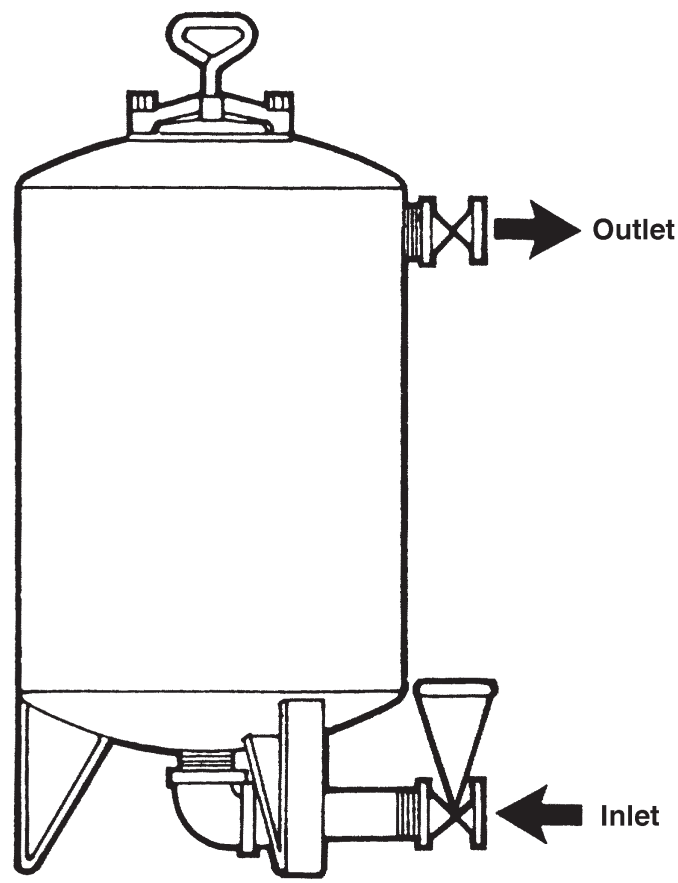
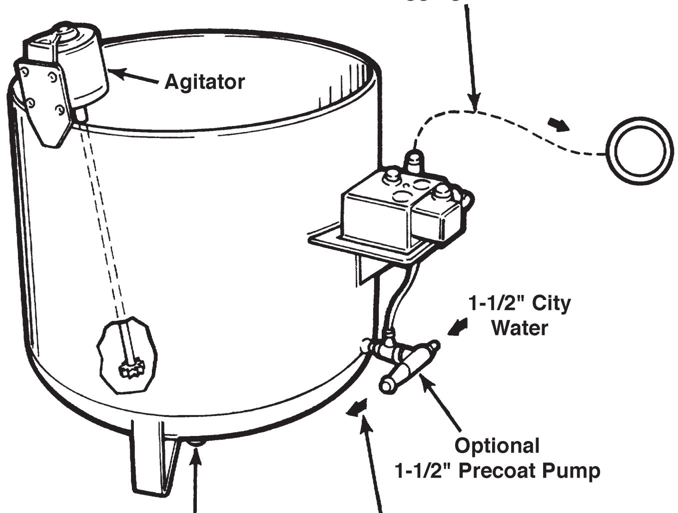


Figure 5



HOW TO USE THE PRECOAT AND SLURRY DOSAGE CHART

1. FILTER AREA (SQ. FT.)
   175 Sq. Ft. Filter
2. SLURRY TANK SIZE
   24” x 36”
3. CAPACITY (GALLONS)
   65 (Tank filled within 6” from top)
4. LBS. D.E. FOR 5% SOLUTION
   Add 26 lbs. of D.E. into Slurry Tank
5. FEED PUMP MODEL
   Precision Model 6401-11F capable of feeding 1.2 gph
6. NUMBER OF HOURS RUN PER TANK
   Length of slurry tank run – 54 hours
7. FEED PUMP SETTING – GPH
   Set feed rate to 50%
8. PRECOAT, POUNDS OF D.E.
   17.5 lbs. of D.E. precoat required for a 175 sq. ft. filter (Ref.). The precoat charge of 17.5 lbs. plus 54 lbs. of D.E. slurry (two tanks full) is the maximum amount of D.E. that can be fed into a 175 sq. ft. filter.

SLURRY FEEDING AND PRECOAT DOSAGE CHART

1	2	3	4	5	6	7	8
Filter Area (Sq. Ft.)	**Slurry Tank Size**	**Capacity (Gallons)**	**Lbs. D.E. for 5% Solution**	**Fee Pump Model**	**No. Hrs. Run per Tank**	**Feed Pump Setting GPH – %**	**Precoat Pounds of D.E.**
78					108	.6 – 25%	7.8
106					81	.8 – 33%	10.6
119					81	.8 – 33%	11.9
133					72	.9 – 38%	13.3
147	24” x 36”	65	26	6401-11F	65	1.0 – 42%	14.7
161					59	1.1 – 46%	16.1
175					54	1.2 – 50%	17.5
189					50	1.3 – 54%	18.9
210					43	1.5 – 63%	21.0
266				6401-21F	34	1.9 – 38%*	26.6
294					49	2.1 – 42%*	29.4
322					45	2.3 – 46%*	32.2
350	30” x 36”	104	42	6401-21F	41	2.5 – 50%*	35.0
378					34	3.0 – 63%*	37.8
420					34	3.0 – 63%*	42.0
483					44	3.4 – 37%*	48.3
525	36” x 36”	150	60	6402-21DF	40	3.7 – 41%*	52.5
567					37	4.0 – 44%*	56.7
630					45	4.5 – 50%*	63.0
700	42” x 36”	205	82	6402-21DF	41	5.0 – 55%*	70.0
756					38	5.4 – 60%*	75.6
840					45	6.0 – 66%*	84.0
945	48” x 36”	272	108	6402-21DF	40	6.7 – 74%*	94.5
1050					36	7.5 – 83%*	105.0

* Dual head pump percentage each head.

Diatomaceous Earth Filters

SLURRY FEEDING WITH DIAPHRAGM FEEDER PUMPS

A feeder pump is provided for the accurate feeding of D.E., slurry and water, in conjunction with filtration equipment. The primary use will be for continuous feeding of D.E. (slurry). The process, if done properly, will greatly increase the operating efficiency of the filter plant.

The **maximum** density the feeder pump is designed to handle is 5% solution by weight. (Water weighs approximately 8.33 pounds per gallon – D.E. weighs approximately 9 pounds per cubic foot).

Example: For 50 gallons of “make-up” water, add 20 pounds of D.E. for the maximum density of slurry mixture.

Formula: Capacity of vessel (gallons X 8.33 pounds = total weight x 5% = amount of D.E.)

The amount of feed can be determined by the turbidity of the water. The ideal balance would be 50% – 50% turbidity in parts per million as to slurry in ppm. For example, the average turbidity of a swimming pool runs about 3 ppm.

Formula: Total pool gallons X 8.33 (weight of one gallon) X .000001 X ppm = amount of a slurry feed charge.

Example: 240,000 gallons X 8.33 lbs. = 2,000,000 lbs.
2,000,000 lbs. X .000001 = 2 lbs. = 1 ppm
2 lbs. X 3 ppm = 6 lbs. of D.E. to be fed with every 240,000 gallons to be filtered.

FEED RATE ADJUSTMENT:

Example: Using Precision Slurry Feeder

The rate of flow on the feeder pump is specified in percents of total capacity based on a 24 hour run. the capacity of the Precision No. 601 slurry pump is 60 gallons per 24 hours when the pump is set at 100%. In the event it were set at 50%, 30 gpd would be the quantity of gallons pumped.

Based on the 100% pumping rate (60 gpd) 24.9 pounds of filter aid will be delivered every 24 hours.

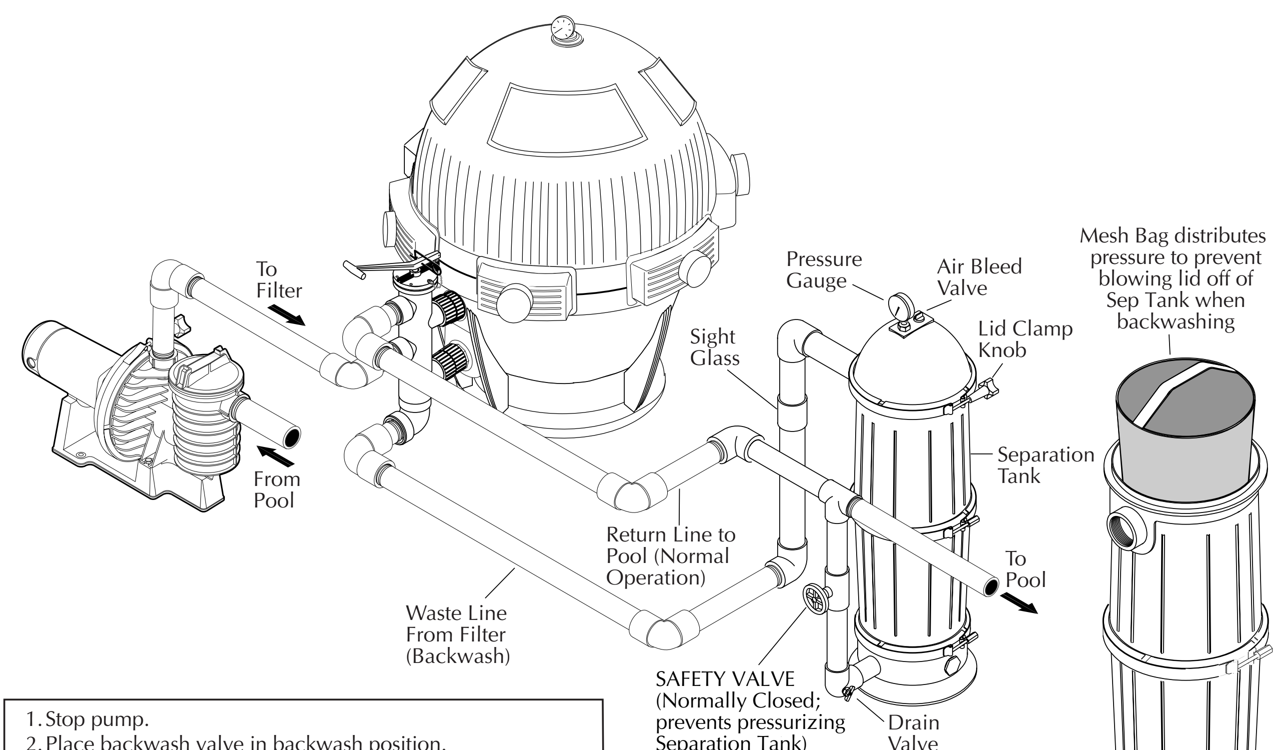
Example: 60 gpd X 8.33 = 499.8 lbs. of water
499.8 X 5% = 24.9 lbs. of filter aid

Or: 30 gallons X 8.33 = 249.9 lbs. water
249.9 lbs. X 5” = 12.5 lbs. of filter aid

A typical commercial system may operate at 390 gallons per minute. During a 24 hour period, basing the turbidity of unfiltered water 3 ppm, you will be feeding 14 lbs. of filter aid per 24 hours; therefore, your pump should be set at approximately 54%.

With increased bathing load, thus increasing turbidity, naturally the rate of feed should be increased. The filter plant operator can experiment on the most desirable rate of feed for a particular situation.

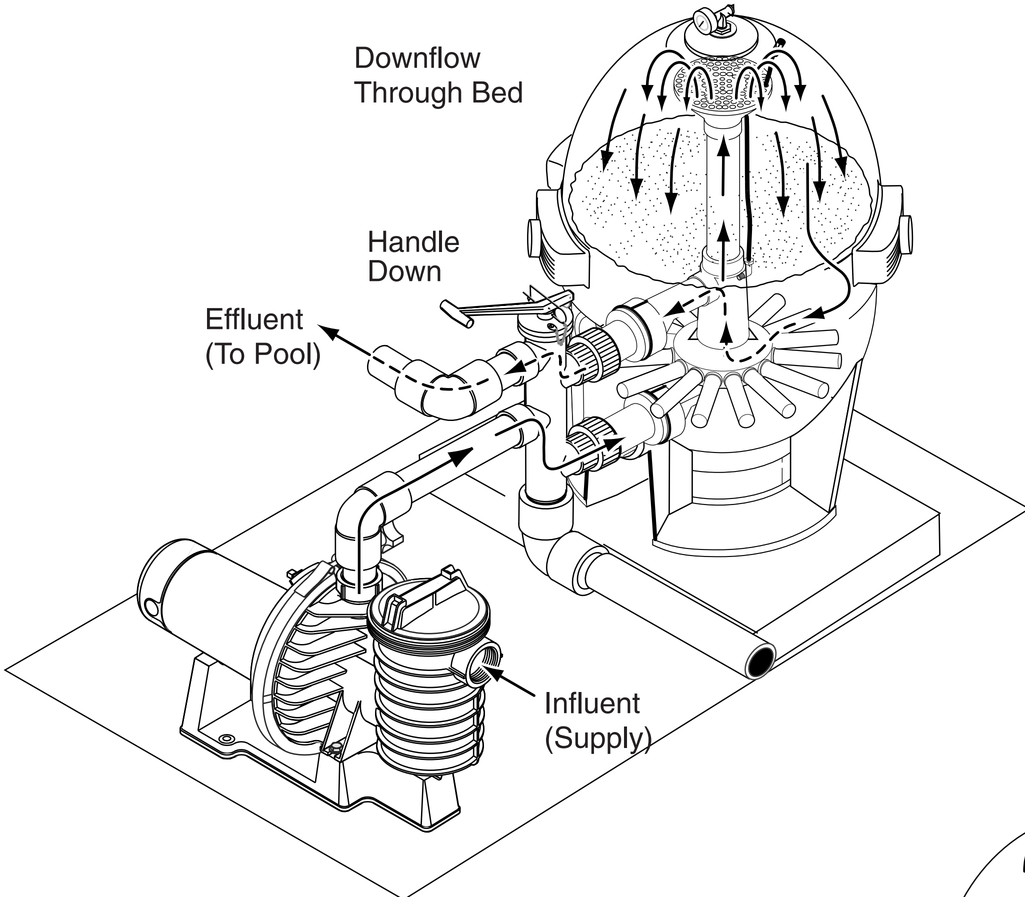
Separation Tank



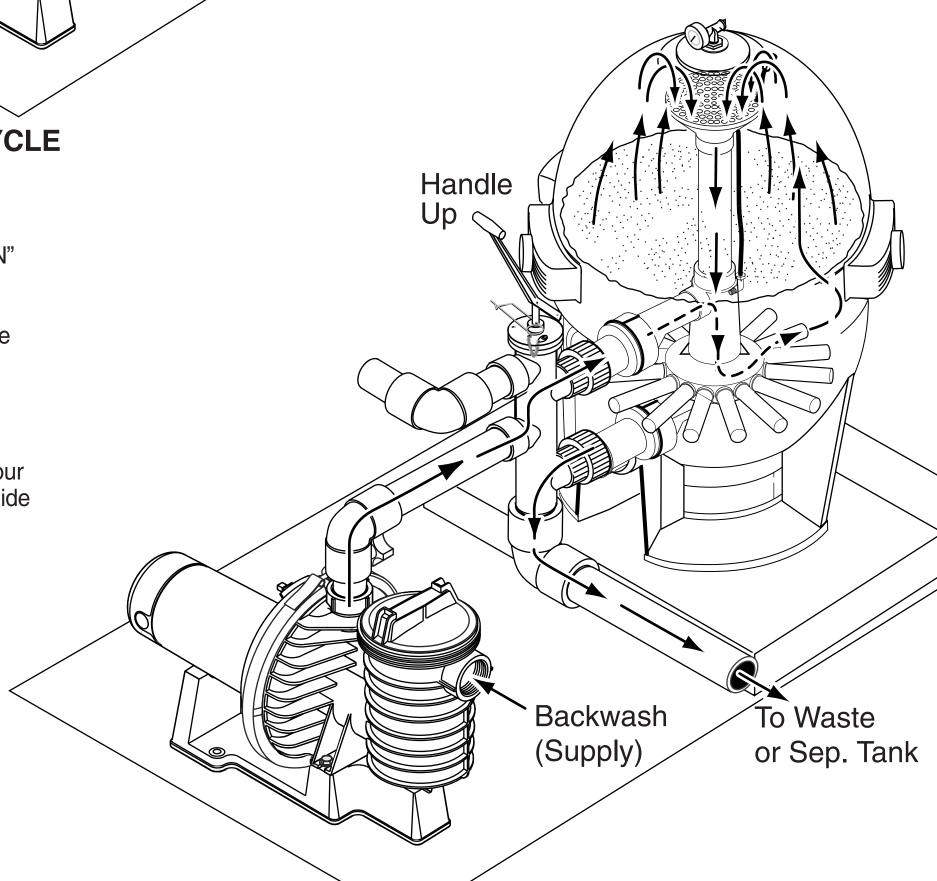
1. Stop pump.
2. Place backwash valve in backwash position.
3. Open Safety Valve and Separation Tank Air Bleed Valve.
4. Check that Sep Tank clamp(s) are on correctly
5. Start pump until water runs from Air Bleed Valve; then close Air Bleed.
6. Run pump until dirt and spent DE have been transferred to Sep Tank.
7. STOP PUMP; place Backwash Valve in normal position and close Safety Valve.
8. Open Sep Tank Drain and Air Bleed and DO NOT attempt to remove the Sep Tank Bag until ALL the water has drained out (usually 24 hours)

MODEL HRP/S HI-RATE SAND FILTER

Liquid Flow Path During Filter and Backwash Cycles
Manual System with (Unitrol) Slide Vavle



FILTER CYCLE



BACKWASH CYCLE

MANUAL SYSTEM

In the filter cycle the flow direction is "IN" through the bottom port. The internals direct the flow to provide down flow through the media bed. By reversing the flow direction backwash is achieved.

AUTOMATIC SYSTEM

The same tank and internals are used with the automatic backwash feature; four diaphragm control valves replace the slide valve.

High Rate Sand Filters

BASIC PRINCIPLE OF OPERATION

The Hi-Rate permanent media pressure filter operates at rates seven to ten times higher than conventional rapid sand filters.

Figure 1 shows diagramatically the Hi-Rate permanent media filter and Figure 2 shows a conventional sand filter operating at accelerated flow rates. The units differ in two main respects:

1. Distribution and collection equipment is designed on scientific principles in the Hi-Rate, whereas the rapid sand filter uses a simplified form of inlet baffling and filtered water collection.
2. The sand filter has many grades of rock, gravel and sand, whereas the Hi-Rate permanent media filter by using one grade of working media provides a greater working depth in a tank of equal size.

With the scientific, balanced hydraulic flow design of the permanent media filter, water turbulence is reduced to very low limits, thus flow paths at the media surface are almost wholly parallel and vertical. It is observed that flow rates in excess of 20 gpm/sq. ft. can be applied to the Hi-Rate filter without displacing media or causing channeling which occurs in the conventional unit.

At high flow rates, collected solids are forced deep into the media, but selection of a fine media particle size enables good filtration to be achieved. A conventional sand filter retains the collected solids in the top 3/4" of the bed. The same volume of solids can be collected in a Hi-Rate filter on a much reduced surface area, as the full depth of the media is utilized.

The Hi-Rate permanent media filter is cleaned when the differential pressure reaches 15 to 20 psi.

Our underdrain system in the Hi-Rate is designed to create strong agitation in the working media during backwash. Media grains are rubbed together to release solids and circulation patterns are established to progressively cause each particle of the media to rise to the surface of the bed at least once every minute during the backwash cycle. The balanced-flow conditions induced by our collector system insures that the up flow water velocity during backwash is equal to that of the settling rate of the media grain thereby preventing media loss while insuring good cleaning. Bed expansion is approximately 6" at backwash rates of 15 gpm/sq. ft. Complete fluidization of the media allows collection solids to be discharged during the first 90 seconds of backwash. The recommended backwash period is 2 to 4 minutes to insure complete removal of collected solids.

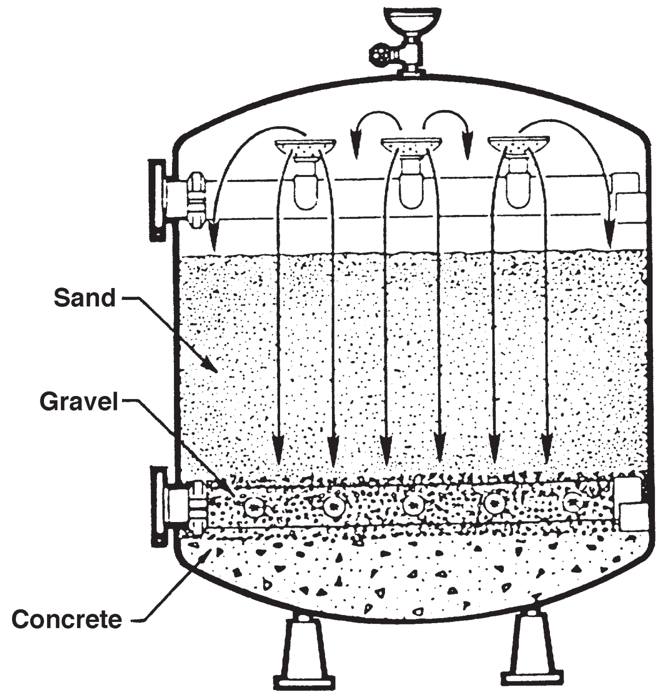


Figure 1

HI-RATE FILTER

Scientifically engineered over and underdrains allow high velocity parallel flow through the filter with a minimum of turbulence.

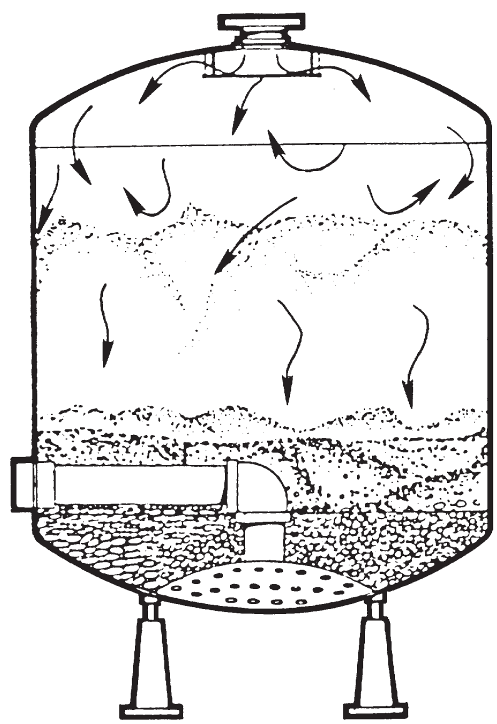
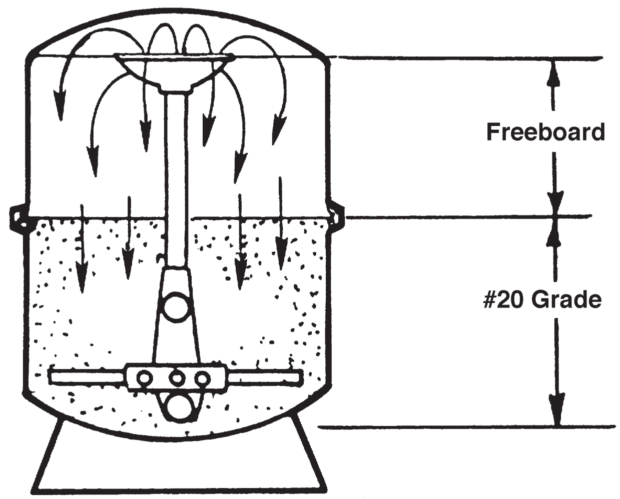


Figure 2

CONVENTIONAL SAND FILTER

Simplified over and underdrain in regular sand filter with its many layers of rock and sand causes turbulence and channeling at high flow rates.



RESIDENTIAL AND COMMERCIAL HI-RATE PERMANENT MEDIA FILTERS

Scientifically engineered over and underdrains in the vertical Hi-Rate permanent media filter produces a high velocity parallel flow through the filter with a minimum of turbulence. Only one layer of media provides a greater depth of filtering medium.

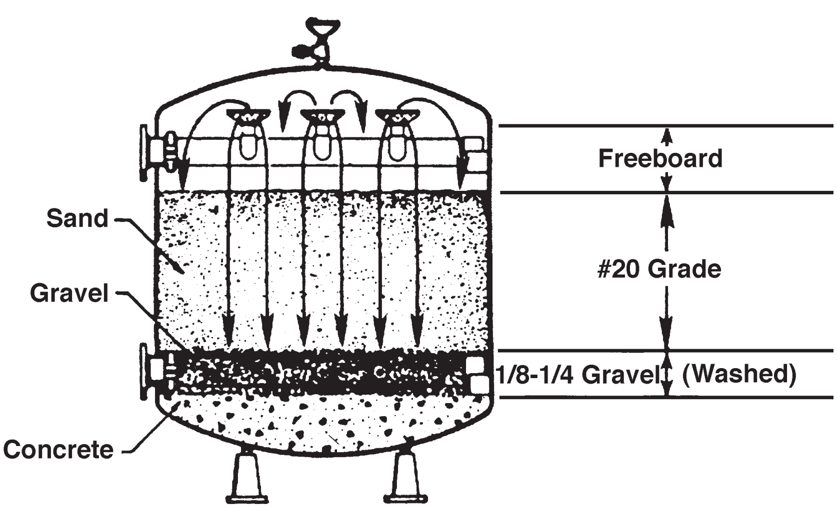
The Hi-Rate permanent media filter operates at flow rates from 15 gpm to 20 gpm per square foot of filter area. The backwash flow rates are the same as for the filtering cycle.

When selecting a Hi-Rate filter, multiple tanks of the same size may be combined for increased capacity.

FILTER MEDIA REQUIREMENT CHART FOR SYSTEM 3 SAND FILTERS

Model Number	Tank Size		Approximate Freeboard	Grade #20 Silica Sand	
	Diameter	Height		Number of Sacks Req.	Weight in Pounds
HRPB20	20”	34”	11”	2	200
S7S50	28.5”	42”	11”	2	200
HRPB24	24”	34”	11”	2.5	250
S8S70	32.5”	42.25”	11”	3	300
HRPB30	30”	34”	11”	4	400

NOTE: 1 cu. ft. of silica sand equals 1 sack or approximately 100 pounds. Freeboard is the open area between the top of the filter sand and the backwash outlet of the tank. During the first few backwashes, the lighter particles of sand and any excess will be flushed from the tank. DO NOT use a finer grade of filter media than specified.

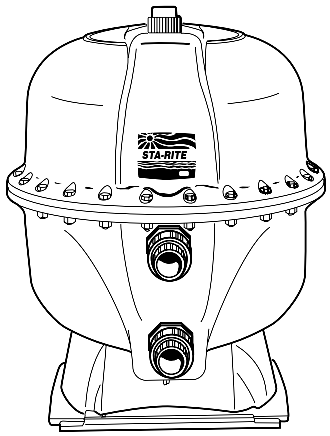


FILTER MEDIA FOR VERTICAL HI-RATE FILTERS

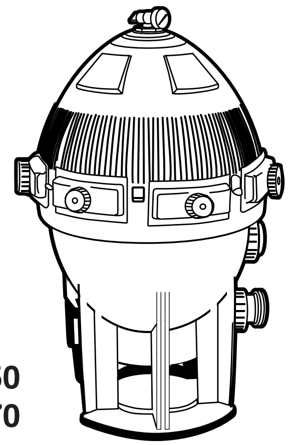
Sieve Analysis	
Grade #20 Silica Sand	
Tyler Sieve No.	% Retained
20	2
30	58
40	36
50	4
—	—
—	—
Effective Size –.45 mm Uniformity coefficient 1.5 maximum	

High Rate Sand Filters

HRPB and SYSTEM 3 Sand Filters



HRPB30



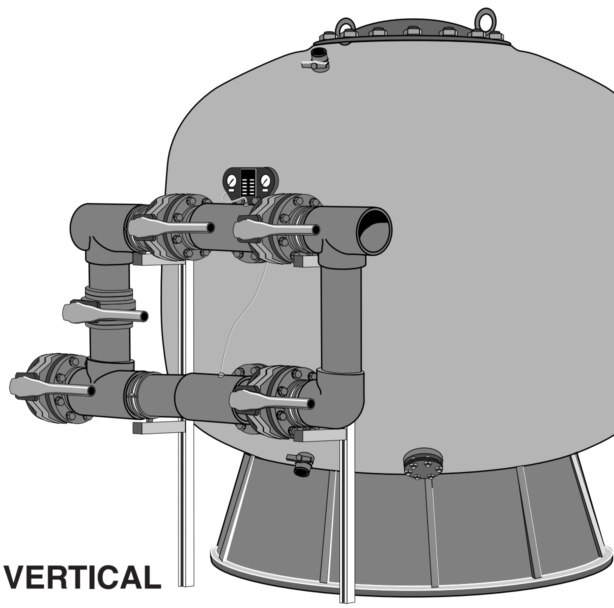
SYSTEM 3
Model S7S50
Model S8S70

RESIDENTIAL HI-RATE PERMANENT MEDIA FILTER RATE AND CAPACITY CHART

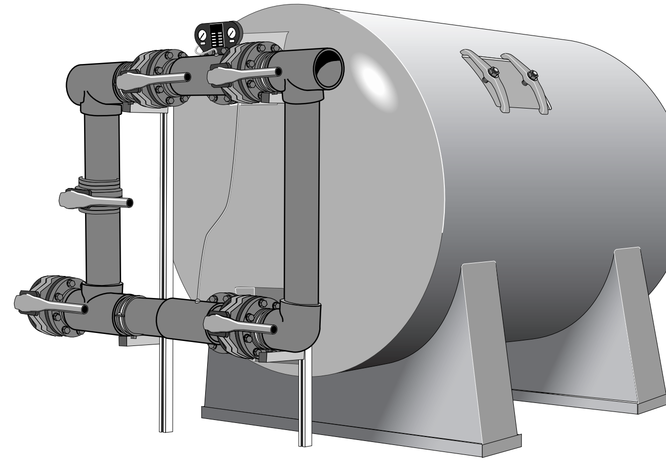
Model Number	Total Sq. Ft. of Filter Area	Flow Rate at 15 GPM per Sq. Ft. of Filter Area			Flow Rate at 20 GPM per Sq. Ft. of Filter Area		
		GPM	GP 6 Hours	GP 8 Hours	GPM	GP 6 Hours	GP 8 Hours
S7S50	2.4	36	12,960	17,800	–	–	–
		–	–	–	48	17,280	23,040
S8S70	3.4	51	18,360	24,480	–	–	–
		–	–	–	68	24,480	32,640
HRPB30	4.9	74	26,640	35,520	–	–	–
		–	–	–	98	35,280	47,040

Model Number	No. of Units	Filter Area Sq. Ft.	Flow Rate		Turnover Rate		Manifold Pipe Size	7 f.p.s. GPM	Silica Sand
			15 GPM	20 GPM	6 Hours	8 Hours			
HRPB30	2	9.8	147	–	52,920	70,560	3”	441	800
			–	196	70,560	94,080	3”	588	
	3	14.7	220.5	–	79,380	105,840	4”	662	1200
			–	294	105,840	141,120	4”	882	
	4	19.6	394	–	105,840	141,120	4”	882	1600
			–	392	141,120	188,160	4”	1,176	
	5	24.5	367.5	–	132,300	176,400	6”	1,103	2000
			–	480	176,400	235,200	6”	1,440	
	6	29.4	441	–	158,760	211,680	6”	1,323	2400
			–	588	211,680	282,240	6”	1,764	
	7	34.3	514.5	–	185,220	246,960	6”	1,544	2800
			–	686	246,960	329,280	6”	2,058	
	8	39.2	588	–	211,680	282,240	6”	1,764	3200
			–	784	282,240	376,320	6”	2,352	
SR-300-2U	1	4.9	74	–	26,640	35,520	2”	74	550
			–	98	35,280	47,040	2-1/2”	105	
SR-360-2U	1	7.1	106	–	38,160	50,880	2-1/2”	105	875
			–	142	51,120	68,160	3”	165	
SR-360-3T	1	7.1	106	–	38,160	50,880	2-1/2”	105	875
			–	142	51,120	68,160	3”	165	

NOTES: Recommended flow rate – 15 gpm per sq. ft. of filter area.
Recommended Velocity of Schedule 40 Rigid PVC Pipe is 7 fps. Check local codes.
100 lbs. of #20 Silica Sand is one bag. 1 bag is approximately 1 cu. ft.
Backwash Gallons is based on minimum of 3 minutes in the backwash cycle.



VERTICAL



HORIZONTAL

FILTER CAPACITY – VERTICAL

Catalog Number	Sq. Ft. of Filter Area	15 GPM per Sq. Ft. Rate	20 GPM per Sq. Ft. Rate	Gallons per 4 Hours	Gallons per 6 Hours	Gallons per 8 Hours
21603-1042	9.26	139	–	33,360	50,040	66,720
		–	186	44,640	66,960	89,280
21603-1047	12.17	182	–	43,680	65,820	87,360
		–	244	58,560	87,840	117,120
21603-1055	16.56	249	–	59,760	89,640	119,520
		–	332	79,680	119,520	159,360
21603-1063	21.63	325	–	78,000	50,040	66,720
		–	432	44,640	117,000	156,000
21603-1071	27,38	410	–	98,400	149,600	196,800
		–	546	131,040	176,560	262,080
21603-1079	33.80	507	–	121,680	182,520	243,360
		–	676	162,240	243,360	324,470
21603-1093	46.72	701	–	168,240	252,360	336,480
		–	934	224,160	336,240	448,320

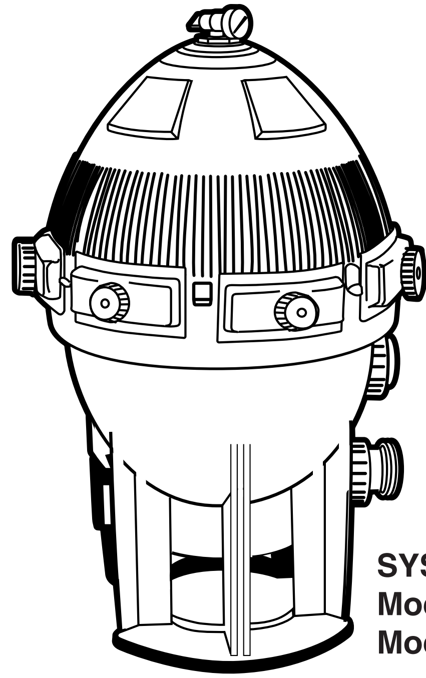
NOTE: Filter Media and pumping equipment ARE NOT included with filter tanks.
ENGINEERING NOTES: The Vertical Hi-Rate Filter(s) should be backwashed when a 15 P.S.I.G. (104 to 117 kPa) differential is indicated on the influent and effluent pressure gauges.
When sizing the main recirculating pump for the Vertical Hi-Rate Filter(s), calculate head loss for maximum dirt load at 15 to 20 P.S.I.G. (104 to 138 kPa) through the filter and face piping.

FILTER CAPACITY – HORIZONTAL

Catalog Number	Sq. Ft. of Filter Area	15 U.S. GPM per Sq. Ft. Rate	U.S. Gals. Per 4 Hours	U.S. Gals. Per 6 Hours	U.S. Gals. Per 8 Hours	Face Piping Size (I.P.S.)	Lbs. #20 Filter Sand Required	Approx. Shipping Wt. Lbs.
24601-36143	14.3	215 GPM	51,600	77,400	103,200	N/A	2,300	630
24601-36173	17.3	260 GPM	62,400	93,600	124,800	N/A	2,800	740
24601-36203	20.3	305 GPM	73,200	109,800	146,400	N/A	2,600	830

* For other sizes call for quote.

Modular Media for Commercial Applications



SYSTEM 3
Model S7M120
Model S8M150

Model Number	No. of Tanks	Filter Area Sq. Ft.	Filter Capacity at Max. Flow Rate GPM	6 Hours	8 Hours	Flow Rate*	Dirt Loading Capacity in Lbs.	Filter Dimensions in Inches: Tank Width	Service Width	Tank Height	Service Height
S7M120	1	300	100	36,000	48,000	.333	35	28.5	36	42	68
	2	600	200	72,000	96,000		70				
	3	900	300	108,000	144,000		105				
	4	1,200	400	144,000	192,000		140				
	5	1,500	500	180,000	240,000		175				
	6	1,800	600	216,000	288,000		210				
	7	2,100	700	252,000	336,000		245				
	8	2,400	800	288,000	384,000		280				
S8M150	1	450	125	45,000	60,000	.278	55	32.5	40	42.25	68
	2	900	250	90,000	120,000		110				
	3	1,350	375	135,000	180,000		165				
	4	1,800	500	180,000	240,000		220				
	5	2,250	625	225,000	300,000		275				
	6	2,700	750	270,000	360,000		330				
	7	2,100	875	312,000	420,000		385				
	8	2,400	1,000	360,000	480,000		400				

* Flow rate at maximum GPM per square foot of filter area.

Head Loss Charts

Component	GPM	Head Loss (Ft.)	Component	GPM	Head Loss (Ft.)
Main drain 1-1/2" Outlet	20 30 40 50 60	0.5 1.0 1.5 2.0 2.5	Skimmer 1-1/2"	20 30 40 50 60	1.0 2.0 3.0 4.0 5.5
Main drain 2" Outlet	40 50 60 70 80	1.0 1.5 2.0 3.0 4.0	Skimmer 2" Outlet	20 30 40 50 60 70 80	0.5 1.0 2.0 3.0 4.0 5.0 6.0
Heater	–	7.0 Average			
Backwash Valves					
1-1/2" Push/Pull	50 75	6.0 13.5	1-1/2" Multiport	50 75	5.0 10.0
2" Push/Pull	75 120	7.0 17.6	2" Multiport	75 100 120	3.5 6.0 8.5

Cartridge Filters	GPM (.75)	Head Loss (Ft.)	GPM (.375)	Head Loss (Ft.)
25 sq. ft.	18.75	1.1	9.38	7.0 Average
35 sq. ft.	26.25	2.0	13.13	7.0 Average
50 sq. ft.	37.50	4.3	18.75	7.0 Average
70 sq. ft.	52.50	7.5	26.25	7.0 Average
75 sq. ft.	56.25	8.0	28.13	7.0 Average
100 sq. ft.	75.00	17.5	37.50	7.0 Average
135 sq. ft.	101.25	28.0	50.63	7.0 Average

Sand Filters	GPM (20)	Head Loss (Ft.)	GPM (15)	Head Loss (Ft.)
14" 1.05 sq. ft.	21.0	10 (est.)	15.8	7.0 Average
16" 1.41 sq. ft.	28.2	12 (est.)	21.2	7.0 Average
18" 1.80 sq. ft.	36.0	14 (est.)	27.0	7.0 Average
20" 2.20 sq. ft.	44.0	16	33.0	7.0 Average
22" 2.66 sq. ft.	53.2	18 (est.)	39.9	7.0 Average
24" 3.10 sq. ft.	63.0	25	46.5	7.0 Average
30" 4.90 sq. ft.	98.0	17	73.5	7.0 Average
36" 7.10 sq. ft.	142.0	24 (est.)	106.5	7.0 Average

Modular Media Filters	GPM	Head Loss (Ft.)	GPM (.375)	Head Loss (Ft.)
100 sq. ft. "Mini Mods."	75	6.0	38	1.5
125 sq. ft. "Mini Mods."	94	9.0	47	2.5
150 sq. ft. "Mini Mods."	113	12.0	56	3.5
175 sq. ft. "Mini Mods."	131	16.0	66	4.5
200 sq. ft. "Mini Mods."	150	20.0	75	6.0
300 sq. ft. "Mini Mods."	150	20.0	113	13.0

Modular Media Filters	GPM (NSF)	Head Loss (Ft.)
200 sq. ft. - System3	100	3.0
400 sq. ft. - System3	115	4.6
450 sq. ft. - System3	124	5.5
500 sq. ft. - System3	130	6.3

Modular D.E. Filters	GPM (1.5)	Head Loss (Ft.)	GPM (NSF)	Head Loss (Ft.)
36 sq. ft.	54	5.5	70	9.0
60 sq. ft.	90	7.0	120	13.0
72 sq. ft.	108	10.0	144	18.0

Head Loss Charts

EXIT LOSS CHARTS

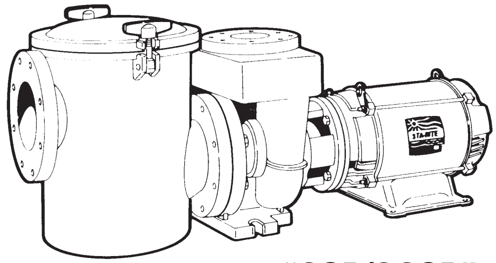
3/8" (.375 ID)		
GPM	Velocity FPS	Exit Head (Ft.)
1	2.91	.13
2	5.81	.53
3	8.71	1.18
4	11.62	2.10
5	14.53	3.28
6	17.43	4.72
7	20.34	6.43
8	23.24	8.40
9	26.15	10.63
10	29.05	13.12

1/2" (.50 ID)		
GPM	Velocity FPS	Exit Head (Ft.)
5	8.17	1.04
6	9.80	1.49
7	11.44	2.03
8	13.07	2.66
9	14.71	3.36
10	16.34	4.15
11	17.98	5.02
12	19.61	5.98
13	21.24	7.02
14	22.88	8.14
15	24.51	9.34
16	26.15	10.63
17	27.78	12.00
18	29.41	13.45
19	31.05	14.99
20	32.68	16.61

3/4" (.75 ID)		
GPM	Velocity FPS	Exit Head (Ft.)
5	3.63	.21
6	4.36	.30
7	5.08	.41
8	5.81	.53
9	6.54	.67
10	7.27	.82
11	7.99	.99
12	8.72	1.18
13	9.44	1.39
14	10.17	1.61
15	10.89	1.85
16	11.62	2.10
17	12.35	2.37
18	13.07	2.66
19	13.80	2.96
20	14.53	3.28
21	15.25	3.62
22	15.98	3.97
23	16.70	4.34
24	17.43	4.72
25	18.16	5.13
26	18.88	5.54
27	19.60	5.98
28	20.34	6.43
29	21.06	6.90
30	21.79	7.38

7/8" (.875 ID)		
GPM	Velocity FPS	Exit Head (Ft.)
10	5.34	.44
11	5.87	.54
12	6.40	.64
13	6.94	.75
14	7.47	.87
15	8.00	1.00
16	8.54	1.13
17	9.07	1.28
18	9.60	1.43
19	10.14	1.60
20	10.67	1.77
21	11.21	1.95
22	11.74	2.14
23	12.27	2.34
24	12.81	2.55
25	13.34	2.77
26	13.87	2.99
27	14.41	3.23
28	14.94	3.47
29	15.47	3.72
30	16.01	3.98
31	16.54	4.25
32	17.08	4.53
33	17.61	4.82
34	18.14	5.11
35	18.68	5.42
36	19.21	5.74
37	19.74	6.06
38	20.28	6.39
39	20.81	6.73
40	21.34	7.08

1.0" (1.0 ID)								
GPM	Velocity FPS	Exit Head (Ft.)	GPM	Velocity FPS	Exit Head (Ft.)	GPM	Velocity FPS	Exit Head (Ft.)
15	6.13	.58	27	11.03	1.89	39	15.93	3.95
16	6.54	.66	28	11.44	2.03	40	16.34	4.15
17	6.95	.75	29	11.85	2.18	41	16.75	4.36
18	7.35	.84	30	12.26	2.34	42	17.16	4.58
19	7.76	.94	31	12.66	2.49	43	17.57	4.80
20	8.17	1.04	32	13.07	2.66	44	17.98	5.02
21	8.58	1.14	33	13.48	2.83	45	18.38	5.25
22	8.99	1.26	34	13.89	3.00	46	18.79	5.49
23	9.40	1.37	35	14.30	3.18	47	19.20	5.73
24	9.81	1.50	36	14.71	3.36	48	19.61	5.98
25	10.21	1.62	37	15.12	3.55	49	20.02	6.23
26	10.62	1.75	38	15.52	3.75	50	20.43	6.49

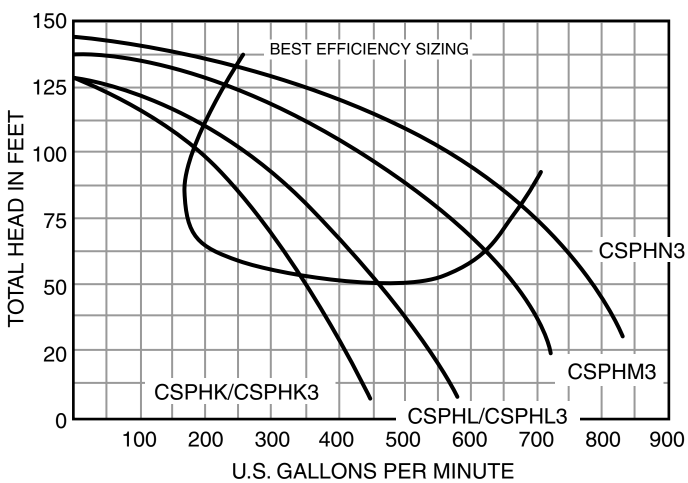


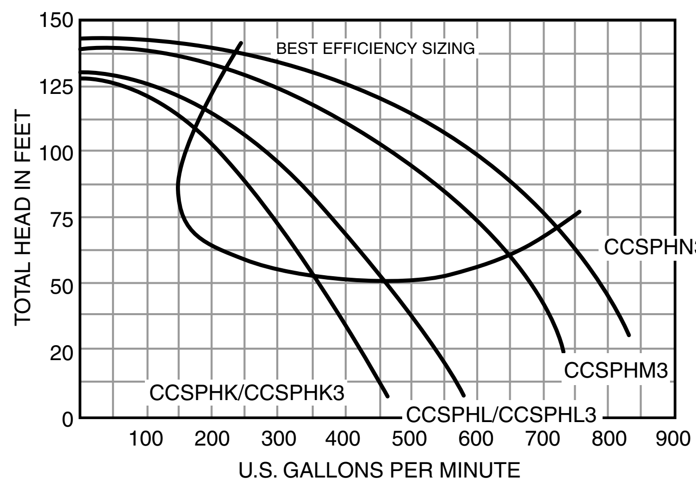
“CSP/CCSP”

COMMERCIAL SELF-PRIMING PUMP

- Especially designed for commercial/public swimming pools or spas where very high performance and self-priming characteristics are desired.
- Oversized hair and lint strainer for large debris capacity.
- Rugged cast iron construction with bronze impellers.
- “CC” models also available with specially coated trap and volute for maximum hydraulic performance and corrosion prevention.
- Available in 7-1/2, 10, 15 and 20 horsepower models.

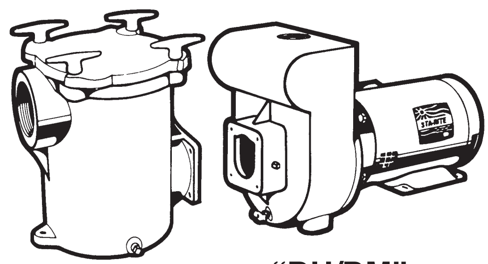
PUMP PERFORMANCE (WITH TRAP INSTALLED)



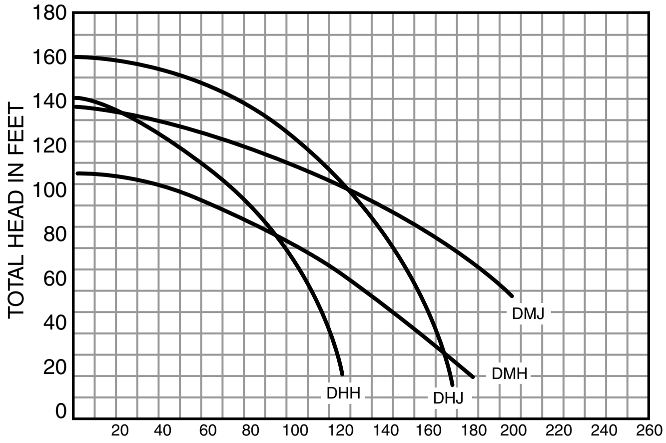


CAST IRON SELF-PRIMING COMMERCIAL POOL PUMP

- Especially suited for commercial/public pools and spas where high performance and self-priming characteristics are desired.
- Available in medium head and high head models.
- Diffuser design assures high efficiency, rapid re-priming, and high suction lift capabilities.
- Rugged cast iron construction and bronze impellers.
- Consult Sta-Rite for a complete listing of certifications and approvals.



“DH/DM”



Type "B" Centrifugal Pumps

MOTOR DRIVE

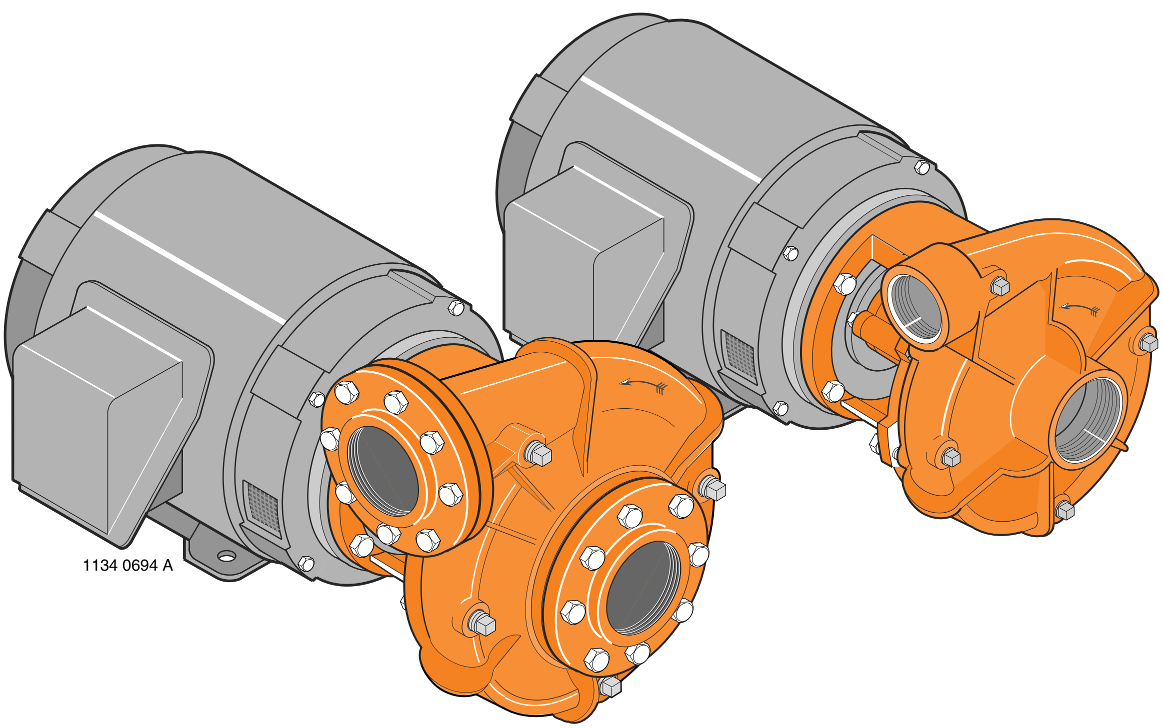
Berkeley Type "B" centrifugal pumps are back pull-out design. Removal of easily accessible bolts permit access to the impeller without disturbing the piping. These motor driven pumps are ideal for most industrial and agricultural installations that require high performance, easy maintenance and moderate initial cost.

Sizes: Tapped Discharge – 1 inch through 3 inches NPT;
Flanged Discharge – 4 inches through 10 inches.
Capacitites to 5000 gallons per minute; Heads to 500 feet.

See Centrifugal Accessories for additional components needed to make a complete installation.

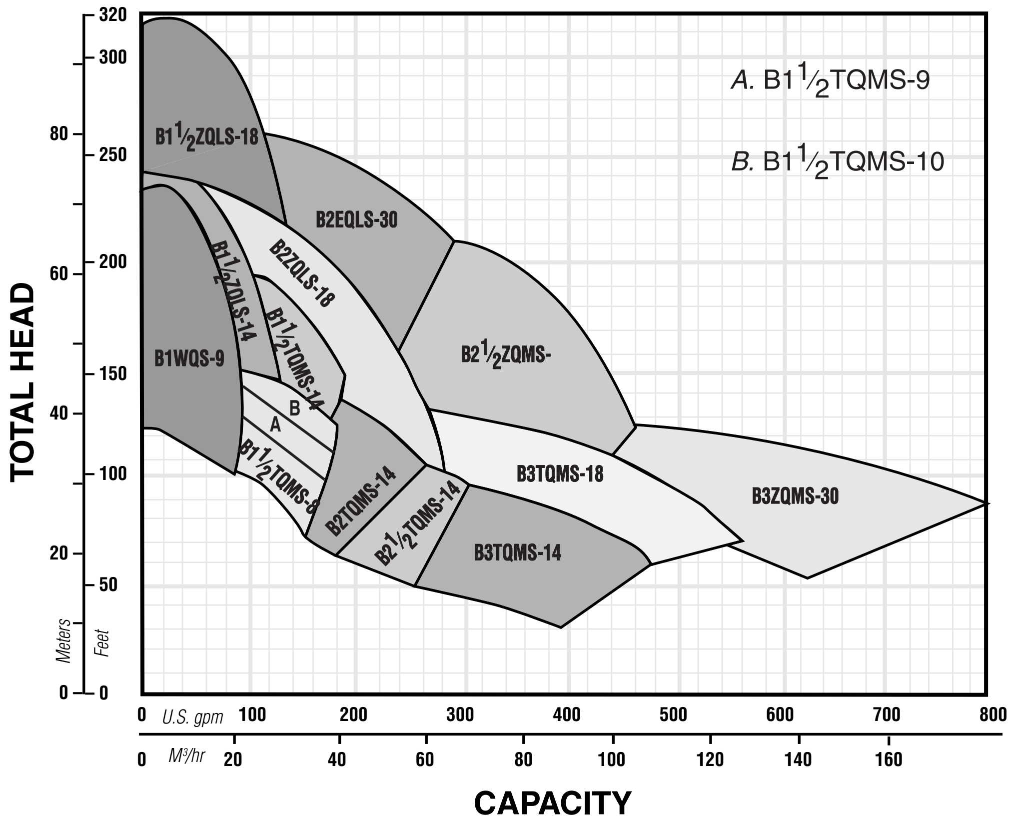
Features

1. **VOLUTE CASE** – Precision machined gray cast iron, engineered to modern hydraulic standards. Discharge may be rotated to any of four positions for convenience in piping.
2. **BRACKET** – Heavy cast iron bracket maintains positive shaft alignment between motor and impeller.
3. **IMPELLER** – Enclosed type impeller is balanced to provide smooth operation. Impeller is keyed to shaft and locked with special cap screw and washer.
4. **SHAFT SEAL** – Extra deep stuffing box with adjustable gland is standard and provides extra protection against leakage, prolongs shaft life. The shaft is protected through the stuffing box by a stainless steel sleeve. Rotary mechanical seals are available. The mechanical seal unit is identified by the letter "S" at the end of the model number.
5. **MOTOR** – NEMA standard close coupled pump motors available at 1180, 1760 and 3450 RPM. Entire rotating element of the pump is built directly on the motor shaft, minimizing shaft over-hang and assuring positive alignment. Incorporation of slinger ring provides extra protection for motor bearings. Special motor constructions are available to meet specific requirements.



End-Suction Centrifugal Pumps

COMPOSITE PUMP CURVES

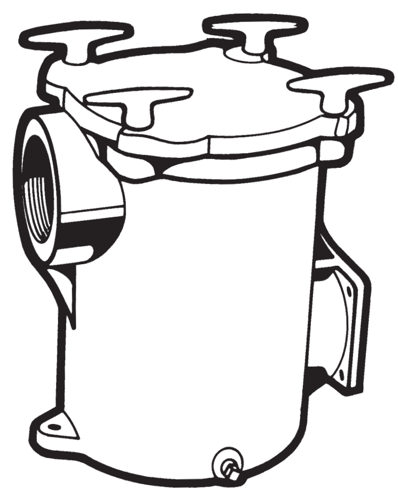


Hair and Lint Traps

For Commercial Pumps

- Bronze or Cast Iron
- 6", 8", 9-1/2" or 11" Trap Diameters

6" Cast Iron or Bronze Trap
(Pkg. 51/56/94)

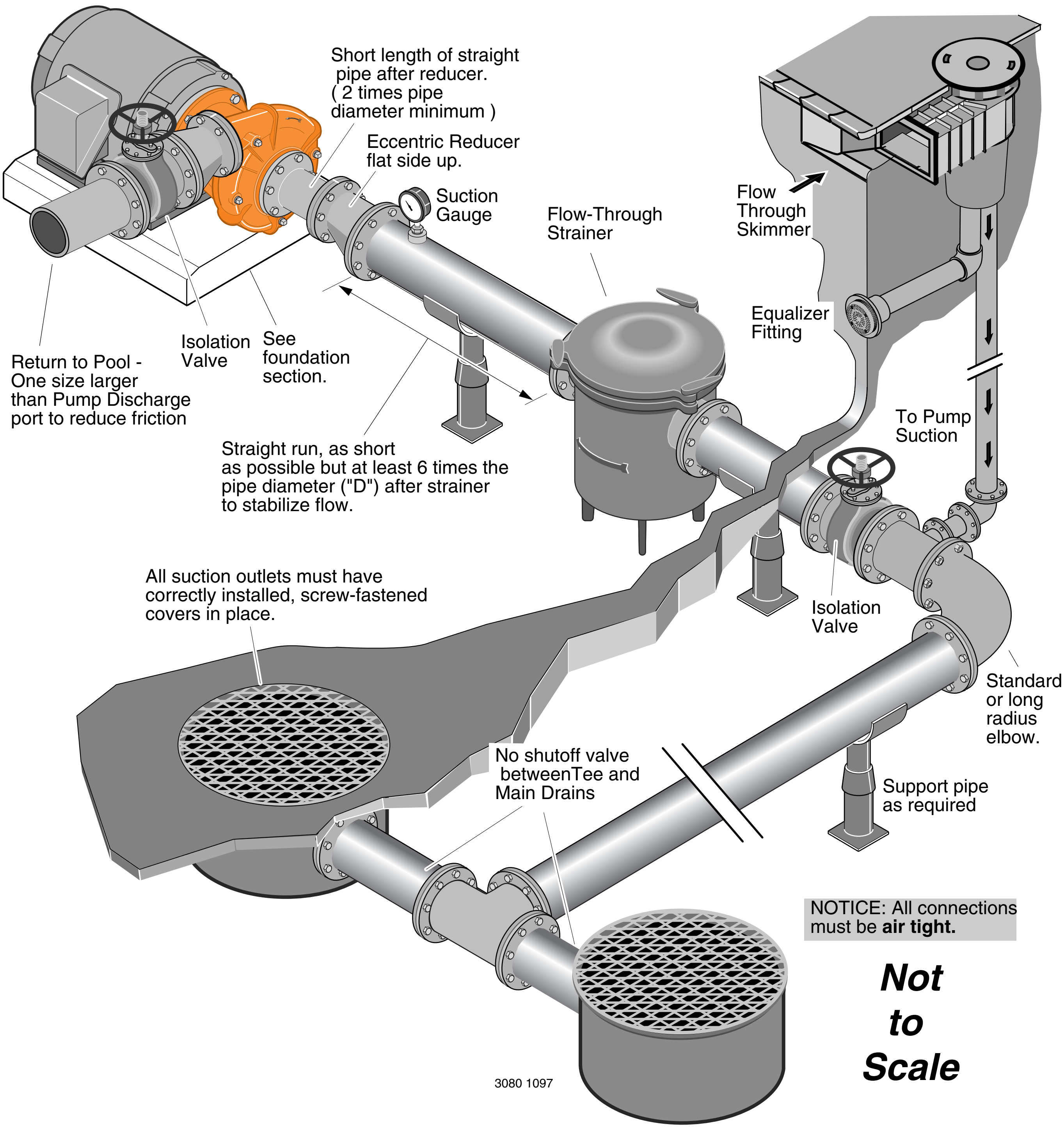


8" Cast Iron or Bronze Trap
(Pkg. 98/99)

Package No.	Description	Suction Port Size	Ship Wt. (lbs.)
51	6" Cast Iron Trap with Basket	2" NPT	20
56	6" Bronze Trap with Basket	2" NPT	20
98	8" Cast Iron Trap with Basket	3" NPT	40
99	8" Bronze Trap with Basket	3" NPT	40
76	Cast Iron Flange for a Remote Installation of 8" Trap	3" NPT	4
74	11" Cast Iron Trap with Basket	3" NPT	65
184	1100 cu. in. Hair & Lint Strainer	6" Flange	180
184C	1100 cu. in. Hair & Lints Strainer (coated)	6" Flange	180

Installation Considerations

ARRANGEMENT RECOMMENDED



LOCATION OF UNIT

The pump unit should be located as near the source of water as practical to minimize the vertical lift of water to the pump and so that a short, direct suction pipe with a minimum number of fittings can be used to keep the pipe friction energy loss as low as possible.

Both the suction and discharge pipes should be naturally aligned with the pump and independently supported near the inlet and discharge flanges to prevent strain on the pump case.

The pump unit must be adequately supported to prevent movement during operation.

The motor feet should be mounted on an elevated pad, 3 to 4 inches high, to prevent water from accumulating under the motor air intake openings.

SUCTION PIPING

General

TYPE – Use pipe, tubing or wire-reinforced hose with sufficient strength to resist collapse under atmospheric pressure differential. All joints must be air tight.

SUCTION PIPE SIZE – Satisfactory operation will depend on control of pipe friction loss within acceptable limits. The minimum size of suction pipe to be used can be determined by a comparison of NPSH AVAILABLE at the pump inlet, against the NPSH REQUIRED by the impeller, as shown on the pump performance curve (for details on procedure for NPSH comparisons, see Berkeley Pump Company, Engineering Spec. 0307, which is available on request).

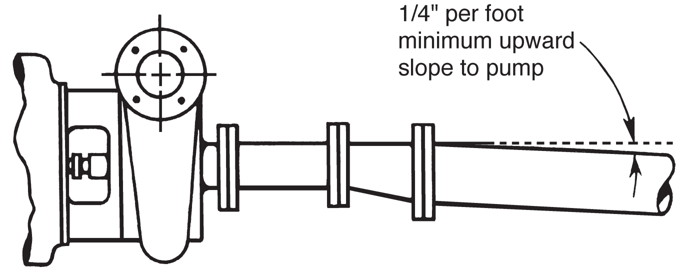
Generally, satisfactory results will be obtained when the average flow velocity is less than 10 feet/second which may require that the suction pipe be larger than the suction opening of the pump.

⚠ CAUTION Local conditions (elevation above sea level, suction lift elevation, vapor pressure of liquid, etc.) may require a reduction of velocity by increasing pipe size.

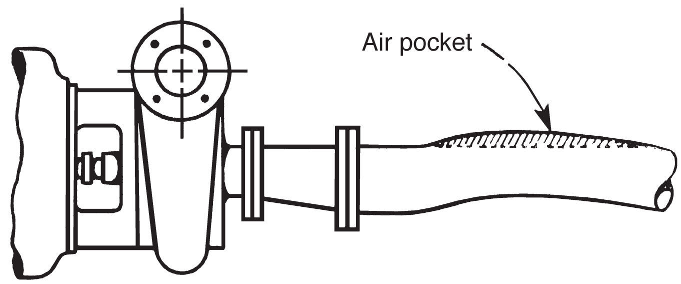
Suction Lift

SUCTION PIPE SLOPE – All suction piping must have a continuous rise to the pump suction inlet.

RECOMMENDED



NOT RECOMMENDED



SUCTION STRAINER – A screen assembly attached to the inlet end of the suction pipe to exclude objects too large to pass thru the pump. The strainer should have a free, open area of at least three times the area of the suction pipe. A strainer is often combined with a foot valve to retain the prime when the pump is stopped.
NOTE: If great amounts of solid material can occur in the liquid as it approaches the pump suction pipe, then one or more stages of prescreening may be necessary in addition to the suction strainer.

MAIN DRAIN OUTLETS

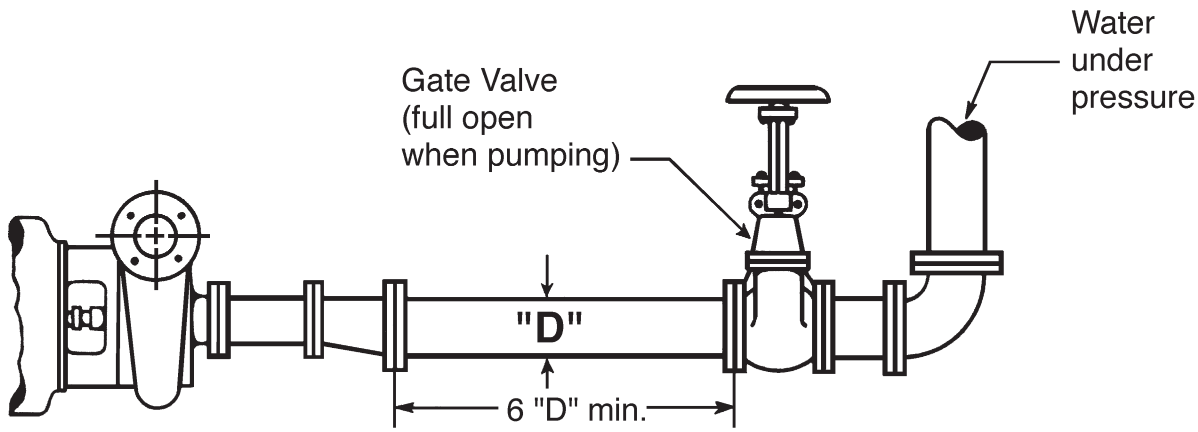
8" Round Grate – Sta-Rite No. 07017-0751 – Open Flow Area = 19.5 sq. in.										
Flow (gpm)	40	60	80	100	120	140	160	180	200	220
Velocity (ft./sec.)	.66	.99	1.32	1.65	1.97	2.30	2.63	2.96	3.30	3.62
v = gpm x .01645	IAPMO Listed Maximum Flow Rate = 80 GPM									
8" Round Anti-Vortex Plate – Sta-Rite No. 07017-0741 – Open Flow Area = 8.7 sq. in.										
Flow (gpm)	40	60	80	100	120	140	160	180	200	220
Velocity (ft./sec.)	1.48	2.21	2.95	3.69	4.42	5.15	5.90	6.64	7.38	8.12
v = gpm x .0369	IAPMO Listed Maximum Flow Rate = 60 GPM									
12" x 12" Square Grate – Open Flow Area = 37.5 sq. in.										
Flow (gpm)	50	100	150	200	250	300	350	400	500	700
Velocity (ft./sec.)	.43	.86	1.28	1.71	2.14	2.57	3.00	3.42	4.28	6.00
v = gpm x .00855	Maximum Recommended Flow Rate = 175 GPM									
18" x 18" Square Grate – Open Flow Area = 104.8 sq. in.										
Flow (gpm)	100	200	300	400	500	600	700	800	900	1,000
Velocity (ft./sec.)	.31	.61	.92	1.22	1.53	1.84	2.14	2.45	2.76	3.06
v = gpm x .003061	Maximum Recommended Flow Rate = 490 GPM									

Installation Considerations

FLOODED SUCTION

A gate valve is used in a pressurized suction pipe as an isolation valve to permit servicing the pump. Use a bleed valve on top of the pump volute case to allow trapped air to escape.

RECOMMENDED



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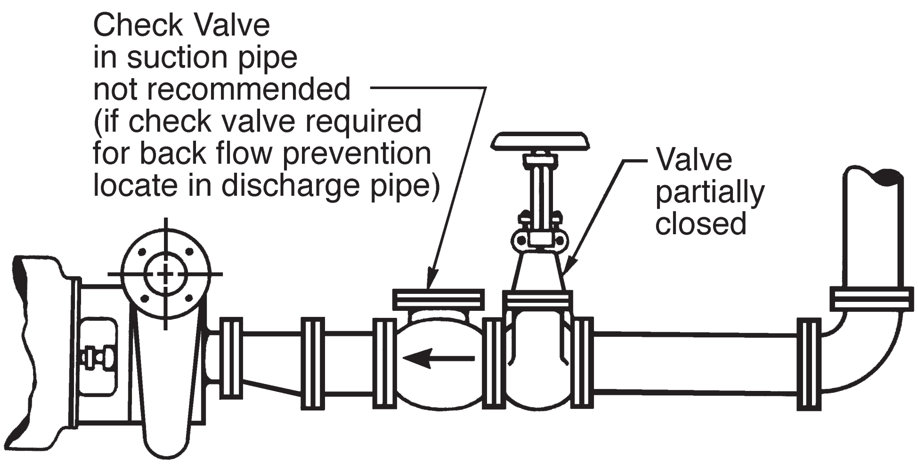


DISCHARGE PIPING

TYPE – Use pipe, tubing or hose with sufficient strength to contain the highest anticipated operating pressure.

DISCHARGE PIPE SIZE – Because of the increasingly high cost of the additional energy necessary to overcome the larger friction losses of small pipe, the discharge pipe size is commonly one or more nominal pipe sizes larger than the discharge opening of the pump.

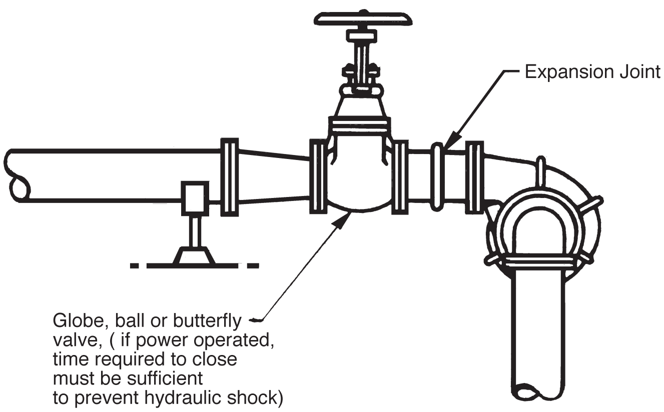
To determine the optimum size of the discharge pipe, compare the total cost of the operating system (sum of the pump with driver control, plus the cost of the pipe, plus the cost of the power projected for the term of operation), for several adjacent pipe sizes.

The number of pipe fittings (elbows, tees, etc.) should be kept to a minimum to avoid needless energy loss.

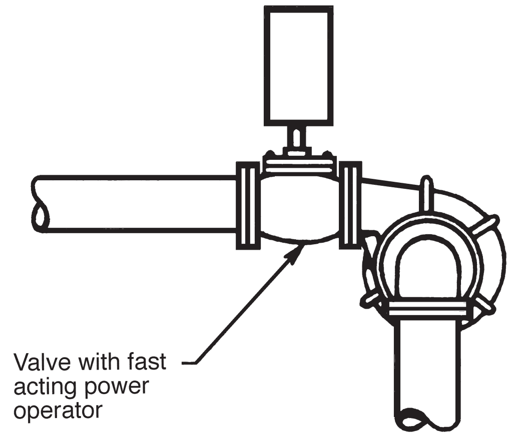
PIPE ALIGNMENT – Piping and fittings must be naturally aligned with the pump openings and independently supported to prevent strain on the pump and driver unit. If necessary, restrain piping system and/or provide expansion joints to protect pump unit against excessive thermal or pressure growth forces.

DISCHARGE FLOW CONTROL VALVE – For throttling of discharge for flow rate control.

RECOMMENDED

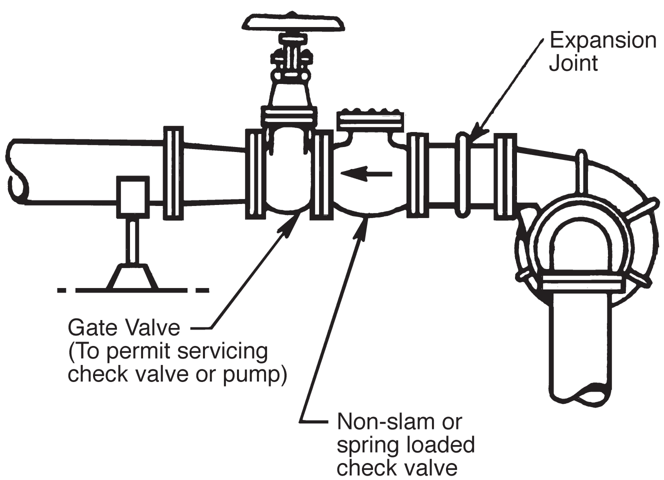


NOT RECOMMENDED

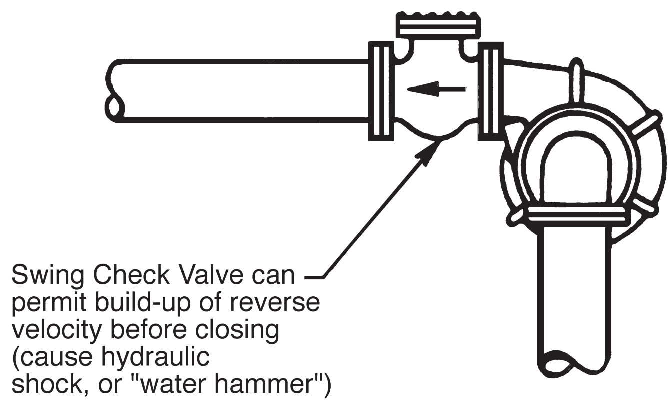


DISHCARGE CHECK VALVE – To prevent back flow through the pump during operation.

RECOMMENDED

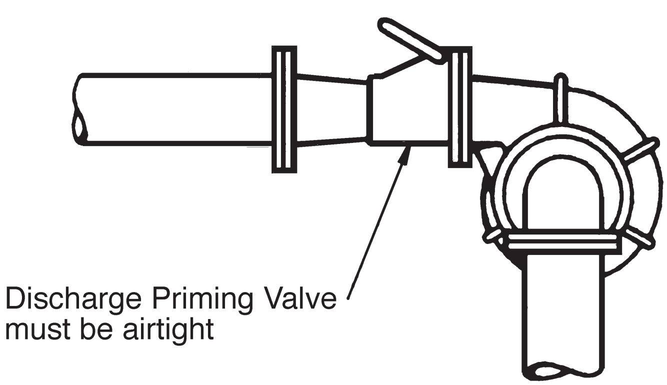


NOT RECOMMENDED



DISCHARGE PRIMING VALVE – Isolates pump case from atmosphere during air evacuation type priming.

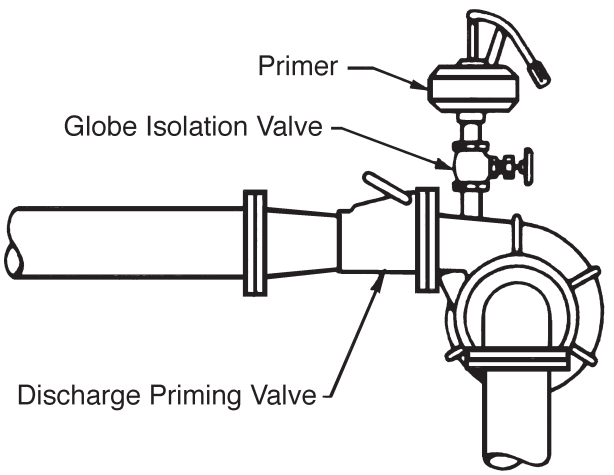
RECOMMENDED



PRIMER CONNECTIONS

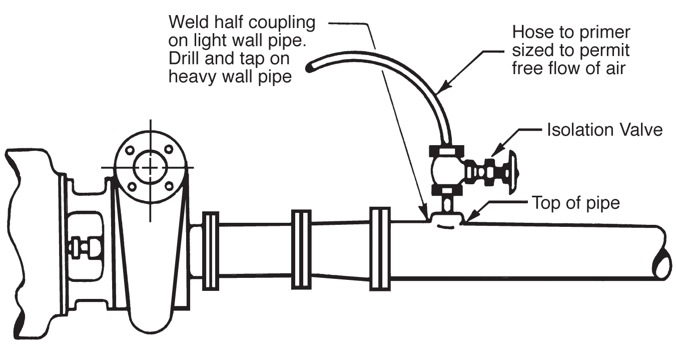
PUMP NOT RUNNING

RECOMMENDED

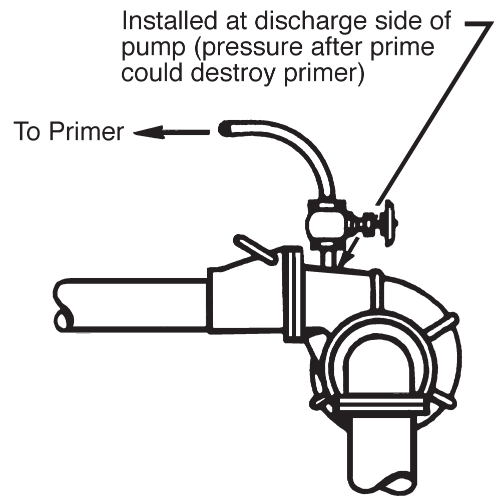


PUMP RUNNING – As with engine drive with exhaust primer or intake manifold vacuum primer.

RECOMMENDED



NOT RECOMMENDED



COLD WEATHER/WET WEATHER INSTALLATIONS

SYSTEM DRAINS – Provide drain valves to empty system, including pump case, to prevent freezing damage.

SHELTER - If possible, provide shelter for unit to protect from weather. Allow adequate space around pump unit for service. When effectively sheltered, a small amount of heat will keep temperature above freezing. Provide adequate ventilation for unit when running. For severe weather problems, where other shelter is not practical, a totally enclosed fan-cooled enclosure can be considered for electric motors.

CONDENSATION – When the temperature of metal parts is below dew point and the surrounding air is moist, water will condense on the metal surfaces and can cause corrosion damage. In severe situations, a space heater can be considered to warm the unit.

Natural Gas Heater Sizing

Initial Heat Up – BTU Required - 24 Hrs

Temperature Rise:	10°	15°	20°	25°	30°
Pool Size Sq. Ft.	**Heat Loss = Required Heater Output (BTUs/Hour)**				
200	55,900	83,800	111,840	139,800	167,760
300	83,880	125,820	127,760	209,700	251,640
400	111,850	167,775	223,700	279,625	335,550
500	139,810	209,715	279,620	349,525	419,430
600	167,770	251,655	335,540	419,435	503,310
700	195,720	293,595	391,460	489,325	587,190
800	223,690	335,535	447,380	559,225	671,070
900	251,650	377,475	503,300	629,125	754,950
1000	279,610	419,415	559,220	699,025	838,830

Note: Chart prepared by the Commercial Water Heating Sub-committee of the American Gas Association in Oct. 1995.

BTU Required to Maintain Temperature

Temperature Rise:	10°	15°	20°	25°	30°
Pool Size Sq. Ft.	**Heat Loss = Required Heater Output (BTUs/Hour)**				
200	21,000	31,500	42,000	52,500	63,000
300	31,500	47,250	63,000	78,750	94,500
400	42,000	63,000	84,000	105,000	126,000
500	52,500	78,750	105,000	131,250	157,500
600	63,000	94,500	126,000	157,500	189,000
700	73,500	110,250	147,000	183,750	220,500
800	84,000	126,000	168,000	210,000	252,000
900	94,500	141,750	189,000	236,250	283,500
1000	105,000	157,500	210,000	262,500	315,000

Note: Outdoors, 3.5 mph Wind.
Note: Chart prepared by the Commercial Water Heating Sub-committee of the American Gas Association in Oct. 1995.

Spa Heater Sizing – Recommended Max-E-Therm Model

	Minutes for 30° F Temperature Rise (Heater Input In 1000 BTU/HR)		
Spa Volume (Gallons)	**SR200NA**	**SR333NA**	**SR400NA**
200	18	11	9
300	27	16	13
400	35	21	18
500	44	27	22
600	53	32	27
700	62	37	31
800	71	43	35
900	80	48	40
1000	89	53	44

Note: The chart is based on a 30° F temperature rise, discounting losses and only based on heat requried to raise temperature in minutes.

Formulas:

Initial Heat Up in a 24 Hour Period
Gallons x 8.33 x Temp Rise = BTU x 24 hrs
= Total BTU's Required

Maintaining Temperaure
Using the chart at the upper right, determine the heat loss to maintain the desired temperature rise. Then, divide the heat loss BTU's by the heater efficiency.
126,000 BTU ÷ 80% = 157,500 BTU (Heater Size)

Heater Efficiencies

Input x % Efficiency

Heater Input BTU/Hr	Heater Output (BTU/Hr) 70%	75%	80%	85%	90%
100,000	70,000	75,000	80,000	85,000	90,000
200,000	140,000	150,000	160,000	170,000	180,000
300,000	210,000	225,000	240,000	255,000	270,000
400,000	280,000	300,000	320,000	340,000	360,000

Hydraulic Charts and Tables

Low Pressure Natural Gas & Propane Gas Pipe Size

Heater Size Impute BTU	0-50'	Pipe Size 51-100'	100-200'	200-300'
100,000	3/4"	3/4"	1'	1¼"
200,000	1¼"	1¼"	1½"	1½"
300,000	1¼"	1¼"	1½"	1½"
400,000	1¼"	1½"	1½"	1½"

Natural Gas Consumption Meter

BTU	RPM	CFM	CFH
100,000	3.3	1.67	100
150,000	5.0	2.50	150
200,000	6.7	3.34	200
250,000	8.3	4.17	250
300,000	10.0	5.00	300
350,000	11.7	5.84	250
400,000	13.3	6.67	400

Note: Each revolution of the 'half cubic foot dial needle' = 1/2 cubic foot of gas.
RPM - 1 RPM = .5 CUBIC FEET
CMF = CFM / 60 minutes
CFH = BTU / 1,000
BTU = CFH (1000) APPROXIMATELY

Ventilation Requirements – Indoors

Heater Size	Top Of Room	Bottom Of Room
100,000	100 Sq. In.	100 Sq. In.
150,000	150 Sq. In.	150 Sq. In.
200,000	200 Sq. In.	200 Sq. In.
250,000	250 Sq. In.	250 Sq. In.
300,000	300 Sq. In.	300 Sq. In.
350,000	350 Sq. In.	350 Sq. In.
400,000	400 Sq. In.	400 Sq. In.

Note: Ventilation requirements are in addition to any other device that needs ventilation, such as a pump motor.

Centigrade and Fahrenheit Equivalents

Degrees		Degrees		Degrees		Degrees		Degrees		Degrees		Degrees		Degrees	
C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
0	32.0	13	55.4	26	78.8	39	102.2	52	125.6	65	149.0	78	172.4	91	195.8
1	33.8	14	57.2	27	80.6	40	104.0	53	127.4	66	150.8	79	174.2	92	197.6
2	35.6	15	59.0	28	82.4	41	105.8	54	129.2	67	152.6	80	176.0	93	199.4
3	37.4	16	60.8	29	84.2	42	107.6	55	131.0	68	154.4	81	177.8	94	201.2
4	39.2	17	62.6	30	86.0	43	109.4	56	132.8	69	156.2	82	179.6	95	203.0
5	41.0	18	64.4	31	87.8	44	111.2	57	134.6	70	158.0	83	181.4	96	204.8
6	42.8	19	66.2	32	89.6	45	113.0	58	136.4	71	159.8	84	183.2	97	206.6
7	44.6	20	68.0	33	91.4	46	114.8	59	138.2	72	161.6	85	185.0	98	208.4
8	46.4	21	69.8	34	93.2	47	116.6	60	140.0	73	163.4	86	186.8	99	210.2
9	48.2	22	71.6	35	95.0	48	118.4	61	141.8	74	165.2	87	188.6	100	212.0
10	50.0	23	73.4	36	96.8	49	120.2	62	143.6	75	167.0	88	190.4	—	—
11	51.8	24	75.2	37	98.6	50	122.0	63	145.4	76	168.8	89	192.2	—	—
12	53.6	25	77.0	38	100.4	51	123.8	64	147.2	77	170.6	90	194.0	—	—

Friction/Flow Chart For Schedule 40 Rigid PVC Pipe

Friction Loss of Water in Feet per 100 Feet Length of Pipe
Based on Williams & Hazen Formula Using Constant 150. Sizes of Standard Pipe in Inches.

U.S. Gals. per Min.	¾" Pipe		1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe		4" Pipe		6" Pipe		U.S. Gals. per Min.
	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	
1	.60	.25	.37	.07	....	....	....	....	....	....	....	....	....	....	....	....	....	....	**1**
2	1.20	.90	.74	.28	.43	.07	....	....	....	....	....	....	....	....	....	....	....	....	**2**
3	1.80	1.92	1.11	.60	.64	.16	.47	.07	....	....	....	....	....	....	....	....	....	....	**3**
4	2.41	3.28	1.48	1.02	.86	.25	.63	.12	....	....	....	....	....	....	....	....	....	....	**4**
5	3.01	5.8	1.86	1.52	1.07	.39	.79	.18	....	....	....	....	....	....	....	....	....	....	**5**
6	3.61	7.0	2.33	2.15	1.29	.55	.95	.25	.57	.07	....	....	....	....	....	....	....	....	**6**
8	4.81	11.8	2.97	3.6	1.72	.97	1.25	.46	.76	.14	.54	.05	....	....	....	....	....	....	**8**
10	6.02	17.9	3.71	5.5	2.15	1.46	1.58	.69	.96	.21	.67	.09	....	....	....	....	....	....	**10**
15	9.02	37.8	5.57	11.7	3.22	3.07	2.36	1.45	1.43	.44	1.01	.18	.65	.07	....	....	....	....	**15**
20	....	....	7.42	19.9	4.29	4.2	3.15	2.47	1.91	.74	1.34	.30	.87	.12	....	....	....	....	**20**
25	....		9.28	30.0	5.36	7.9	3.94	3.8	2.39	1.11	1.67	.46	1.08	.16	....	....	....	....	**25**
30	....	**U.S.**	11.14	42.0	6.43	11.1	4.73	5.2	2.87	1.55	2.01	.65	1.30	.23	....	....	....	....	**30**
35	....	**GAL.**			7.51	14.7	5.52	7.0	3.35	2.06	2.35	.88	1.52	.30	.88	.07	....	....	**35**
40	....	**PER**	**8" PIPE**		8.58	18.9	6.30	8.9	3.82	2.63	2.64	1.11	1.73	.39	1.01	.09	....	....	**40**
45	....	**MIN.**			9.65	23.5	7.09	11.1	4.30	3.28	3.01	1.39	1.95	.48	1.13	.12	....	....	**45**
50	....	**700**	4.37	.66	10.72	28.5	7.88	13.5	4.78	4.0	3.35	1.69	2.17	.58	1.26	.16	....	....	**50**
60	....	**750**	4.70	.75	....	....	9.46	18.9	5.74	5.6	4.02	2.36	2.60	.81	1.51	.21	....	....	**60**
70	....	**800**	4.99	.82	....	....	11.03	25.1	6.69	7.4	4.69	3.14	3.04	1.09	1.76	.28	....	....	**70**
80	....	**850**	5.37	.95	....	....	....	....	7.65	9.5	5.35	4.0	3.47	1.39	2.02	.37	....	....	**80**
90	....	**900**	5.64	1.06	....	....	....	....	8.60	11.8	6.03	5.0	3.91	1.73	2.27	.46	....	....	**90**
100	....	**950**	5.94	1.23	....		....	....	9.56	14.4	6.70	6.1	4.34	2.10	2.52	.55	1.11	.07	**100**
125	....	**1000**	6.25	1.28	....	**U.S.**	....	....	11.95	21.8	8.38	9.2	5.42	3.19	3.15	.85	1.39	.12	**125**
150	....	**1050**	6.57	1.40	....	**GAL.**			....	....	10.05	12.8	6.51	4.5	3.78	1.18	1.67	.16	**150**
175	....	**1100**	6.89	1.51	....	**PER**	**10" PIPE**		....	....	....	....	7.59	5.9	4.41	1.57	1.94	.21	**175**
200	....	**1150**	7.20	1.65	....	**MIN.**			....	....	....	....	8.68	7.9	5.04	2.08	2.22	.28	**200**
225	....	**1200**	7.51	1.79	....	**1500**	5.99	.92	....	....	....	....	9.76	9.4	5.67	2.52	2.50	.35	**225**
250	....	**1250**	7.82	1.94	....	**1600**	6.40	1.03	....	....	....	....	10.85	11.5	6.30	3.05	2.78	.42	**250**
275	....	**1300**	8.13	2.09	....	**1700**	6.80	1.15	....	....	....	....	....	....	6.93	3.6	3.05	.48	**275**
300	....	**1350**	8.45	2.23	....	**1800**	7.20	1.27	....	....	....	....	....	....	7.56	4.3	3.33	.58	**300**
325	....	**1400**	8.77	2.37	....	**1900**	7.60	1.41	....	....	....	....	....	....	8.19	5.0	3.61	.67	**325**
350	....	**1450**	9.08	2.53	....	**2000**	7.99	1.54	....	....	....	....	....	....	8.82	5.7	3.89	.79	**350**
375	....	**1500**	9.39	2.68	....	**2100**	8.39	1.68	....	....	....	....	....	....	9.45	6.5	4.17	.88	**375**
400	....	**1550**	9.70	2.85	....	**2200**	8.80	1.82	....	....	....	....	....	....	10.08	7.3	4.44	.99	**400**
425	....	**1600**	10.00	3.01	....	**2300**	9.20	1.99	....	....	....	....	....	....	....	....	4.72	1.11	**425**
450	....	**1650**	10.32	3.21	....	**2400**	9.60	2.17	....	....	....	....	....	....	....	....	5.00	1.22	**450**
475	....	**1700**	10.64	3.40	....	**2500**	10.00	2.34	....	....	....	....	....	....	....	....	5.28	1.36	**475**
500	....	**1750**	10.96	3.59	....	**2600**	10.40	2.50	....	....	....	....	....	....	....	....	5.55	1.50	**500**
550	....	**1800**	11.27	3.78	....	**2700**	10.79	2.69	....	....	....	....	....	....	....	....	6.11	1.80	**550**
600	....	**1850**	11.58	3.98	....	**2800**	11.18	2.88	....	....	....	....	....	....	....	....	6.67	2.10	**600**
650	....	**1900**	11.89	4.19	....	**2900**	11.59	3.08	....	....	....	....	....	....	....	....	7.22	2.44	**650**
700	....	**1950**	12.21	4.40	....	**3000**	11.99	3.28	....	....	....	....	....	....	....	....	7.78	2.79	**700**
750	....	**2000**	12.52	4.61	....	**3100**	12.39	3.32	....	....	....	....	....	....	....	....	8.33	3.19	**750**
800	....	....	....	....	....	**3200**	12.79	3.35	....	....	....	....	....	....	....	....	8.89	3.6	**800**

Normal safe operating selection; ☐ Suction piping; ☐ Discharge or pressure piping.
Note: Where long pipe runs are encountered, make selection in minimum head loss range.

P.V.C. Pipe Specifications

PVC Pipe Size	Nominal Diameter (Inches)	Nominal Square Inch	Cubic Feet Water	Gallons Water/ Foot
0.5	0.622	0.303858694	0.00211013	0.01578
0.75	0.824	0.53326775	0.003703248	0.02770
1	1.049	0.864254945	0.00600177	0.04489
1.25	1.38	1.49571576	0.010386915	0.07769
1.5	1.61	2.03583534	0.014137745	0.10575
2	2.067	3.355612861	0.023302867	0.17431
2.5	2.469	4.787767769	0.033248387	0.24870
3	3.068	7.39267489	0.05133802	0.38401
4	4.026	12.73029413	0.08840482	0.66127
6	6.065	28.89033032	0.200627294	1.50069
8	7.961	49.77670499	0.345671562	2.58562
10	10.02	78.85447416	0.547600515	4.09605
12	11.938	111.9319439	0.777305166	5.81424

Friction/Flow Chart For Schedule 80 Rigid PVC Pipe

Friction Loss of Water in Feet per 100 Feet Length of Pipe

Based on Williams & Hazen Formula Using Constant 150. Sizes of Standard Pipe in Inches.

U.S.	½" Pipe		¾" Pipe		1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe		3½" Pipe		4" Pipe	
Gals. per Min.	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet
2	2.74	6.72	1.48	1.51	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4	5.48	24.2	2.97	5.45	1.79	1.54	1.00	.39	.73	.177	....	....	....	....	....	....	....	....	....	....
6	8.23	51.2	4.45	11.5	2.68	3.34	1.50	.82	1.09	.375	.65	.107	....	....	....	....	....	....	....	....
8	11.0	86.9	5.94	19.6	3.57	5.69	2.00	1.39	1.45	.64	.87	.183	.61	.077	....	....	....	....	....	....
10	13.7	132.0	7.42	29.6	4.46	8.60	2.50	2.10	1.82	.96	1.09	.276	.76	.115	.485	.039	....	....	....	....
12	....	....	8.91	41.5	5.36	12.0	3.00	2.94	2.18	1.35	1.30	.387	.91	.161	.572	.055	....	....	....	....
15	....	....	11.1	62.7	6.7	22.9	3.76	4.45	2.72	2.04	1.63	.585	1.14	.243	.727	.083	.54	.035	....	....
18			13.4	87.9	8.03	25.5	4.50	6.25	3.27	2.86	1.96	.818	1.36	.340	.873	.116	.65	.056	....	....
20	**5" PIPE**		14.8	107	8.92	30.9	5.00	7.57	3.63	3.47	2.17	.996	1.51	.414	.97	.140	.72	.068	.56	.037
25	....	....	....	....	11.2	58.8	6.25	11.4	4.55	5.25	2.71	1.51	1.9	.625	1.21	.212	.90	.103	.695	.055
30	.53	.025	....	....	13.4	65.3	7.50	16.0	5.45	7.38	3.26	2.11	2.27	.874	1.44	.297	1.08	.145	.84	.077
35	.62	.034	....	....	15.6	86.9	8.75	21.3	6.38	9.78	3.80	2.81	2.65	1.16	1.70	.396	1.26	.192	.973	.103
40	.71	.043			17.9	111	10.0	27.3	7.26	12.5	4.35	3.59	3.03	1.49	1.94	.507	1.44	.246	1.12	.132
45	.795	.054	**6" PIPE**		....	....	11.2	33.9	8.26	15.6	4.89	4.46	3.41	1.86	2.18	.629	1.63	.306	1.25	.164
50	.88	.065	.62	.027	....	....	12.5	41.3	9.08	18.9	5.43	5.41	3.79	2.25	2.42	.766	1.80	.372	1.40	.199
55	.973	.078	.676	.032	....	....	13.7	49.2	10.0	32.0	5.98	6.44	4.16	2.68	2.67	.912	1.99	.443	1.53	.237
60	1.06	.091	.74	.039	....	....	15.0	57.8	10.9	26.5	6.52	7.61	4.54	3.16	2.92	1.07	2.17	.522	1.67	.279
65	1.15	.106	.80	.044	....	....	16.1	67.0	11.8	30.7	7.06	8.84	4.92	3.66	3.14	1.25	2.35	.604	1.81	.323
70	1.23	.121	.86	.051	....	....	17.5	77.1	12.7	35.3	7.61	10.1	5.30	4.20	3.39	1.43	2.53	.691	1.95	.371
75	1.33	.138	.923	.057	....	....	18.8	87.4	13.6	40.1	8.15	11.5	5.68	4.79	3.64	1.62	2.70	.787	2.08	.421
80	1.41	.155	.98	.065	....	....	20.0	98.2	14.5	45.2	8.69	12.9	6.05	5.36	3.88	1.83	2.89	.888	2.23	.475
85	1.50	.174	1.04	.072	....	....	21.2	110	15.4	50.3	9.03	14.5	6.43	6.02	4.10	2.04	3.05	.992	2.34	.531
90	1.59	.193	1.11	.080	....	....	22.5	122	16.3	55.9	9.78	16.1	6.81	6.53	4.33	2.27	3.25	1.10	2.51	.592
95	1.67	.213	1.20	.089	....	....	....	....	17.2	62.0	10.3	17.8	7.19	7.38	4.57	2.51	3.42	1.21	2.64	.652
100	1.76	.234	1.23	.098	....	....	....	....	18.2	68.2	10.9	19.6	7.57	8.13	4.85	2.76	3.67	1.34	2.79	.719
110	1.95	.279	1.36	.117			....	....	20.0	81.3	12.0	23.4	8.33	9.68	5.33	3.29	3.97	1.60	3.07	.855
120	2.11	.329	1.48	.137	**8" PIPE**		....	....	21.8	95.4	13.0	27.4	9.08	11.4	5.80	3.87	4.33	1.88	3.35	1.00
130	2.3	.381	1.60	.159	....	....	....	....	23.6	111	14.1	31.8	9.84	13.2	6.30	4.48	4.69	2.18	3.63	1.16
140	2.47	.437	1.72	.182	.98	.047	....	....	25.4	127	15.2	36.5	10.6	15.1	6.80	5.12	5.05	2.50	3.91	1.33
150	2.65	.496	1.85	.207	1.05	.054	....	....	....	....	16.3	41.5	11.3	17.2	7.27	5.87	5.41	2.84	4.19	1.52
160	2.82	.559	1.97	.234	1.12	.059	....	....	....	....	17.4	46.7	12.1	19.4	7.75	6.58	5.78	3.20	4.47	1.71
170	3.0	.626	2.08	.261	1.19	.067	....	....	....	....	18.5	52.2	12.9	21.7	8.20	7.37	6.14	3.58	4.75	1.91
180	3.16	.696	2.22	.290	1.26	.074	....	....	....	....	19.6	58.3	13.6	24.1	8.60	8.18	6.50	3.97	5.02	2.12
190	3.36	.769	2.34	.321	1.33	.082	....	....	....	....	20.6	64.4	14.4	26.6	9.20	9.05	6.85	4.39	5.30	2.35
200	3.52	.846	2.46	.353	1.41	.091	....	....	....	....	21.7	70.5	15.1	29.3	9.70	9.96	7.22	4.84	5.58	2.58
220	3.88	1.01	2.71	.421	1.55	.108	....	....	....	....	23.9	84.1	16.7	34.9	10.6	11.9	7.94	5.78	6.14	3.08
240	4.23	1.18	2.96	.484	1.69	.126	....	....	....	....	26.1	98.7	18.2	41.0	11.6	13.9	8.66	6.77	6.70	3.62
260	4.58	1.37	3.20	.573	1.83	.147	....	....	....	....	28.3	115	19.7	47.5	12.6	16.2	9.38	7.85	7.26	4.19
280	4.94	1.57	3.45	.658	1.97	.168	....	....	....	....	....	....	21.2	54.5	13.5	18.6	10.1	9.02	7.82	4.79
300	5.29	1.79	3.69	.747	2.11	.191	....	....	....	....	....	....	22.7	62.0	14.4	21.1	10.8	10.2	8.38	5.45
320	5.64	2.01	3.94	.841	2.24	.215	....	....	....	....	....	....	24.2	69.9	15.5	23.7	11.5	11.5	8.94	6.16
340	5.99	2.26	4.19	.940	2.39	.240	....	....	....	....	....	....	25.8	78.2	16.3	26.6	12.3	12.9	9.50	6.91
360	6.35	2.51	4.43	1.05	2.64	.261	....	....	....	....	....	....	27.2	86.9	17.4	29.5	13.0	14.3	10.0	7.66
380	6.70	2.77	4.68	1.16	2.68	.295	....	....	....	....	....	....	28.8	96.1	18.6	32.6	13.7	15.8	10.6	8.46
400	7.05	3.05	4.93	1.27	2.81	.325	....	....	....	....	....	....	30.3	106	19.4	35.9	14.4	17.4	11.2	9.31
450	7.95	3.79	5.54	1.58	3.16	.404	....	....	....	....	....	....	....	....	21.8	44.6	16.2	21.6	12.5	11.6
500	8.82	4.61	6.16	1.92	3.51	.493	....	....	....	....	....	....	....	....	23.2	54.1	18.1	26.3	14.0	14.1
550	9.70	5.50	6.77	2.29	3.86	.587	....	....	....	....	....	....	....	....	26.5	64.9	19.9	31.4	15.3	16.8
600	10.6	6.44	7.39	2.69	4.22	.686	....	....	....	....	....	....	....	....	29.1	76.1	21.7	36.9	16.7	19.7
650	11.5	7.47	8.00	3.12	4.57	.799	....	....	....	....	....	....	....	....	....	....	23.5	42.8	18.1	22.9
700	12.3	8.60	8.63	3.58	4.92	.916	....	....	....	....	....	....	....	....	....	....	25.3	48.9	19.5	26.2
750	13.2	9.77	9.24	4.07	5.27	1.04	....	....	....	....	....	....	....	....	....	....	27.1	55.9	20.9	29.8
800	14.1	11.0	9.85	4.58	5.62	1.17	....	....	....	....	....	....	....	....	....	....	28.9	61.6	22.3	33.6
850	15.0	12.3	10.5	5.12	5.97	1.31	....	....	....	....	....	....	....	....	....	....	30.7	70.5	23.7	37.6
900	15.9	13.7	11.1	5.69	6.32	1.46	....	....	....	....	....	....	....	....	....	....	....	....	25.1	41.8
950	16.7	15.1	11.7	6.29	6.67	1.61	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1000	17.6	16.6	12.3	6.91	7.03	1.77	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1100	19.4	19.8	13.5	8.27	7.83	2.11	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1200	21.1	23.3	14.8	9.73	8.43	2.48	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1300	....	....	....	....	9.13	2.87	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1400	....	....	....	....	9.83	3.30	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1500	....	....	....	....	10.5	3.75	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1600	....	....	....	....	11.2	4.23	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1800	....	....	....	....	12.6	5.26	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2000	....	....	....	....	14.1	6.39	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2200	....	....	....	....	15.5	7.80	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2400	....	....	....	....	16.9	8.93	....	....	....	....	....	....	....	....	....	....	....	....	....	....

* Data shown is calculated from Williams and Hazen Formula $H = \frac{3.023}{C^{1.852}} \frac{V^{1.852}}{D^{1.167}}$ using C-150.

For water at 60° F. Where H = head loss, V = fluid velocity ft./sec., D = diameter of pipe, ft.

C = coefficient representing roughness of pipe interior surface.

Friction/Flow Chart For Standard Steel Pipe

Friction Loss of Water in Feet per 100 Feet Length of Pipe

Based on Williams & Hazen Formula Using Constant 100. Sizes of Standard Pipe in Inches.

U.S.	½" Pipe		¾" Pipe		1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe		4" Pipe		5" Pipe		6" Pipe	
Gals. per Min.	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet
2	2.10	7.4	1.20	1.9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4	4.21	27.0	2.41	7.0	1.49	2.14	.86	.57	.63	.26	....	....	....	....	....	....	....	....	....	....	....	....
6	6.31	57.0	3.61	14.7	2.23	4.55	1.29	1.20	.94	.56	.61	.20	....	....	....	....	....	....	....	....	....	....
8	8.42	98.0	4.81	25.0	2.98	7.8	1.72	2.03	1.26	.95	.82	.33	.52	.11	....	....	....	....	....	....	....	....
10	10.52	147.0	6.02	38.0	3.72	11.7	2.14	3.05	1.57	1.43	1.02	.50	.65	.17	.45	.07	....	....	....	....	....	....
12	....	....	7.22	53.0	4.46	16.4	2.57	4.3	1.89	2.01	1.23	.79	.78	.23	.54	.10	....	....	....	....	....	....
15	....	....	9.02	80.0	5.60	25.0	3.21	6.5	2.36	3.00	1.53	1.08	.98	.36	.68	.15	....	....	....	....	....	....
18	....	....	10.84	108.2	6.69	35.0	3.86	9.1	2.83	4.24	1.84	1.49	1.18	.50	.82	.21	....	....	....	....	....	....
20	....	....	12.03	136.0	7.44	42.0	4.29	11.1	3.15	5.20	2.04	1.82	1.31	.61	.91	.25	.51	.06	....	....	....	....
25	....	....	....	....	9.30	64.0	5.36	16.6	3.80	7.30	2.55	2.73	1.63	.92	1.13	.38	.64	.09	....	....	....	....
30	....	....	....	....	11.15	89.0	6.43	23.0	4.72	11.0	3.06	3.84	1.96	1.29	1.36	.54	.77	.13	.49	.04	....	....
35	....	....	....	....	13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.10	2.29	1.72	1.59	.71	.89	.17	.57	.06	....	....
40	....	....	....	....	14.88	152.0	8.58	40.0	6.30	18.8	4.08	6.6	2.61	2.20	1.82	.91	1.02	.22	.65	.08	....	....
45	....	....	....	....	....	....	9.65	50.0	7.08	23.2	4.60	8.2	2.94	2.80	2.04	1.15	1.15	.28	.73	.09	....	....
50	....	....	....	....	....	....	10.72	60.0	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38	1.28	.34	.82	.11	.57	.04
55	....	....	....	....	....	....	11.78	72.0	8.66	34.0	5.62	11.8	3.59	4.01	2.45	1.58	1.41	.41	.90	.14	.62	.05
60	....	....	....	....	....	....	12.87	85.0	9.44	39.6	6.13	13.9	3.92	4.65	2.72	1.92	1.53	.47	.98	.16	.68	.06
65	....	....	....	....	....	....	13.92	99.7	10.23	45.9	6.64	16.1	4.24	5.4	2.89	2.16	1.66	.53	1.06	.19	.74	.076
70	....	....	....	....	....	....	15.01	113.0	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57	1.79	.63	1.14	.21	.79	.08
75	....	....	....	....	....	....	16.06	129.0	11.80	60.0	7.66	20.9	4.91	7.1	3.33	3.00	1.91	.73	1.22	.24	.85	.10
80	....	....	....	....	....	....	17.16	145.0	12.59	68.0	8.17	23.7	5.23	7.9	3.63	3.28	2.04	.81	1.31	.27	.91	.11
85	....	....	....	....	....	....	18.21	163.8	13.38	75.0	8.68	26.5	5.56	8.1	3.78	3.64	2.17	.91	1.39	.31	.96	.12
60	....	....	....	....	....	....	19.30	180.0	14.71	84.0	9.19	29.4	5.88	9.8	4.09	4.08	2.30	1.00	1.47	.34	1.02	.14
95	....	....	....	....	....	....	....	....	14.95	93.0	9.70	32.6	6.21	10.8	4.22	4.33	2.42	1.12	1.55	.38	1.08	.15
100			....	....	....	....	....	....	15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96	2.55	1.22	1.63	.41	1.13	.17
110	8" PIPE		....	....	....	....	....	....	17.31	122.0	11.23	42.9	7.18	14.5	5.00	6.0	2.81	1.46	1.79	.49	1.25	.21
120	....	....	....	....	....	....	....	....	18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0	3.06	1.17	1.96	.58	1.36	.24
130	....	....	....	....	....	....	....	....	20.46	166.0	13.28	58.0	8.48	18.7	5.91	8.1	3.31	1.97	2.12	.67	1.47	.27
140	.90	.08	....	....	....	....	....	....	22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2	3.57	2.28	2.29	.76	1.59	.32
150	.96	.09	....	....	....	....	....	....	....	....	15.32	76.0	9.81	25.5	6.82	10.5	3.82	2.62	2.45	.88	1.70	.36
160	1.02	.10	....	....	....	....	....	....	....	....	16.34	86.0	10.46	29.0	7.26	11.8	4.08	2.91	2.61	.98	1.82	.40
170	1.08	.11			....	....	....	....	....	....	17.36	96.0	11.11	34.1	7.71	13.3	4.33	3.26	2.77	1.08	1.92	.45
180	1.15	.13	10" PIPE		....	....	....	....	....	....	18.38	107.0	11.76	35.7	8.17	14.0	4.60	3.61	2.94	1.22	2.04	.50
190	1.21	.14	....	....	....	....	....	....	....	....	19.40	118.0	12.42	39.6	8.63	15.5	4.84	4.01	3.10	1.35	2.16	.55
200	1.28	.15	....	....	....	....	....	....	....	....	20.42	129.0	13.07	43.1	9.08	17.8	5.11	4.4	3.27	1.48	2.27	.62
220	1.40	.18	.90	.06	....	....	....	....	....	....	22.47	154.0	14.38	52.0	9.99	21.3	5.62	5.2	3.59	1.77	2.50	.73
240	1.53	.22	.98	.07	....	....	....	....	....	....	24.51	182.0	15.69	61.0	10.89	25.1	6.13	6.2	3.92	2.08	2.72	.87
260	1.66	.25	1.06	.08	....	....	....	....	....	....	26.55	211.0	16.99	70.0	11.80	29.1	6.64	7.2	4.25	2.41	2.95	1.00
280	1.79	.28	1.15	.09	....	....	....	....	....	....	....	....	18.30	81.0	12.71	33.4	7.15	8.2	4.58	2.77	3.18	1.14
300	1.91	.32	1.22	.11	....	....	....	....	....	....	....	....	19.61	92.0	13.62	38.0	7.66	9.3	4.90	3.14	3.40	1.32
320	....	....	....	....			....	....	....	....	....	....	20.92	103.0	14.52	42.8	8.17	10.5	5.23	3.54	3.64	1.47
340	2.18	.41	1.39	.14	12" PIPE		....	....	....	....	....	....	22.22	116.0	15.43	47.9	8.68	11.7	5.54	3.97	3.84	1.62
360	2.30	.45	1.47	.15	....	....			....	....	....	....	23.53	128.0	16.34	53.0	9.19	13.1	5.87	4.41	4.08	1.83
380	2.43	.50	1.55	.17	1.08	.069	14" PIPE		....	....	....	....	24.84	142.0	17.25	59.0	9.69	14.0	6.19	4.86	4.31	2.00
400	2.60	.54	1.63	.19	1.14	.075	....	....	....	....	....	....	26.14	156.0	18.16	65.0	10.21	16.0	6.54	5.4	4.55	2.20
450	2.92	.68	1.84	.23	1.28	.095	....	....	....	....	....	....	....	....	20.40	78.0	11.49	19.8	7.35	6.7	5.11	2.74
500	3.19	.82	2.04	.28	1.42	.113	1.04	.06	....	....	....	....	....	....	22.70	98.0	12.77	24.0	8.17	8.1	5.68	2.90
550	3.52	.97	2.24	.33	1.56	.135	1.15	.07	....	....	....	....	....	....	24.96	117.0	14.04	28.7	8.99	9.6	6.25	3.96
600	3.84	1.14	2.45	.39	1.70	.159	1.25	.08	....	....	....	....	....	....	27.23	137.0	15.32	33.7	9.80	11.3	6.81	4.65
650	4.16	1.34	2.65	.45	1.84	.19	1.37	.09	....	....	....	....	....	....	....	....	16.59	39.0	10.62	13.2	7.38	5.40
700	4.46	1.54	2.86	.52	1.99	.22	1.46	.10	....	....	....	....	....	....	....	....	17.87	44.9	11.44	15.1	7.95	6.21
750	4.80	1.74	3.06	.59	2.13	.24	1.58	.11			....	....	....	....	....	....	19.15	51.0	12.26	17.2	8.50	7.12
800	5.10	1.90	3.26	.66	2.27	.27	1.67	.13	16" PIPE		....	....	....	....	....	....	20.42	57.0	13.07	19.4	9.08	7.96
850	5.48	2.20	3.47	.75	2.41	.31	1.79	.14	1.36	.08	....	....	....	....	....	....	21.70	64.0	13.89	21.7	9.65	8.95
900	5.75	2.46	3.67	.83	2.56	.34	1.88	.16	1.44	.084			....	....	....	....	22.98	71.0	14.71	24.0	10.20	10.11
950	6.06	2.87	3.88	.91	2.70	.38	2.00	.18	1.52	.095	20" PIPE		....	....	....	....	....	....	15.52	26.7	10.77	11.20
1000	6.38	2.97	4.08	1.03	2.84	.41	2.10	.19	1.60	.10	1.02	.04	....	....	....	....	....	....	16.34	29.2	11.34	12.04
1100	7.03	3.52	4.49	1.19	3.13	.49	2.31	.23	1.76	.12	1.12	.04	....	....	....	....	....	....	17.97	34.9	12.48	14.55
1200	7.66	4.17	4.90	1.40	3.41	.58	2.52	.27	1.92	.14	1.23	.05	....	....	....	....	....	....	19.61	40.9	13.61	17.10
1300	8.30	4.85	5.31	1.62	3.69	.67	2.71	.32	2.08	.17	1.33	.06	....	....	....	....	....	....	....	....	14.72	18.4
1400	8.95	5.50	5.71	1.87	3.98	.78	2.92	.36	2.24	.19	1.43	0.64			....	....	....	....	....	....	15.90	22.60
1500	9.58	6.24	6.12	2.13	4.26	.89	3.15	.41	2.39	.21	1.53	.07	24" PIPE		....	....	....	....	....	....	17.02	25.60
1500	10.21	7.00	6.53	2.39	4.55	.98	3.34	.47	2.56	.24	1.63	.08	....	....			....	....	....	....	18.10	26.9
1800	11.50	8.78	7.35	2.95	5.11	1.21	3.75	.58	2.87	.30	1.84	.10	1.28	.04	30" PIPE		....	....	....	....	....	....
2000	12.78	10.71	8.16	3.59	5.68	1.49	4.17	.71	3.19	.37	2.04	.12	1.42	.05	....	....	....	....	....	....	....	....
2200	14.05	12.78	8.98	4.24	6.25	1.81	4.59	.84	3.51	.44	2.25	.15	1.56	.06	....	....	....	....	....	....	....	....
2400	15.32	14.2	9.80	5.04	6.81	2.08	5.00	.99	3.83	.52	2.45	.17	1.70	.07	1.09	.02	....	....	....	....	....	....
2600	....	....	10.61	5.81	7.38	2.43	5.47	1.17	4.15	.60	2.66	.20	1.84	.08	1.16	0.27	....	....	....	....	....	....
2800	....	....	11.41	6.70	7.95	2.75	5.84	1.32	4.47	.68	2.86	.23	1.98	.09	1.27	.03	....	....	....	....	....	....
3000	....	....	12.24	7.62	8.52	3.15	6.01	1.49	4.79	.78	3.08	.27	2.13	.10	1.37	.037	....	....	....	....	....	....
3200	....	....	13.05	7.8	9.10	3.51	6.68	1.67	5.12	.88	3.27	.30	2.26	.12	1.46	.041	....	....	....	....	....	....
3500	....	....	14.30	10.08	9.95	4.16	7.30	1.97	5.59	1.04	3.59	.35	2.49	.14	1.56	.47	....	....	....	....	....	....
3800	....	....	15.51	13.4	10.80	4.90	7.98	2.36	6.07	1.20	3.88	.41	2.69	.17	1.73	.05	....	....	....	....	....	....
4200	....	....	....	....	11.92	5.88	8.76	2.77	6.70	1.44	4.29	.49	2.99	.20	1.91	.07	....	....	....	....	....	....
4500	....	....	....	....	12.78	6.90	9.45	3.22	7.18	1.64	4.60	.56	3.20	.22	2.04	.08	....	....	....	....	....	....
5000	....	....	....	....	14.20	8.40	10.50	3.92	8.01	2.03	5.13	.68	3.54	.27	2.26	.09	....	....	....	....	....	....
5500	....	....	....	....	....	....	11.55	4.65	8.78	2.39	5.64	.82	3.90	.33	2.50	.11	....	....	....	....	....	....
6000	....	....	....	....	....	....	12.60	5.50	9.58	2.79	6.13	.94	4.25	.38	2.73	.13	....	....	....	....	....	....
6500	....	....	....	....	....	....	13.65	6.45	10.39	3.32	6.64	1.10	4.61	.45	2.96	.15	....	....	....	....	....	....
7000	....	....	....	....	....	....	14.60	7.08	11.18	3.70	7.15	1.25	4.97	.52	3.18	.17	....	....	....	....	....	....
8000	....	....	....	....	....	....	....	....	12.78	4.74	8.17	1.61	5.68	.66	3.64	.23	....	....	....	....	....	....
9000	....	....	....	....	....	....	....	....	14.37	5.90	9.20	2.01	6.35	.81	4.08	.28	....	....	....	....	....	....
10000	....	....	....	....	....	....	....	....	15.96	7.19	10.20	2.44	7.07	.98	4.54	.33	....	....	....	....	....	....
12000	....	....	....	....	....	....	....	....	....	....	12.25	3.41	8.50	1.40	5.46	.48	....	....	....	....	....	....
14000	....	....	....	....	....	....	....	....	....	....	14.30	4.54	9.95	1.87	6.37	.63	....	....	....	....	....	....
16000	....	....	....	....	....	....	....	....	....	....	....	....	11.38	2.40	7.28	.81	....	....	....	....	....	....
18000	....	....	....	....	....	....	....	....	....	....	....	....	12.76	2.97	8.18	1.02	....	....	....	....	....	....
20000	....	....	....	....	....	....	....	....	....	....	....	....	14.20	3.60	9.10	1.23	....	....	....	....	....	....

Normal safe operating selection; ☐ Suction piping; ☐ Discharge or pressure piping.

Note: Where long pipe runs are encountered, make selection in minimum head loss range.

Type K Copper

Flow of Water and Friction Loss per 100 Feet of Type K Copper Tube
⅜" to 2" Nominal Sizes

Flow, Gallons per Minute	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second
	⅜"			½"			⅝"			¾"		
1	4.7	11	2.53	1.3	3.0	1.47	.47	1.1	.961	.25	.58	.736
2	16	37	5.1	3.5	10	2.9	1.6	3.7	1.9	.85	2.0	1.5
3	33	76	7.6	9.0	21	4.4	3.3	7.6	2.9	1.7	3.9	2.2
4	55	130	10.1	15	36	5.9	5.5	13	3.8	2.8	6.5	2.9
5	80	180	12.7	22	51	7.9	8.0	18	4.8	4.2	9.7	3.7
6	110	250	15.2	31	72	8.8	11	25	5.8	5.8	13	4.4
7	150	350	17.7	40	92	10.3	15	35	6.7	7.5	17	5.2
8	190	440	20.2	50	115	11.8	19	44	7.7	9.3	21	5.9
9	230	530	22.8	62	140	13.2	23	53	8.6	11	25	6.6
10	280	650	25.3	79	180	14.7	28	65	9.6	14	32	7.4
15	–	–	–	160	370	22.0	59	140	14.4	30	69	10.1
20	–	–	–	–	–	–	95	220	19.2	50	120	14.7
25	–	–	–	–	–	–	140	320	24.0	75	170	18.4
30	–	–	–	–	–	–	–	–	–	100	230	22.1
	1"			**1¼"**			**1½"**			**2"**		
1	.065	.15	.413	–	–	–	–	–	–	–	–	–
2	.23	.52	.83	.07	.16	.53	–	–	–	–	–	–
3	.45	1.0	1.2	.15	.35	.79	.063	.15	.56	–	–	–
4	.75	1.7	1.7	.25	.58	1.1	.10	.23	.75	–	–	–
5	1.1	2.5	2.1	.36	.83	1.3	.16	.37	.93	.042	.10	.53
6	1.5	3.5	2.5	.50	1.2	1.6	.22	.51	1.1	.058	.13	.64
7	2.0	4.6	2.9	.65	1.5	1.8	.28	.65	1.3	.073	.17	.74
8	2.5	5.7	3.3	.80	1.8	2.1	.36	.83	1.5	.098	.21	.85
9	3.1	7.2	3.7	1.0	2.3	2.4	.44	1.0	1.7	.11	.25	.95
10	3.7	8.5	4.1	1.3	3.0	2.6	.52	1.2	1.9	.15	.35	1.1
15	7.4	18	6.6	2.5	5.8	4.0	1.1	2.5	2.8	.30	.69	1.6
20	13	30	8.3	4.2	9.7	5.3	1.8	4.2	3.7	.50	1.2	2.1
25	18	42	10.3	6.1	14	6.6	2.6	6.0	4.7	.70	1.6	2.7
30	25	57	12.4	8.5	20	7.9	3.6	8.3	5.6	.95	2.2	3.2
35	34	78	14.5	11	25	9.2	4.8	11.0	6.7	1.3	3.0	3.7
40	41	95	16.5	14	32	10.6	6.0	14.0	7.5	1.6	3.7	4.2
45	51	120	18.6	16	37	11.9	7.2	17.0	8.4	1.9	4.4	4.8
50	61	140	20.7	20	46	13.2	8.9	21.0	9.3	2.4	5.5	5.3
60	–	–	–	29	67	15.8	12	28.0	11.2	3.3	7.6	6.4
70	–	–	–	36	83	18.5	16	37.0	13.1	4.2	9.7	7.4
80	–	–	–	46	105	21.1	20	46.0	15.0	5.2	12	8.5
90	–	–	–	–	–	–	25	58	16.8	6.5	15	9.5
100	–	–	–	–	–	–	30	69	18.7	8.0	18	10.6
150	–	–	–	–	–	–	–	–	–	16	37	15.9
200	–	–	–	–	–	–	–	–	–	27	62	21.2

Note: To avoid erosion of copper pipe, velocities should not exceed eight feet per second. Where long pipe runs are encountered, make selection in minimum head loss range.

Type K Copper

Flow of Water and Friction Loss per 100 Feet of Type K Copper Tube
2½" to 10" Nominal Sizes

Flow, Gallons per Minute	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second
	2½"			3"			3½"			4"		
10	.05	.12	.69	.025	.06	.48	–	–	–	–	–	–
15	.10	.23	1.0	.047	.11	.72	–	–	–	–	–	–
20	.17	.39	1.4	0.75	.17	.97	0.40	.09	.71	–	–	–
25	.24	.55	1.7	.10	.23	1.2	0.55	.13	.89	–	–	–
30	.33	.76	2.1	.15	.35	1.5	0.75	.17	1.1	.040	.09	.82
35	.44	1.0	2.4	.20	.46	1.7	.10	.23	1.2	.050	.12	.96
40	.53	1.2	2.8	.25	.57	1.9	.12	.28	1.4	.062	.14	1.1
45	.65	1.5	3.1	.30	.69	2.2	.15	.35	1.6	.075	.17	1.2
50	.80	1.8	3.5	.38	.88	2.4	.18	.42	1.8	.095	.22	1.4
60	1.1	2.5	4.2	.50	1.2	2.9	.25	.58	2.1	.13	.30	1.6
70	1.5	3.5	4.9	.68	1.5	3.4	.34	.78	2.5	.17	.39	1.9
80	1.8	4.2	5.6	.85	2.0	3.8	.42	.97	2.8	.21	.48	2.2
90	2.3	5.3	6.3	1.0	2.3	4.3	.50	1.2	3.2	.26	.60	2.5
100	2.9	6.7	7.0	1.3	3.0	4.8	.61	1.4	3.6	.32	.74	2.7
150	6.0	14	10.5	2.6	6.0	7.2	1.3	3.0	5.3	.65	1.5	4.1
200	9.8	23	14.0	4.3	10	9.7	2.0	4.6	7.1	1.1	2.5	5.5
250	14	32	17.5	6.2	14	12.1	3.0	6.9	8.9	1.6	3.7	6.9
300	20	46	21.0	9.0	21	14.5	4.3	10	10.7	2.2	5.1	8.2
350	–	–	–	11	25	16.9	5.5	13	12.4	3.0	6.9	9.6
400	–	–	–	15	35	19.3	7.0	16	14.2	3.6	8.3	11.0
450	–	–	–	18	42	21.7	8.5	20	16.0	4.5	10	12.2
500	–	–	–	–	–	–	10	23	17.8	5.5	13	13.7
600	–	–	–	–	–	–	15	35	21.3	7.5	17	16.4
700	–	–	–	–	–	–	–	–	–	9.5	22	19.2
800	–	–	–	–	–	–	–	–	–	12	28	21.9
	5"			6"			8"			10"		
40	.023	.05	.71	–	–	–	–	–	–	–	–	–
45	.027	.06	.80	–	–	–	–	–	–	–	–	–
50	.033	.08	.89	–	–	–	–	–	–	–	–	–
60	.044	.10	1.1	.020	.05	.73	–	–	–	–	–	–
70	.060	.14	1.2	.026	.06	.85	–	–	–	–	–	–
80	.071	.16	1.4	.033	.08	.98	–	–	–	–	–	–
90	.090	.21	1.6	.042	.10	1.1	–	–	–	–	–	–
100	.11	.25	1.8	.049	.11	1.2	.013	.03	.71	–	–	–
150	.23	.53	2.7	.10	.23	1.8	.027	.06	1.1	–	–	–
200	.39	.90	3.5	.17	.39	2.4	.045	.10	1.4	.016	.04	.91
250	.55	1.3	4.4	.24	.55	3.1	.063	.15	1.8	.023	.05	1.1
300	.80	1.8	5.3	.35	.81	3.7	.09	.21	2.1	.032	.07	1.4
350	1.0	2.3	6.2	.45	1.0	4.3	.12	.28	2.5	.041	.09	1.6
400	1.3	3.0	7.1	.56	1.3	4.9	.15	.35	2.8	.051	.12	1.8
450	1.6	3.7	7.8	.70	1.6	5.5	.18	.42	3.2	.061	.14	2.0
500	1.9	4.4	8.9	.85	2.0	6.1	.22	.51	3.5	.076	.18	2.3
600	2.7	6.2	10.6	1.1	2.5	7.3	.30	.69	4.3	.10	.23	2.8
700	3.5	8.1	12.4	1.5	3.5	8.5	.40	.92	5.0	.14	.32	3.2
800	4.3	10	14.2	1.9	4.4	9.8	.50	1.2	5.7	.17	.39	3.7
900	5.2	12	15.9	2.3	5.3	11.0	.60	1.4	6.4	.21	.48	4.1
1000	6.1	14	17.7	2.8	6.5	12.2	.75	1.7	7.1	.26	.60	4.6
1500	13	30	26.6	5.8	13	18.3	1.6	3.7	10.7	.54	1.2	6.9
2000	–	–	–	9.5	22	24.4	2.6	6.0	14.2	.90	2.1	9.2
2500	–	–	–	–	–	–	3.8	8.8	17.8	1.3	3.0	10.5
3000	–	–	–	–	–	–	5.0	12	21.3	1.8	4.2	13.8
3500	–	–	–	–	–	–	–	–	–	2.4	5.5	16.0
4000	–	–	–	–	–	–	–	–	–	3.0	6.9	18.3
4500	–	–	–	–	–	–	–	–	–	3.7	8.5	20.6

Note: To avoid erosion of copper pipe, velocities should not exceed eight feet per second. Where long pipe runs are encountered, make selection in minimum head loss range.

Type L Copper

Flow of Water and Friction Loss per 100 Feet of Type L Copper Tube

⅜" to 2" Nominal Sizes

Flow, Gallons per Minute	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second
		⅜"			½"			⅝"			¾"	
1	.35	8.1	2.21	1.1	2.5	1.38	.43	1.0	.920	.20	.46	.663
2	12	28	4.4	3.8	8.8	2.8	1.5	3.5	1.8	.69	1.6	1.3
3	24	55	6.6	7.7	18	4.1	3.0	6.9	2.8	1.4	3.2	2.0
4	40	92	8.8	13	30	5.5	4.9	11	3.7	2.2	5.1	2.7
5	60	140	11.0	19	44	6.9	7.0	16	4.6	3.4	7.8	3.3
6	82	190	13.3	26	60	8.3	10	23	5.5	4.6	11	4.0
7	105	240	15.5	35	81	9.7	12	28	6.4	6.0	14	4.6
8	130	300	17.7	42	97	11.0	16	37	7.4	7.5	17	5.3
9	170	390	19.9	53	120	12.4	20	46	8.3	9.1	21	6.0
10	200	460	22.1	65	150	13.8	25	58	9.2	11	25	6.6
15	–	–	–	130	300	20.7	50	115	13.8	23	50	10.0
20	–	–	–	–	–	–	85	200	18.4	39	90	13.3
25	–	–	–	–	–	–	120	280	23.0	58	130	16.6
30	–	–	–	–	–	–	–	–	–	80	180	19.9
35	–	–	–	–	–	–	–	–	–	100	230	23.2
		1"			**1¼"**			**1½"**			**2"**	
1	.055	.13	.389	–	–	–	–	–	–	–	–	–
2	.19	.44	.78	.075	.17	.510	–	–	–	–	–	–
3	.40	.92	1.2	.14	.32	.77	.060	.14	.54	–	–	–
4	.62	1.4	1.6	.22	.51	1.0	.10	.23	.72	–	–	–
5	.93	2.2	1.9	.32	.74	1.3	.15	.35	.90	.040	.092	.520
6	1.3	3.0	2.3	.45	1.0	1.5	.20	.46	1.1	.055	.13	.63
7	1.7	3.9	2.7	.59	1.4	1.8	.26	.60	1.3	.070	.16	.73
8	2.0	4.6	3.1	.74	1.7	2.0	.33	.76	1.5	.090	.21	.83
9	2.6	6.0	3.5	.90	2.1	2.3	.41	.95	1.6	.11	.25	.94
10	3.2	7.4	3.9	1.1	2.5	2.6	.50	1.2	1.8	.14	.32	1.0
15	6.4	15	5.8	2.2	5.1	3.8	1.0	2.3	2.7	.28	.64	1.6
20	10	23	7.8	3.7	8.5	5.1	1.7	3.9	3.6	.45	1.0	2.1
25	16	37	9.7	5.5	13	6.4	2.5	5.8	4.5	.69	1.6	2.6
30	22	51	10.7	7.5	17	7.7	3.5	8.1	5.4	.90	2.1	3.1
35	28	65	13.6	10	23	8.9	4.6	11	6.3	1.2	2.8	3.6
40	35	81	15.6	13	30	10.2	5.6	13	7.2	1.5	3.5	4.2
45	45	105	17.5	15	35	11.5	7.0	16	8.1	1.8	4.4	4.7
50	55	127	19.5	19	44	12.8	8.5	20	9.0	2.2	5.1	5.2
60	–	–	–	26	60	15.3	11	25	10.8	3.0	6.9	6.2
70	–	–	–	33	76	17.8	15	35	12.6	4.0	9.2	7.3
80	–	–	–	40	92	20.4	19	44	14.4	5.0	12	8.3
90	–	–	–	–	–	–	24	55	16.2	6.0	14	9.4
100	–	–	–	–	–	–	29	67	18.0	7.5	17	10.4
150	–	–	–	–	–	–	–	–	–	15	35	15.6
200	–	–	–	–	–	–	–	–	–	26	60	20.8

Note: To avoid erosion of copper pipe, velocities should not exceed eight feet per second. Where long pipe runs are encountered, make selection in minimum head loss range.

Type L Copper

Flow of Water and Friction Loss per 100 Feet of Type L Copper Tube
2½" to 10" Nominal Sizes

Flow, Gallons per Minute	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second	Pressure Drop, Lb. per Sq. In.	Lost Head, Feet	Velocity, Feet per Second
	2½"			**3"**			**3½"**			**4"**		
10	.05	.11	.673	.02	.05	.471	–	–	–	–	–	–
15	.10	.23	1.01	.04	.10	.71	–	–	–	–	–	–
20	.17	.39	1.4	.07	.16	.94	.036	.08	.70	–	–	–
25	.25	.58	1.7	.10	.23	1.2	.051	.12	.87	–	–	–
30	.33	.76	2.0	.15	.35	1.4	.07	.16	1.1	.038	.09	.81
35	.45	1.0	2.4	.19	.44	1.7	.09	.21	1.2	.050	.12	.94
40	.55	1.3	2.8	.24	.55	1.9	.12	.28	1.4	.060	.14	1.1
45	.67	1.6	3.0	.29	.67	2.1	.14	.32	1.6	.073	.17	1.2
50	.80	1.8	3.4	.35	.81	2.4	.17	.39	1.8	.088	.20	1.4
60	1.1	2.5	4.0	.48	1.1	2.8	.24	.55	2.1	.13	.30	1.6
70	1.5	3.5	4.7	.60	1.4	3.3	.31	.72	2.4	.16	.37	1.9
80	1.8	4.2	5.4	.76	1.8	3.8	.40	.92	2.8	.20	.46	2.2
90	2.2	5.1	6.1	.95	2.2	4.2	.49	1.1	3.1	.25	.58	2.4
100	2.8	6.5	6.7	1.2	2.8	4.7	.57	1.3	3.5	.30	.69	2.7
150	5.6	13	10.1	2.4	5.5	7.1	1.2	2.8	5.2	.60	1.4	4.0
200	9.1	21	13.5	4.0	9.2	9.4	2.0	4.6	7.0	1.1	2.5	5.4
250	14	32	16.8	6.0	14	11.8	2.9	6.7	8.7	1.5	3.5	6.7
300	19	44	20.2	8.5	20	14.1	4.0	9.2	10.5	2.1	4.8	8.1
350	–	–	–	11	25	16.5	5.1	12	12.2	2.8	6.5	9.4
400	–	–	–	14	32	18.8	6.8	16	14.0	3.5	8.1	10.8
450	–	–	–	16	37	21.2	8.0	18	15.7	4.3	10	12.1
500	–	–	–	–	–	–	10.0	23	17.5	5.2	12	13.5
600	–	–	–	–	–	–	14.0	32	20.9	7.0	16	16.1
700	–	–	–	–	–	–	–	–	–	9.0	21	18.8
800	–	–	–	–	–	–	–	–	–	11.0	23	21.5
	5"			**6"**			**8"**			**10"**		
40	.021	.05	.69	–	–	–	–	–	–	–	–	–
45	.026	.06	.77	–	–	–	–	–	–	–	–	–
50	.032	.07	.86	–	–	–	–	–	–	–	–	–
60	.045	.10	1.0	.019	.04	.72	–	–	–	–	–	–
70	.056	.13	1.2	.025	.06	.84	–	–	–	–	–	–
80	.07	.16	1.4	.031	.07	.96	–	–	–	–	–	–
90	.09	.20	1.6	.039	.09	1.1	–	–	–	–	–	–
100	.11	.25	1.7	.047	.11	1.2	.013	.030	.68	–	–	–
150	.22	.50	2.6	.094	.22	1.8	.026	.060	1.0	–	–	–
200	.36	.83	3.4	.16	.37	2.4	.043	.10	1.4	.015	.035	.88
250	.54	1.3	4.3	.23	.53	3.0	.06	.14	1.7	.021	.048	1.1
300	.75	1.7	5.1	.32	.74	3.6	.085	.20	2.1	.03	.069	1.3
350	.96	2.2	6.0	.42	.97	4.2	.11	.25	2.4	.04	.092	1.5
400	1.2	2.8	6.9	.52	1.2	4.8	.14	.32	2.7	.05	.12	1.8
450	1.5	3.5	7.7	.64	1.5	5.4	.17	.39	3.1	.06	.14	2.0
500	1.8	4.2	8.6	.77	1.8	6.0	.21	.48	3.4	.075	.17	2.2
600	2.5	5.8	10.3	1.1	2.5	7.2	.29	.65	4.1	.10	.23	2.7
700	3.3	7.6	12.0	1.4	3.2	8.4	.38	.88	4.8	.14	.32	3.1
800	4.0	9.2	13.8	1.8	4.2	9.6	.48	1.1	5.5	.16	.37	3.5
900	5.0	12	16.5	2.1	4.8	10.8	.57	1.3	6.2	.20	.46	4.0
1000	6.0	14	17.2	2.7	6.2	12.0	.70	1.6	6.8	.25	.58	4.4
1500	12	28	25.8	5.4	12.4	18.0	1.5	3.5	10.3	.50	1.2	6.6
2000	–	–	–	9.0	21	24.0	2.4	5.5	13.8	.85	2.0	8.8
2500	–	–	–	–	–	–	3.5	8.1	17.1	1.3	3.0	11.0
3000	–	–	–	–	–	–	5.0	12	20.5	1.7	3.9	13.2
3500	–	–	–	–	–	–	–	–	–	2.3	5.3	15.4
4000	–	–	–	–	–	–	–	–	–	2.8	6.5	17.6
4500	–	–	–	–	–	–	–	–	–	3.5	8.1	19.8

Note: To avoid erosion of copper pipe, velocities should not exceed eight feet per second. Where long pipe runs are encountered, make selection in minimum head loss range.

Friction Loss Created by Pipe Fittings

The friction created by fittings is expressed as the equivalent length of straight pipe. For example, the loss through a 1" regular 90° Ell is equal to that created by 5.2 feet of straight 1" steel pipe. Determine total friction by combining fitting loss with pipe loss.

Equivalent Length of Straight Pipe for Various Fittings. Turbulent Flow Only.

Fittings			Pipe Size															
			¼	⅜	½	¾	1	1¼	1½	2	2½	3	4	5	6	8	10	12
Regular 90° Ell	Screwed	Steel	2.3	3.1	3.6	4.4	5.2	6.6	7.4	8.5	9.3	11.0	13.0					
		C.I.										9.0	11.0					
	Flanged	Steel			.92	1.2	1.6	2.1	2.4	3.1	3.6	4.4	5.9	7.3	8.9	12.0	14.0	17.0
		C.I.										3.6	4.8		7.2	9.8	12.0	15.0
Long Radius 90° Ell	Screwed	Steel	1.5	2.0	2.2	2.3	2.7	3.2	3.4	3.6	3.6	4.0	4.6					
		C.I.										3.3	3.7					
	Flanged	Steel			1.1	1.3	1.6	2.0	2.3	2.7	2.9	3.4	4.2	5.0	5.7	7.0	8.0	9.0
		C.I.										2.8	3.4		4.7	5.7	6.8	7.8
Regular 45° Ell	Screwed	Steel	.34	.52	.71	.92	1.3	1.7	2.1	2.7	3.2	4.0	5.5					
		C.I.										3.3	4.5					
	Flanged	Steel			.45	.59	.81	1.1	1.3	1.7	2.0	2.6	3.5	4.5	5.6	7.7	9.0	11.0
		C.I.										2.1	2.9		4.5	6.3	8.1	9.7
Tee-Line Flow	Screwed	Steel	.79	1.2	1.7	2.4	3.2	4.6	5.6	7.7	9.3	12.0	17.0					
		C.I.										9.9	14.0					
	Flanged	Steel			.69	.82	1.0	1.3	1.5	1.8	1.9	2.2	2.8	3.3	3.8	4.7	5.2	6.0
		C.I.										1.9	2.2		2.1	3.9	4.6	5.2
Tee-Branch Flow	Screwed	Steel	2.4	3.5	4.2	5.3	6.6	8.7	9.9	12.0	13.0	17.0	21.0					
		C.I.										14.0	17.0					
	Flanged	Steel			2.0	2.6	3.3	4.4	5.2	6.6	7.5	9.4	12.0	15.0	18.0	24.0	30.0	34.0
		C.I.										7.7	10.0		15.0	20.0	25.0	30.0
180° Return Bend	Screwed	Steel	2.3	3.1	3.6	4.4	5.2	6.6	7.4	8.5	9.3	11.0	13.0					
		C.I.										9.0	11.0					
	Regular Flanged	Steel			.92	1.2	1.6	2.1	2.4	3.1	3.6	4.4	5.9	7.3	8.9	12.0	14.0	17.0
		C.I.										3.6	4.8		7.2	9.8	12.0	15.0
	Long. Rad. Flanged	Steel			1.1	1.3	1.6	2.0	2.3	2.7	2.9	3.4	4.2	5.0	5.7	7.0	8.0	9.0
		C.I.										2.8	3.4		4.7	5.7	6.8	7.8

Friction Loss Created by Pipe Fittings

The friction created by fittings is expressed as the equivalent length of straight pipe. For example, the loss through a 1” regular 90° Ell is equal to that created by 5.2 feet of straight 1” steel pipe. Determine total friction by combining fitting loss with pipe loss.

Equivalent Length of Straight Pipe for Various Fittings. Turbulent Flow Only.

Fittings			Pipe Size															
			¼	**⅜**	**½**	**¾**	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**4**	**5**	**6**	**8**	**10**	**12**
Globe Valve	Screwed	Steel	21.0	22.0	22.0	24.0	29.0	37.0	42.0	54.0	62.0	79.0	110.0					
		C.I.										65.0	86.0					
	Flanged	Steel			38.0	40.0	45.0	54.0	59.0	70.0	77.0	94.0	120.0	150.0	190.0	260.0	310.0	390.0
		C.I.										77.0	99.0		150.0	210.0	270.0	330.0
Gate Valve	Screwed	Steel	.32	.45	.56	.67	.84	1.1	1.2	1.5	1.7	1.9	2.5					
		C.I.										1.6	2.0					
	Flanged	Steel								2.6	2.7	2.8	2.9	3.1	3.2	3.2	3.2	3.2
		C.I.										2.3	2.4		2.6	2.7	2.8	.29
Angle Valve	Screwed	Steel	12.8	15.0	15.0	15.0	17.0	18.0	18.0	18.0	18.0	18.0	18.0					
		C.I.										15.0	15.0					
	Flanged	Steel			15.0	15.0	17.0	18.0	18.0	21.0	22.0	28.0	38.0	50.0	63.0	90.0	120.0	140.0
		C.I.										23.0	31.0		52.0	74.0	98.0	120.0
Swing Check Valve	Screwed	Steel	7.2	7.3	8.0	8.8	11.0	13.0	15.0	19.0	22.0	27.0	38.0					
		C.I.										22.0	31.0					
	Flanged	Steel			3.8	5.3	7.2	10.0	12.0	17.0	21.0	27.0	38.0	50.0	63.0	90.0	120.0	140.0
		C.I.										22.0	31.0		52.0	74.0	98.0	120.0
Coupling or Union	Screwed	Steel	.14	.18	.21	.24	.29	.36	.39	.45	.47	.53	.65					
		C.I.										.44	.52					
	Bell Mouth Inlet	Steel	.04	.07	.10	.13	.18	.26	.31	.43	.52	.67	.95	1.3	1.6	2.3	2.9	3.5
		C.I.										.55	.77		1.3	1.9	2.4	3.0
	Square Mouth Inlet	Steel	.44	.68	.96	1.3	1.8	2.6	3.1	4.3	5.2	6.7	9.5	13.0	16.0	23.0	29.0	35.0
		C.I.										5.5	7.7		13.0	19.0	24.0	30.0
Re-Entrapment Pipe		Steel	.88	1.4	1.9	2.6	3.6	5.1	6.2	8.5	10.0	13.0	19.0	25.0	32.0	45.0	58.0	70.0
		C.I.										11.0	15.0		26.0	37.0	49.0	61.0
Sudden Enlargement			$b = \frac{(V_1 - V_2)^2}{2g}$ Feet of Fluid; if $V_2 = 0$ $b = \frac{V_1^2}{2g}$ Feet of Fluid															

FRICTION LOSS IN PIPE FITTINGS

The resistance to flow caused by a valve or fitting may be computed from the equation:

$$h = K \frac{V^2}{2g}$$

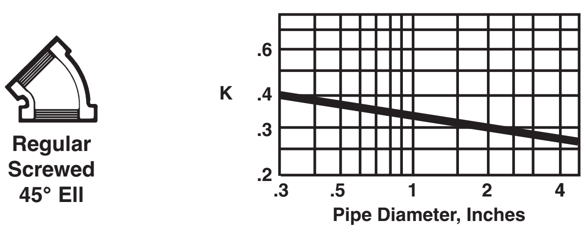
Where h = frictional resistance in feet of fluid

V = average velocity in feet per second in pipe of corresponding diameter

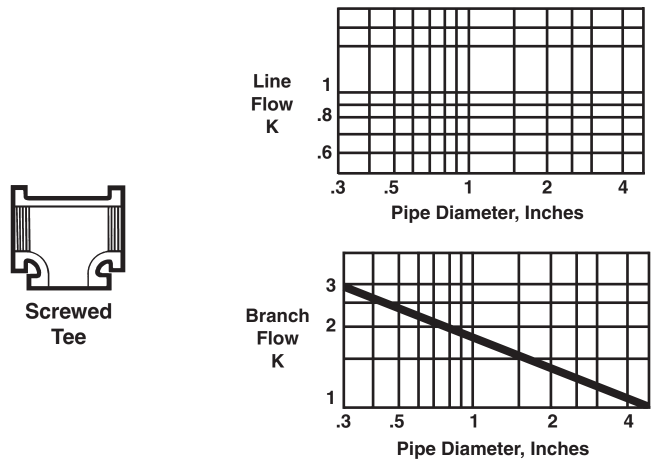
K = resistance coefficient for fitting

Values of K for frequently used fittings may be found in Table 3. Wide differences in the values of K are found in the published literature. Flanged fittings should have lower resistance coefficients than screwed fittings. Resistance coefficients usually decrease with increase in pipe size.

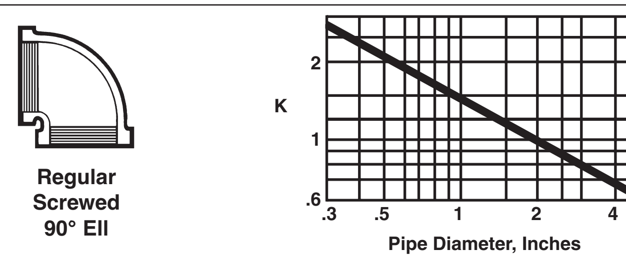
VALUES OF RESISTANCE COEFFICIENT FOR PIPE FITTINGS†



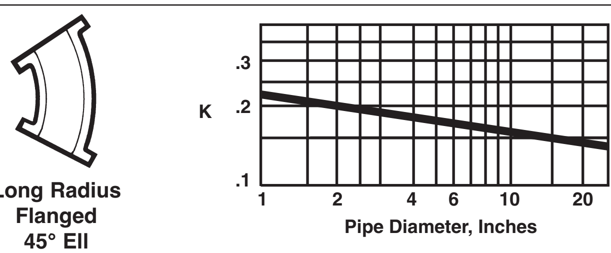
Regular Screwed 45° Ell



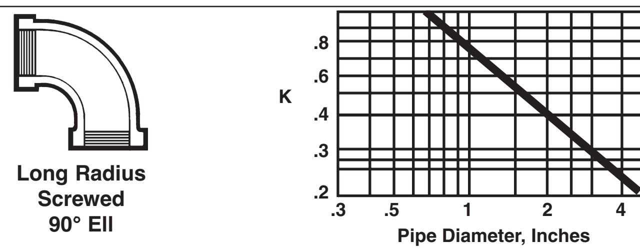
Screwed Tee



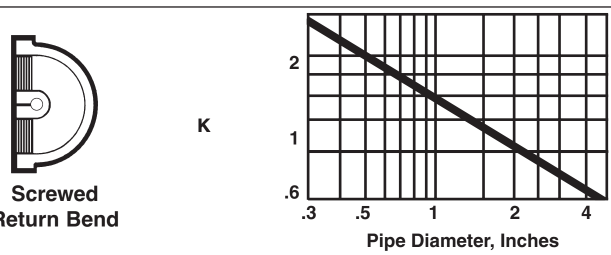
Regular Screwed 90° Ell



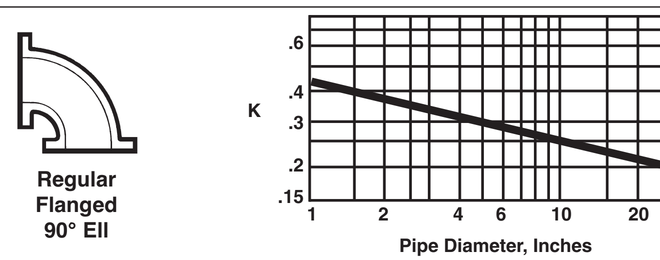
Long Radius Flanged 45° Ell



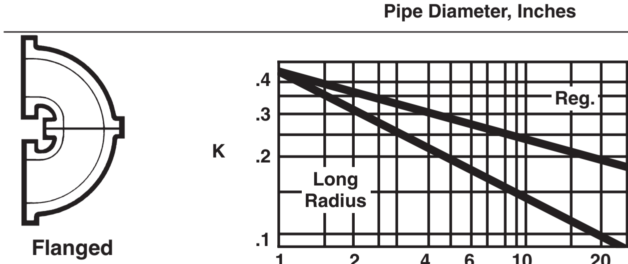
Long Radius Screwed 90° Ell



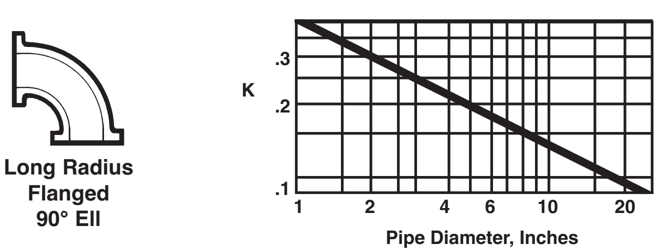
Screwed Return Bend



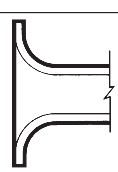
Regular Flanged 90° Ell



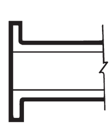
Flanged Return Bend



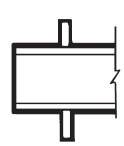
Long Radius Flanged 90° Ell



Bell-Mouth Inlet or Reducer
K = 0.05

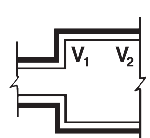


Square Edged Inlet
K = 0.5



Inward Projecting Pipe
K = 1.0

Note: K decreases with increasing wall thickness of pipe and rounding of edges.

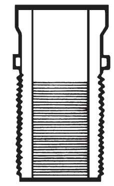


Sudden Enlargement

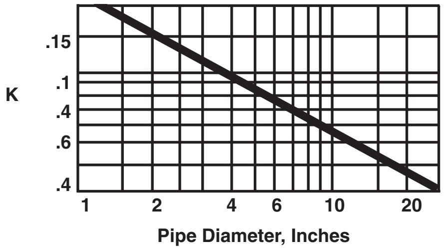
$$h = \frac{(V_1 - V_2)^2}{2g}$$ **Feet of Fluid When $V_2 = O$** $$h = \frac{V_1^2}{2g}$$

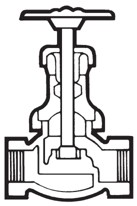
Feet of Fluid

† Courtesy Hydraulic Institute.

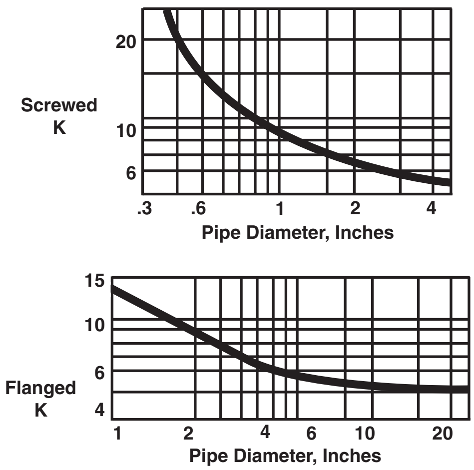


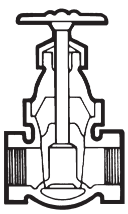
Basket Strainer



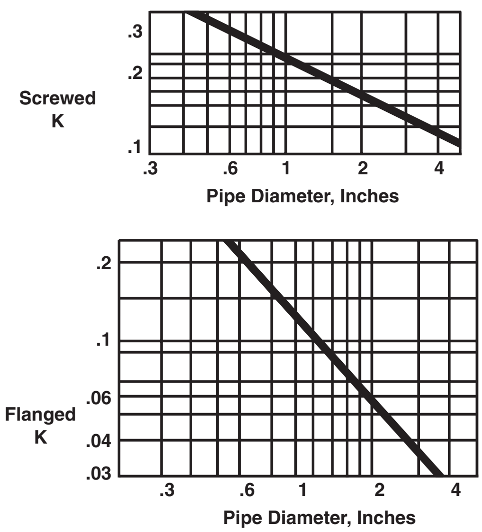


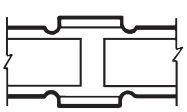
Globe Valve



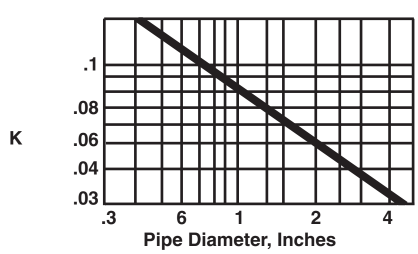


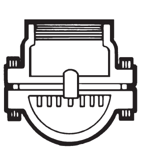
Gate Valve



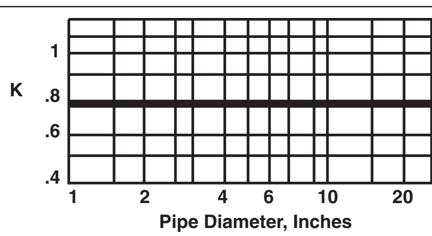


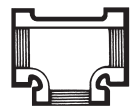
Couplings and Unions



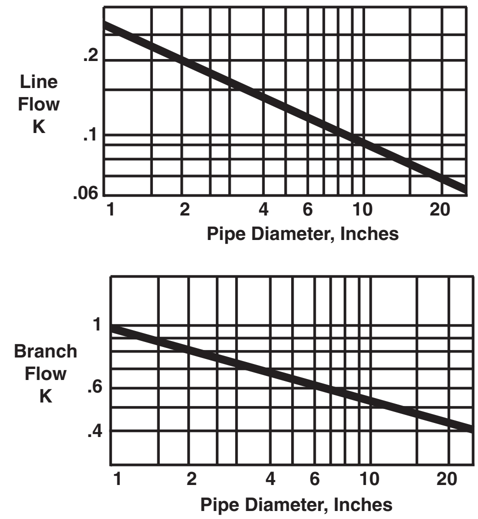


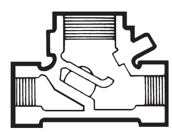
Foot Valve



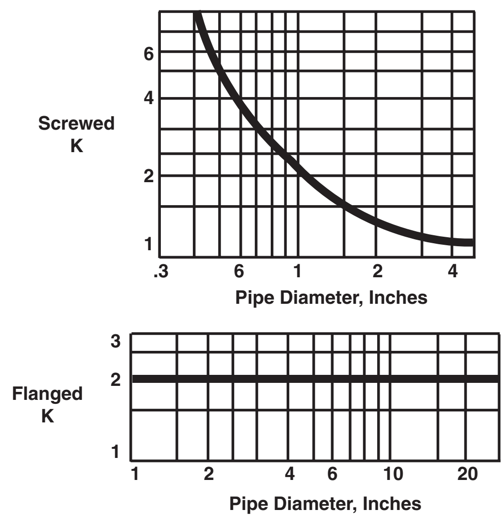


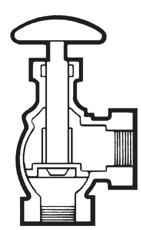
Flanged Tee



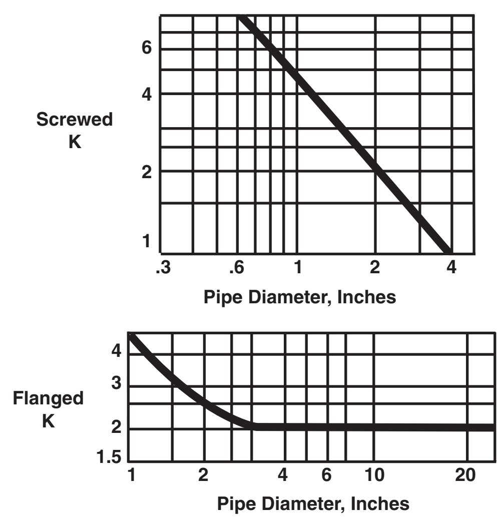


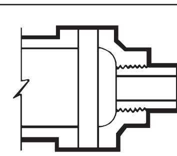
Swing Check Valve





Angle Valve





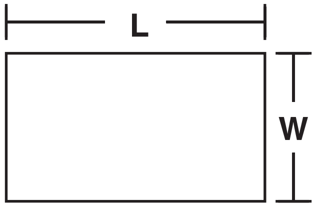
Reducer Bushing and Coupling

Used as Reducer K = 0.05 - 2.0

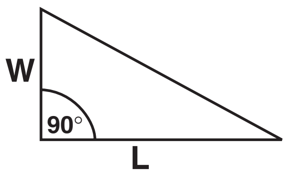
Used as Increaser Loss is up to 40% More than That Caused by a Sudden Enlargement

Hydraulic Charts and Tables

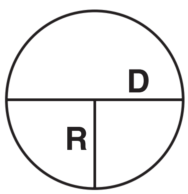
Mathematics and Calculations



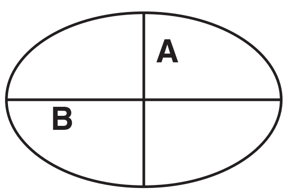
Area of a Square or Retangle
Area = L x W



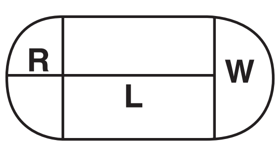
Area of a Right Triangle
Area = (L x W) ÷ 2



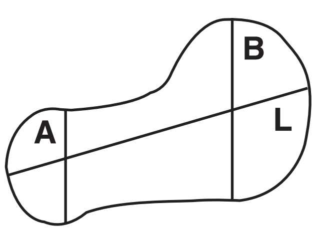
Area of a Circle
Area =Πr^2



Area of an Oval
Area =A x B x Π



Area of an Oblong Shape
Area = (L x W) + Πr^2



Area of a Kidney Shape
Area = (A + B) ÷ 2 x L x .45

CALCULATING GALLONS IN ANY VESSEL

Gallons = Area x Average Depth x 7.48

Example: A vessel 10' wide, 20' long, 4' deep in the shallow end and 7' deep in the deep end (Average depth of 5.5').

1 Cubic foot = 7.48 Gallons

Gallons = 200 sq. ft. x 5.5 ft. x 7.48 = 8,228 Gal.

NOTE:

Calculating the Average Length, Width, and Depth - You may need to take several measurements and average them to get an accurate measurement.

DETERMINING THE TURNOVER RATE

(Number of passes the water takes through a filter in a 24 hour period)

Number of Passes	% of Suspended Solids Removed	Turnover Rate (Hrs.)
1	67%	24
2	86%	12
3	92%	8
*4	95%	6
5	97%	4.8
6	98%	4
7	99%	3.43

*A 6 hour Turnover Rate is the requirement of most health departments for a commercial swimming pool. 60 minutes for a wading pool. 15 to 30 minutes for a commercial spa.

NOTE:

Gallons Per Minute are calculated by dividing the number of minutes in the Turnover Rate into the Gallons of the Swimming Pool or Spa.

Example:

30,000 Gallon Swimming Pool with a Turnover Rate of 6 hours.

30,000 ÷ (6 x 60) = 83 GPM

CALCULATING HEAD LOSS FOR AN EXISTING SWIMMING POOL OR SPA

Pressure Gauge x 2.31 = Head Loss
+
Vacuum Gauge x 1.13 = Head Loss

Total System Loss

Example: Pressure Gauge = 20 lbs.

Vacuum Gauge = 10 inches

Pressure - 20 x 2.31 = 46' of Head
+
Vacuum - 10 x 1.13 = 11' of Head

Total System Head = 57'

NOTE:

Make sure the Filter, Skimmers, Baskets, and Hair Lint Strainers are clean before the pressure and vacuum readings are taken. The gauges will measure the resistance of any dirt or debris in the system.

Steel Pipe Table

Nominal Size	No. Threads per Inch	Diameter Actual External	Tap Drills & Diameter Bore	Standard: Diameter Actual Internal	Internal Area Sq. Inch	GPM at One Foot per Sec. Velocity	Nominal Weight Lbs. per Foot	Bursting Pressure: (a) Lap Weld	*	(b) Butt Weld	*	Extra Heavy: Diameter Actual Internal	Internal Area Sq. Inch	GPM at One Foot per Sec. Velocity	Nominal Weight Lbs. per Foot	Bursting Pressure: (a) Lap Weld	*	(b) Butt Weld	*
⅛"	27	0.405	11/32	0.27	0.06	0.18	0.24	—	1250	13750	2500	0.22	0.04	0.11	0.31	—	2000	19800	3500
¼"	18	0.540	7/16	0.36	0.10	0.32	0.42	—	1250	13350	2500	0.30	0.07	0.22	0.54	—	2000	19000	3500
⅜"	18	0.675	19/32	0.49	0.19	0.60	0.57	—	1250	11050	1500	0.42	0.14	0.44	0.74	—	2000	15500	2500
½"	14	0.840	23/32	0.62	0.30	0.95	0.85	—	1250	10650	1500	0.55	0.23	0.73	1.09	—	2000	14600	2500
¾"	14	1.050	15/16	0.82	0.53	1.66	1.13	—	1250	8850	1500	0.74	0.43	1.35	1.47	—	2000	11900	2000
1"	11½	1.315	1 5/32	1.05	0.86	2.69	1.68	—	1250	8275	1500	0.96	0.72	2.24	2.17	—	2000	11400	2000
1¼"	11½	1.660	1½	1.38	1.50	4.46	2.27	—	1250	6900	1000	1.28	1.28	4.00	3.00	—	2000	9600	1500
1½"	11½	1.900	1 23/32	1.61	2.04	6.35	2.72	—	1250	6275	1000	1.50	1.77	5.51	3.36	—	2000	8850	1500
2"	11½	2.375	2 3/16	2.07	3.36	10.5	3.65	6750	1250	5325	750	1.94	2.95	9.20	5.02	9750	1500	7700	1250
2½"	8	2.875	2⅝	2.47	4.79	14.9	5.79	7350	1000	5800	750	2.32	4.24	13.2	7.66	10100	1500	7950	1250
3"	8	3.500	3¼	3.07	7.39	23.0	7.58	6425	1000	5050	750	2.90	6.61	20.6	10.25	9150	1250	7200	1250
4"	8	4.500	4¼	4.03	12.73	39.7	10.79	5475	750	—		3.83	11.50	35.8	14.98	7900	1250	—	
5"	8	5.563	5 5/16	5.05	20.01	62.4	14.62	4825	750	—		4.81	18.19	56.7	20.78	6950	1250	—	
6"	8	6.625	6⅜	6.07	28.89	90.0	18.97	4375	650	—		5.76	26.07	81.2	28.57	6850	1000	—	
8"	8	8.625	8 11/32	7.98	50.02	156.0	28.55	3875	650	—		7.63	45.66	142	43.34	6050	1000	—	
10"	8	10.75	10 7/16	10.02	78.85	246.0	40.48	3525	500	—		9.75	74.66	233	54.74	4825	750	—	
12"	8	12.75	12 7/16	12.00	113.1	353.0	49.56	3050	500	—		11.75	108.4	338	65.42	4075	750	—	

Bursting pressures (cold water) based on Barlow's Formula $P = \frac{2f\,t}{D}$ Where P = Pressure in lbs. per sq. in.;
f = Fibre; t = Thickness in inches; D = Outside diameter in inches. Stress (a) 41000 (b) 52000 (c) 62000 lbs. per sq. in.
*Pipes serviceable for pressures indicated. If subjected to severe shocks, reduce pressures indicated.

Table for Equalizing Pipes

The size of main pipe is given in the column at the left. The number of branches is given in the line on top, and the proper size of branches is given in the body of the table on the line of each main and beneath the desired number of branches.
In commercial sizes the nominal 1¼ inch pipe is generally over-size, often as large as 1⅜. it is safe to call it 1.3 inch, and it is so figured in the table. Exact sizes are given for branch pipes. The designer of the pipe system can thus better select the commercial sizes to be used.

Size of Main Pipe	Number of Branches: 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Size of Main Pipe
1	.758	.644	.574	.525	.488	.459	.435	.415	.398	.383	.370	.358	.348	.338	.330	1
1¼	.985	.838	.747	.683	.635	.597	.556	.540	.518	.498	.482	.466	.452	.440	.428	1¼
1½	1.14	.967	.861	.788	.733	.689	.653	.623	.597	.575	.555	.538	.522	.508	.494	1½
2	1.52	1.29	1.15	1.05	.977	.918	.870	.830	.796	.766	.740	.717	.696	.677	.660	2
2½	1.89	1.61	1.44	1.31	1.22	1.15	1.09	1.04	.995	.958	.925	.896	.870	.846	.825	2½
3	2.27	1.92	1.72	1.58	1.47	1.38	1.31	1.25	1.19	1.15	1.11	1.08	1.04	1.02	.989	3
3½	2.65	2.26	2.01	1.84	1.71	1.61	1.52	1.45	1.39	1.34	1.30	1.25	1.22	1.18	1.15	3½
4	3.03	2.58	2.30	2.10	1.95	1.84	1.74	1.66	1.59	1.53	1.48	1.43	1.39	1.35	1.32	4
4½	3.41	2.90	2.58	2.36	2.20	2.07	1.96	1.87	1.79	1.72	1.67	1.61	1.57	1.52	1.48	4½
5	3.79	3.22	2.87	2.63	2.44	2.30	2.18	2.08	1.99	1.92	1.85	1.79	1.74	1.69	1.65	5
6	4.55	3.87	3.45	3.15	2.93	2.75	2.61	2.49	2.39	2.30	2.22	2.15	2.09	2.03	1.98	6
7	5.30	4.51	4.02	3.68	3.42	3.21	3.05	2.91	2.79	2.68	2.59	2.51	2.44	2.37	2.31	7
8	6.06	5.16	4.59	4.20	3.91	3.67	3.48	3.32	3.18	3.09	2.96	2.87	2.78	2.71	2.64	8
9	6.82	5.80	5.17	4.73	4.40	4.13	3.92	3.74	3.58	3.45	3.33	3.23	3.13	3.04	2.97	9
10	7.58	6.44	5.74	5.25	4.88	4.59	4.35	4.15	3.98	3.83	3.70	3.59	3.48	3.38	3.30	10
12	9.08	7.73	6.89	6.30	5.86	5.51	5.22	4.98	4.78	4.60	4.44	4.30	4.18	4.06	3.96	12

Uniform Flow Velocity and Capacity of Sanitary Drains at 1/4" Slope per Foot

Pipe Size Inches	Full or Half-Full Flow Velocity V - fps	Half-Full Flow Capacity g - gpm	Full Flow Capacity g - gpm
1½	1.85	5.85	11.70
2	1.98	9.70	19.40
2½	2.30	17.60	35.20
3	2.50	28.60	57.20
4	2.91	57.00	114.00
5	3.15	96.50	193.00
6	3.58	157.50	315.00
8	4.07	318.50	637.00
10	4.69	574.00	1,148.00
12	5.91	936.00	1,872.00
15	6.15	1,690.00	3,380.00

Theoretical Discharge of Nozzles in U.S. Gallons per Minute

Head		Velocity of Discharge Feet	Diameter of Nozzle in Inches								
Pounds	Feet	Per Second	1/16	1/8	3/16	1/4	3/8	1/2	5/8	3/4	7/8
10	23.1	38.6	0.37	1.48	3.32	5.91	13.3	23.6	36.9	63.1	72.4
15	34.6	47.25	0.45	1.81	4.06	7.24	16.3	28.9	45.2	65.0	88.5
20	46.2	54.55	0.52	2.09	4.69	8.35	18.8	33.4	52.2	75.1	102
25	57.7	61.0	0.58	2.34	5.25	9.34	21.0	37.3	58.3	84.0	114
30	69.3	66.85	0.64	2.56	5.75	10.2	23.0	40.9	63.9	92.0	125
35	80.8	72.2	0.69	2.77	6.21	1.11	24.8	44.2	69.0	99.5	135
40	92.4	77.2	0.74	2.96	6.64	11.8	26.6	47.3	73.8	106	145
45	103.9	81.8	0.78	3.13	7.03	12.5	28.2	50.1	78.2	113	153
50	115.5	86.25	0.83	3.30	7.41	13.2	29.7	52.8	82.5	119	162
55	127.0	90.4	0.87	3.46	7.77	13.8	31.1	55.3	86.4	125	169
60	138.6	94.5	0.90	3.62	8.12	14.5	32.5	57.8	90.4	130	177
65	150.1	98.3	0.94	3.77	8.45	15.1	33.8	60.2	94.0	136	184
70	161.7	102.1	0.98	3.91	8.78	15.7	35.2	62.5	97.7	141	191
75	173.2	105.7	1.01	4.05	9.08	16.2	36.4	64.7	101	146	198
80	184.8	109.1	1.05	4.18	9.39	16.7	37.6	66.8	104	150	206
85	196.3	112.5	1.08	4.31	9.67	17.3	38.8	68.9	108	155	211
90	207.9	115.8	1.11	4.43	9.95	17.7	39.9	70.8	111	160	217
95	219.4	119.0	1.14	4.56	10.2	18.2	41.0	72.8	114	164	223
100	230.9	122.0	1.17	4.67	10.0	18.7	42.1	74.7	117	168	229
105	242.4	125.0	1.20	4.79	10.8	19.2	43.1	76.5	120	172	234
110	254.0	128.0	1.23	4.90	11.0	19.6	44.1	78.4	122	176	240
115	265.5	130.9	1.25	5.01	11.2	20.0	45.1	80.1	125	180	245
120	277.1	133.7	1.28	5.12	11.5	20.5	46.0	81.8	128	184	251
125	288.6	136.4	1.31	5.22	11.7	20.9	47.0	83.5	130	188	256
130	300.2	139.1	1.33	5.33	12.0	21.3	48.0	85.2	133	192	261
135	311.7	141.8	1.36	5.43	12.2	21.7	48.9	86.7	136	195	266
140	323.3	144.3	1.38	5.53	12.4	22.1	49.8	88.4	138	199	271
145	334.8	146.9	1.41	5.62	12.6	22.5	50.6	89.9	140	202	276
150	346.4	149.5	1.43	5.72	12.9	22.9	51.5	91.5	143	206	280
175	404.1	161.4	1.55	6.18	13.9	24.7	55.6	98.8	154	222	302
200	461.9	172.6	1.65	6.61	14.8	26.4	59.5	106	165	238	323

Head		Velocity of Discharge Feet	Diameter of Nozzle in Inches								
Pounds	Feet	Per Second	1	1⅛	1¼	1⅜	1½	1¾	2	2¼	2½
10	23.1	38.6	94.5	120	148	179	213	289	378	479	591
15	34.6	47.25	116	147	181	219	260	354	463	585	723
20	46.2	54.55	134	169	209	253	301	409	535	676	835
25	57.7	61.0	149	189	234	283	336	458	598	756	934
30	69.3	66.85	164	207	256	309	368	501	655	828	1023
35	80.8	72.2	177	224	277	334	398	541	708	895	1106
40	92.4	77.2	188	239	296	357	425	578	766	957	1182
45	103.9	81.8	200	263	313	379	451	613	801	1015	1252
50	115.5	86.25	211	267	330	399	475	647	845	1070	1320
55	127.0	90.4	221	280	346	418	498	678	886	1121	1385
60	138.6	94.5	231	293	362	438	521	708	926	1172	1447
65	150.1	98.3	241	305	376	455	542	737	964	1220	1506
70	161.7	102.1	250	317	391	473	563	765	1001	1267	1565
75	173.2	105.7	259	327	404	489	582	792	1037	1310	1619
80	184.8	109.1	267	338	418	505	602	818	1010	1354	1672
85	196.3	112.5	276	349	431	521	620	844	1103	1395	1723
90	207.9	115.8	284	359	443	536	638	868	1136	1436	1773
95	219.4	119.0	292	369	456	551	656	892	1168	1476	1824
100	230.9	122.0	299	378	467	565	672	915	1196	1512	1870
105	242.4	125.0	306	388	479	579	689	937	1226	1550	1916
110	254.0	128.0	314	397	490	593	705	960	1255	1588	1961
115	265.5	130.9	320	406	501	606	720	980	1282	1621	2005
120	277.1	133.7	327	414	512	619	736	1002	1310	1659	2050
125	288.6	136.4	334	423	522	632	751	1022	1338	1690	2090
130	300.2	139.1	341	432	533	645	767	1043	1365	1726	2132
135	311.7	141.8	347	439	543	656	780	1063	1390	1759	2173
140	323.3	144.3	354	448	553	668	795	1082	1415	1790	2212
145	334.8	146.9	360	455	562	680	809	1100	1440	1820	2250
150	346.4	149.5	366	463	572	692	824	1120	1466	1853	2290
175	404.1	161.4	395	500	618	747	890	1210	1582	2000	2473
200	461.9	172.6	423	535	660	799	950	1294	1691	2140	2645

NOTE: The actual quantities will vary from these figures, the amount of variation depending upon the shape of nozzle and size of pipe at the point where the pressure is determined. With smooth taper nozzles the actual discharge is about 94 percent of the figures given in the tables.

Hydraulic Charts and Tables

Pressure and Equivalent Feet Head of Water

Lbs. per Sq. In.	Feet Head	Lbs. per Sq. In.	Feet Head	Lbs. per Sq. In.	Feet Head	Lbs. per Sq. In.	Feet Head
1	2.31	20	46.18	120	277.07	225	519.51
2	4.62	25	57.72	125	288.62	250	577.24
3	6.93	30	69.27	130	300.16	275	643.03
4	9.24	40	92.36	140	323.25	300	692.69
5	11.54	50	115.45	150	346.34	325	750.41
6	13.85	60	138.54	160	369.43	350	808.13
7	16.16	70	161.63	170	392.52	375	865.89
8	18.47	80	184.72	180	415.61	400	922.58
9	20.78	90	207.81	190	438.90	500	1154.48
10	23.09	100	230.90	200	461.78	1000	2309.00
15	34.63	110	253.98	—	—	—	—

Feet Head of Water and Equivalent Pressures

Feet Head	Lbs. per Sq. In.	Feet Head	Lbs. per Sq. In.	Feet Head	Lbs. per Sq. In.	Feet Head	Lbs. per Sq. In.
1	.43	30	12.99	140	60.63	300	129.93
2	.87	40	17.32	150	64.96	325	140.75
3	1.30	50	21.65	160	69.29	350	151.58
4	1.73	60	25.99	170	73.63	400	173.24
5	2.17	70	30.32	180	77.96	500	216.55
6	2.60	80	34.65	190	82.29	600	259.85
7	3.03	90	38.98	200	86.62	700	303.16
8	3.46	100	43.31	225	97.45	800	346.47
9	3.90	110	47.65	250	102.27	900	389.78
10	4.33	120	51.97	275	119.10	1000	433.09
20	8.66	130	56.30	—	—	—	—

Equivalent Values of Pressure

Inches of Mercury – Feet of Water – Pounds per Sq. In.

Inches of Mercury	Feet of Water	Pounds per Sq. In.	Inches of Mercury	Feet of Water	Pounds per Sq. In.	Inches of Mercury	Feet of Water	Pounds per Sq. In.
1	1.13	0.49	11	12.45	5.39	21	23.78	10.3
2	2.26	0.98	12	13.57	5.87	22	24.88	10.8
3	3.39	1.47	13	14.70	6.37	23	26.00	11.28
4	4.52	1.95	14	15.82	6.86	24	27.15	11.75
5	5.65	2.44	15	16.96	7.35	25	28.26	12.25
6	6.78	2.93	16	18.09	7.84	26	29.40	12.73
7	7.91	3.42	17	19.22	8.33	27	30.52	13.23
8	9.04	3.91	18	20.35	8.82	28	31.65	13.73
9	10.17	4.40	19	21.75	9.31	29	32.80	14.22
10	11.30	4.89	20	22.60	9.80	29.929	33.947	14.6969

Practical Suction Lifts at Various Elevations Above Sea Level

Elevation	Barometer Reading Lbs. per Sq. In.	Theoretical Suction Lift Feet	Practical Suction Lift Feet	Vacuum Gauge* Inches
At Sea Level	14.7	34.0	22	19.5
¼ mile – 1,320 feet – above sea level	14.0	32.4	21	18.6
½ mile – 2,640 feet – above sea level	13.3	30.8	20	17.7
¾ mile – 3,960 feet – above sea level	12.7	29.2	18	15.9
1 mile – 5,280 feet – above sea level	12.0	27.8	17	15.0
1¼ mile – 6,600 feet – above sea level	11.4	26.4	16	14.2
1¾ mile – 7,920 feet – above sea level	10.9	25.1	15	13.3
2 miles – 10,560 feet – above sea level	9.9	22.8	14	12.4

Note: Multiply barometer in inches by .491 to obtain lbs. per sq. in. *Vacuum gauge readings in inches correspond to practical suction lift in feet only when pump is stopped. Pipe friction increases vacuum gauge readings when pump is running. For quiet operation, vacuum gauge should never register more than 20 inches when pump is running.

Water

Altitude	Temperatures in Degrees Fahrenheit									
	120	130	140	150	160	170	180	190	200	210
Sea Level..............	-10	-7	-5	-2	0	+3	+5	+7	+10	+12
2000	-5	-5	-2	+1	+3	+5	+7	+10	+12	+15
4000	-5	-2	+1	+3	+5	+7	+10	+12	+14	
6000	0	+1	+3	+5	+7	+10	+12	+14	+16	—
8000	0	+3	+5	+7	+9	+12	+14	+16	—	—
10000	+2	+4	+7	+9	+11	+14	+16	+18	—	—

This table gives the maximum permissible suction lift or the minimum head permitted on the suction side of a pump at various altitudes and liquid temperatures. A minus sign before a number indicates maximum suction lift. A plus sign before a number indicates minimum head. These figures are to be used as a guide and are not guaranteed.

When pumping volatile liquids such as gasoline and naphtha, special consideration must be given to the amount of suction lift and the size of the suction pipe used. On such liquids the suction lift, whether it is actual vertical lift or is caused by pipe line friction, must be kept as low as possible, and should never exceed 12 feet.

For liquids such as lube oil, molasses, etc., a suction lift up to 24 feet, at sea level, is usually satisfactory.

Flexible Polyethylene Pipe					
Nominal Pipe Size	Inside Diameter	SDR-15 Outside Diameter	SDR-11.5 Outside Diameter	SDR-9 Outside Diameter	SDR-7 Outside Diameter
½	.622	.742	.742	.760	.800
¾	.824	.944	.968	1.008	1.060
1	1.049	1.189	1.231	1.283	1.349
1¼	1.380	1.564	1.620	1.686	1.774
1½	1.610	1.824	1.890	1.968	2.070
2	2.067	2.343	2.427	2.527	2.657

Schedule 40 Plastic Pipe			Schedule 80 Plastic Pipe		
Nominal Pipe Size	Inside Diameter	Outside Diameter	Nominal Pipe Size	Inside Diameter	Outside Diameter
½	.622	.840	½	.546	.840
¾	.824	1.050	¾	.742	1.050
1	1.049	1.315	1	.957	1.315
1¼	1.380	1.660	1¼	1.278	1.600
1½	1.610	1.900	1½	1.500	1.900
2	2.067	2.375	2	1.939	2.375
2½	2.469	2.875	2½	2.323	2.875
3	3.068	3.500	3	2.900	3.500
4	4.026	4.500	4	3.826	4.500

CAVITATION

Cavitation is a term used to describe a rather complex phenomenon that may exist in a pumping installation. In a centrifugal pump this may be explained as follows. When a liquid flows through the suction line and enters the eye of the pump impeller an increase in velocity takes place. This increase in velocity is, of course, accompanied by a reduction in pressure. If the pressure falls below the vapor pressure corresponding to the temperature of the liquid, the liquid will vaporize and the flowing stream will consist of liquid plus pockets of vapor. Flowing further through the impeller, the liquid reaches a region of higher pressure and the cavities of vapor collapse. It is this collapse of vapor pockets that causes the noise incident to caviation.

Cavitation need not be a problem in a pump installation if the pump is properly designed and installed, and operated in accordance with the designer's recommendations. Also, caviation is not necessarily destructive. Cavitation varies from very mild to very severe. A pump can operate rather noiselessly yet be cavitating mildly. The only effect may be a slight drop in efficiency. On the other hand severe cavitation will be very noisy and will destroy the pump impeller and/or other parts of the pump.

Any pump can be made to cavitate, so care should be taken in selecting the pump and planning the installation. For centrifugal pumps avoid as much as possible the following conditions:

1. Heads much lower than head at peak efficiency of pump.
2. Capacity much higher than capacity at peak efficiency of pump.
3. Suction lift higher or positive head lower than recommended by manufacturer.
4. Liquid temperatures higher than that for which the system was originally designed.
5. Speeds higher than manufacturer's recommendation.

Cavitation is not confined to pumping equipment alone. It also occurs in piping systems where the liquid velocity is high and the pressure low. Cavitation should be suspected when noise is heard in pipe lines at sudded enlargements of the pipe cross-section, sharp bends, throttled valves or like situations.

NET POSITIVE SUCTION HEAD (NPSH)

NPSH can be defined as the head that causes liquid to flow through the suction piping and finally enter the eye of the impeller.

This head that causes flow comes from either the pressure of the atmosphere or from static head plus atmospheric pressure. A pump operating under a suction lift has as a source of pressure to cause flow only the pressure of the atmosphere. The work that can be done, therefore, on the suction side of a pump is limited, so NPSH becomes very important to the successful operation of the pump. There are two values of NPSH to consider.

REQUIRED NPSH is a function of the pump design. It varies between different makes of pumps, between different pumps of the same make and varies with the capacity and speed of any one pump. This is a value that must be supplied by the maker of the pump.

The required NPSH of a water pump at rated capacity is 17 ft. Water Temperature 85° F. Elevation 1000 ft. above sea level.

Entrance and friction losses in suction piping calculated = 2 ft. What will be the maximum suction lift permissible?

To better visualize the problem the solution is presented graphically on the right. The two horizontal lines are spaced apart a distance equal to the barometric pressure in feet.

AVAILABLE NPSH is a function of the system in which the pump operates. It can be calculated for any installation. Any pump installation, to operate successfully, must have an available NPSH equal to or greater than the required NPSH of the pump at the desired pump conditions.

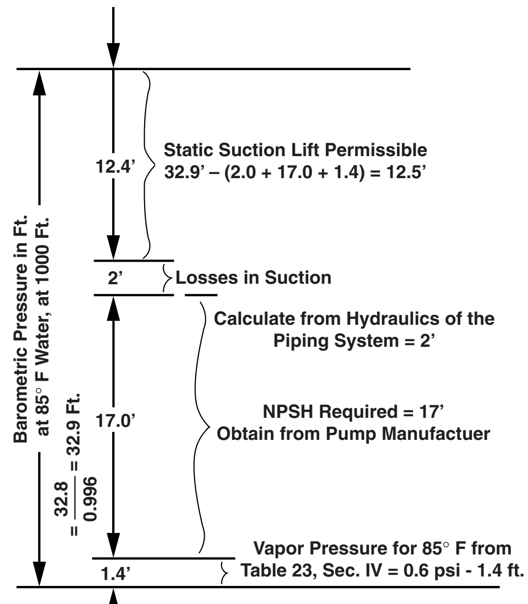
When the source of liquid is above the pump:

NPSH = Barometric Pressure, ft. + Static Head on suction, ft. -friction losses in suction piping, ft. - Vapor Pressure of liquid, ft.

When the source of liquid is below the pump:

NPSH = Barometric Pressure, ft. - Static Suction lift, ft. -friciton losses in suction piping, ft. - Vapor Pressure of liquid, ft.

To Illustrate the Use of These Equations
Consider the Following Example:



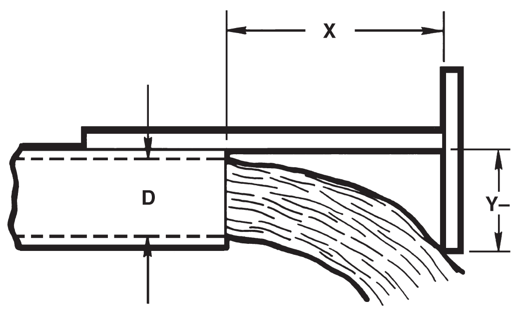
Graphic Solution NPSH Problem

APPROXIMATING WATER FLOW

It is possible to approximate water flow from horizontal or vertical pipes when it is not practical to use flow meters or other measuring devices. This can be done by measuring to the top of the flowing stream, always measuring the horizontal distance "X" in inches as illustrated, and determining the flow from the chart show below.

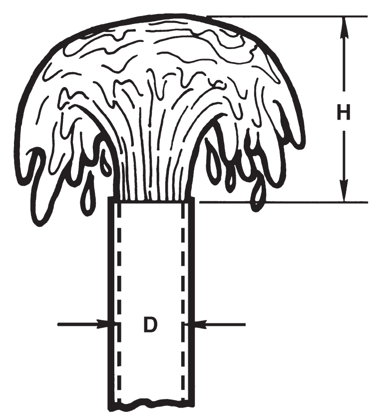
Approximate Capacity, GPM, for Full Flowing Horizontal Pipes

Std. Wt. Steel Pipe, Inside Dia., In.		Distance X, In., When Y = 12"										
Nominal	Actual	12	14	16	18	20	22	24	26	28	30	32
2	2.067	42	49	56	63	70	77	84	91	98	105	112
2½	2.469	60	70	80	90	100	110	120	130	140	150	160
3	3.068	93	108	123	139	154	169	185	200	216	231	246
4	4.026	159	186	212	239	266	292	318	345	372	398	425
5	5.067	250	292	334	376	417	459	501	543	585	627	668
6	6.065	362	422	482	542	602	662	722	782	842	902	962
8	7.981	627	732	837	942	1047	1150	1255	1360	1465	1570	1675
10	10.020	980	1145	1310	1475	1635	1800	1965	2130	2290	2455	2620
12	12.000	1415	1650	1890	2125	2360	2595	2830	3065	3300	3540	3775

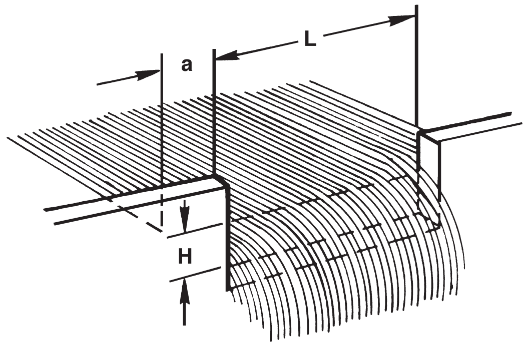


Approximate Capacity, GPM, for Full Flowing Vertial Pipes

Nominal	Vertical Height, H, of Water Jet, In.										
I.D. Pipe, In.	3	3.5	4	4.5	5	5.5	6	7	8	10	12
2	38	41	44	47	50	53	56	61	65	74	82
3	81	89	96	103	109	114	120	132	141	160	177
4	137	151	163	174	185	195	205	222	240	269	299
6	318	349	378	405	430	455	480	520	560	635	700
8	567	623	684	730	776	821	868	945	1020	1150	1270
10	950	1055	1115	1200	1280	1350	1415	1530	1640	1840	2010



The accuracy of these methods will vary up to 10%. The pipe must be flowing full.



Discharge from Rectangular Weir with End Contractions

Figures in Table are in Gallons Per Minute								
Head (H) in Inches	Length (L) of Weir in Feet: 1	3	5	Additional GPM for Each Ft. Over 5 Ft.	Head (H) in Inches	Length (L) of Weir in Feet: 3	5	Additional GPM for Each Ft. Over 5 Ft.
1	35.4	107.5	179.8	36.05	8	2338	3956	814
1¼	49.5	150.4	250.4	50.4	8¼	2442	4140	850
1½	64.9	197	329.5	66.2	8½	2540	4312	890
1¾	81	248	415	83.5	8¾	2656	4511	929
2	98.5	302	506	102	9	2765	4699	970
2¼	117	361	605	122	9¼	2876	4899	1011
2½	136.2	422	706	143	9½	2985	5098	1051
2¾	157	485	815	165	9¾	3101	5288	1091
3	177.8	552	926	187	10	3216	5490	1136
3¼	199.8	624	1047	211	10½	3480	5940	1230
3½	222	695	1167	236	11	3716	6355	1320
3¾	245	769	1292	261	11½	3960	6780	1410
4	269	846	1424	288	12	4185	7165	1495
4¼	293.6	925	1559	316	12½	4430	7595	1575
4½	318	1006	1696	345	13	4660	8010	1660
4¾	344	1091	1835	374	13½	4950	8510	1780
5	370	1175	1985	405	14	5215	8980	1885
5¼	395.5	1262	2130	434	14½	5475	9440	1985
5½	421.6	1352	2282	465	15	5740	9920	2090
5¾	449	1442	2440	495	15½	6015	10400	2165
6	476.5	1535	2600	528	16	6290	10900	2300
6¼		1632	2760	560	16½	6565	11380	2410
6½		1742	2920	596	17	6925	11970	2520
6¾		1826	3094	630	17½	7140	12410	2640
7		1928	3260	668	18	7410	12900	2745
7¼		2029	3436	701.5	18½	7695	13410	2855
7½		2130	3609	736	19	7980	13940	2970
7¾		2238	3785	774	19½	8280	14460	3090

This table is based on Francis formula:

$Q = 3.33 (L - 0.2H)H^{1.5}$

which

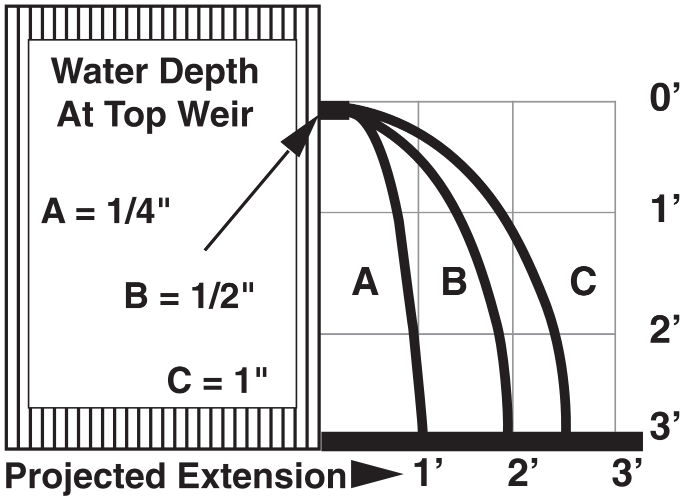
Q = ft.^{3} of water flowing per second.

L = length of weir opening in feet (should be 4 to 8 times H).

H = head on weir in feet (to be measured at least 6 ft. back of weir opening).

a = should be at least 3 H.

Hydraulic Charts and Tables



WATER FALL AND VANISHING EDGE DESIGN POINTS

1. Water falls with a drop of over 3 feet and a 1/4" depth at the top of the weir. For every 3' over the first 3' drop, you should add an additional 1/4" in depth at the top of the weir.
2. Rounded or Copping edged weirs require at least 1" depth of water to break the plane and not rap under the edge.
3. Water surges from swimmers can increase the required extension by as much as one foot.

Vanishing Edge Sump Capacities in Gallons

Water Feature Surface Area	Water Depth at Top of Weir (*Capacity in Gallons)							
	1/4"	1/2"	3/4"	1"	1¼"	1½"	1¾"	2"
100 sq. ft.	486	935	190	1,870	2,356	2,805	3,254	3,740
200 sq. ft.	935	1,870	2,805	3,740	4,675	5,610	6,545	7,479
300 sq. ft.	1,421	2,805	4,188	5,610	7,031	8,414	9,798	11,219
400 sq. ft.	1,870	3,740	5,610	7,479	9,349	11,219	13,089	14,959
500 sq. ft.	2,356	4,675	6,993	9,349	11,705	14,024	16,343	18,699
600 sq. ft.	2,842	5,610	8,377	11,219	14,061	16,829	19,596	22,438
700 sq. ft.	3,291	6,545	9,798	13,089	16,380	19,634	22,887	26,178
800 sq. ft.	3,740	7,479	11,219	14,959	18,699	22,438	26,178	29,918
900 sq. ft.	4,226	8,414	12,603	16,829	21,055	25,243	29,432	33,657
1,000 sq. ft.	4,712	9,349	13,987	18,699	23,411	28,048	32,685	37,397

* Sump capacity calculated at 4 times absolute minimum.

NOTES:

1. Sump should be 6" to 1' wider that the weir to catch "leakage" at both ends of the weir.
2. Main drains should not exceed 50 gpm each to avoid eddy's and possible entrapment. A minimum of two are required for flows below 100 gpm.
3. An over flow protection should be installed to handle "Swimmer Waves" and heavy rains.
4. A low water float switch should be installed no closer than 1 foot from the bottom of the sump to protect the pump(s) in case the water level drops too low.
5. An automatic water fill should be located in the sump to maintain the correct water level.

Conversion Tables

Units of Length				
Unit	Inch	Foot	Yard	Meter
Inch	1.0	.0833	.0278	.0254
Foot	12.0	1.0	.333	.0348
Yard	36.0	3.0	1.0	.9144
Meter	39.37	3.281	1.094	1.0

Units of Area				
Unit	Inch	Foot	Yard	Meter
Square Inch	1.0	.00694	.000772	.000645
Square Foot	144.0	1.0	.1111	.0929
Square Yard	1,296.0	9.0	1.0	.836
Square Meter	1,550.0	10.76	1.196	1.0

Units of Volume					
Unit	U.S. Gallon	Imperial Gallon	Cubic Feet	Pounds of Water	Cubic Meters
U.S. Gallon	1.0	.833	.1337	8.33	.003785
Imperial Gallon	1.2	1.0	.1605	10.9	.004546
Cubic Feet	7.481	6.232	1.0	62.37	.0283
Pounds of Water	.12	.1	.0160	1.0	.00045
Cubic Meters	264.2	220.0	35.31	2,204.0	1.0

Units of Flow					
Unit	U.S. GPM	Imperial GPM	Cubic Feet/Second	Cubic Feet/Hour	Liters/Second
U.S. GPM	1.0	.833	.00223	.227	.0631
Imperial GPM	1.2	1.0	.00268	.272	.0757
Cubic Feet/Second	448.4	374.0	1.0	101.9	28.32
Cubic Feet/Hour	4.403	3.67	.00981	1.0	.2778
Liters/Second	15.85	13.21	.0353	3.60	1.0

Units of Pressure				
Unit	Inches of Water	Feet of Water	Pounds per Square Inch	Inches of Mercury
Inches of Water	1.0	.833	.0361	.0736
Feet of Water	12.0	1.0	.433	.883
Pounds per Square Inch	27.72	2.31	1.0	2.04
Inches of Mercury	13.596	1.133	.4906	1.0

Hydraulic Charts and Tables

Capacity of Square Tanks

	Temperatures in Degrees Fahrenheit							
Dimension in Feet	**1'**	**4'**	**5'**	**6'**	**8'**	**10'**	**11'**	**12'**
4 x 4	119.68	479	598	718	957	1197	1316	1436
5 x 5	187.00	748	935	1202	1516	1870	2057	2244
6 x 6	269.28	1077	1346	1616	2154	2693	2968	3231
7 x 7	366.52	1466	1833	2199	2922	3665	4032	4398
8 x 8	478.72	1915	2394	2872	3830	4787	5266	5745
9 x 9	605.88	2424	3029	3635	4847	6059	6665	7212
10 x 10	748.08	2992	3740	4488	5984	7480	8228	8976
11 x 11	905.08	3620	4525	5430	7241	9051	9956	10861
12 x 12	1077.12	4308	5386	6463	8617	10771	11848	12925

To find the capacity of a depth not given, multiply the capacity for one foot by the required depth in feet.

Cylindrical Tanks Set Horizontally and Partially filled

	Gallons per Foot of Length When Tank is Filled								
Diameter	**1/10**	**1/5**	**3/10**	**2/5**	**1/2**	**3/5**	**7/10**	**4/5**	**9/10**
1 Ft.	.3	.8	1.4	2.1	2.9	3.6	4.3	4.9	5.5
2 Ft.	1.2	3.3	5.9	8.8	11.7	14.7	17.5	20.6	22.2
3 Ft.	2.7	7.5	13.6	19.8	26.4	33.0	39.4	45.2	50.1
4 Ft.	4.9	13.4	23.8	35.0	47.0	59.0	70.2	80.5	89.0
5 Ft.	7.6	20.0	37.0	55.0	73.0	92.0	110.0	126.0	139.0
6 Ft.	11.0	30.0	53.0	78.0	106.0	133.0	158.0	182.0	201.0
7 Ft.	15.0	41.0	73.0	107.0	144.0	181.0	215.0	247.0	272.0
8 Ft.	19.0	52.0	96.0	140.0	188.0	235.0	281.0	322.0	356.0
9 Ft.	25.0	67.0	112.0	178.0	238.0	298.0	352.0	408.0	450.0
10 Ft.	30.0	83.0	149.0	219.0	294.0	368.0	440.0	504.0	556.0
11 Ft.	37.0	101.0	179.0	265.0	356.0	445.0	531.0	610.0	672.0
12 Ft.	44.0	120.0	214.0	315.0	423.0	530.0	632.0	741.0	800.0
13 Ft.	51.0	141.0	250.0	370.0	496.0	621.0	740.0	850.0	940.0
14 Ft.	60.0	164.0	291.0	430.0	576.0	722.0	862.0	989.0	1084.0
15 Ft.	68.0	188.0	334.0	494.0	661.0	829.0	988.0	1134.0	1253.0

Capacity of Round Tanks

Per Foot of Depth

Diam.	Gals.	Area Sq. Ft.	Diam.	Gals.	Area Sq. Ft.	Diam.	Gals.	Area Sq. Ft.	Diam.	Gals.	Area Sq. Ft.
1’	5.87	.785	4’	94.00	12.566	11’	710.90	95.03	22’	2843.60	380.13
1’ 1”	6.89	.922	4’ 1”	97.96	13.095	11’ 3”	743.58	99.40	22’ 3”	2908.60	388.82
1’ 2”	8.00	1.069	4’ 2”	102.00	13.635	11’ 6”	776.99	103.87	22’ 6”	2974.30	397.61
1’ 3”	9.18	1.227	4’ 3”	106.12	14.186	11’ 9”	811.14	108.43	22’ 9”	3040.80	406.49
1’ 4”	10.44	1.396	4’ 4”	110.32	14.748	12’	846.03	113.10	23’	3108.00	415.48
1’ 5”	11.79	1.576	4’ 5”	114.61	15.321	12’ 3”	881.65	117.86	23’ 3”	3175.90	424.56
1’ 6”	13.22	1.767	4’ 6”	118.97	15.90	12’ 6”	918.00	122.72	23’ 6”	3244.60	433.74
1’ 7”	14.73	1.969	4’ 7”	123.42	16.50	12’ 9”	955.09	127.68	23’ 9”	3314.00	443.01
1’ 8”	16.32	2.182	4’ 8”	127.95	17.10	13’	992.73	132.73	24’	3384.10	452.39
1’ 9”	17.99	2.405	4’ 9”	132.56	17.72	13’ 3”	1031.50	137.89	24’ 3”	3455.00	461.86
1’ 10”	19.75	2.640	4’ 10”	137.25	18.35	13’ 6”	1070.80	142.14	24’ 6”	3526.60	471.44
1’ 11”	21.58	2.885	4’ 11”	142.02	18.99	13’ 9”	1110.80	148.49	24’ 9”	3598.90	481.11
2’	23.50	3.142	5’ 8”	188.66	25.22	14’	1151.50	153.94	25’	3672.00	490.87
2’ 1”	25.50	3.409	5’ 9”	194.25	25.97	14’ 3”	1193.00	159.48	25’ 3”	3745.80	500.74
2’ 2”	27.58	3.687	5’ 10”	199.92	26.73	14’ 6”	1235.30	165.13	25’ 6”	3820.30	510.71
2’ 3”	29.74	3.976	5’ 11”	205.67	27.49	14’ 9”	1278.20	170.87	25’ 9”	3895.60	527.77
2’ 4”	31.99	4.276	6’	211.51	28.27	15’	1321.90	176.71	26’	3971.60	530.93
2’ 5”	34.31	4.587	6’ 3”	229.50	30.68	15’ 3”	1366.40	182.65	26’ 3”	4048.40	541.19
2’ 6”	36.72	4.909	6’ 6”	248.23	35.18	15’ 6”	1411.50	188.69	26’ 6”	4125.90	551.55
2’ 7”	39.21	5.241	6’ 9”	267.69	35.78	15’ 9”	1457.40	194.83	26’ 9”	4204.10	562.00
2’ 8”	41.78	5.585	7’	287.88	38.48	16’	1504.10	201.06	27’	4283.00	572.66
2’ 9”	44.43	5.940	7’ 3”	308.81	41.28	16’ 3”	1551.40	207.39	27’ 3”	4362.70	583.21
2’ 10”	47.16	6.305	7’ 6”	330.48	44.18	16’ 6”	1599.50	213.82	27’ 6”	4443.10	593.96
2’ 11”	49.98	6.681	7’ 9”	352.88	47.17	16’ 9”	1648.40	220.35	27’ 9”	4524.30	604.81
3’	52.88	7.069	8’	376.01	50.27	19’	2120.90	283.53	28’	4606.20	615.75
3’ 1”	55.86	7.467	8’ 3”	399.80	53.46	19’ 3”	2177.10	291.04	28’ 3”	4688.80	626.80
3’ 2”	58.92	7.876	8’ 6”	424.48	56.75	19’ 6”	2234.00	298.65	28’ 6”	4772.10	637.94
3’ 3”	62.06	8.296	8’ 9”	449.82	60.13	19’ 9”	2291.70	306.35	28’ 9”	4856.20	649.18
3’ 4”	65.28	8.727	9’	475.89	63.62	20’	2350.10	314.16	29’	4941.00	660.52
3’ 5”	68.58	9.168	9’ 3”	502.70	67.20	20’ 3”	2409.20	322.06	29’ 3”	5026.60	671.96
3’ 6”	71.97	9.621	9’ 6”	530.24	70.88	20’ 6”	2469.10	330.06	29’ 6”	5112.90	683.49
3’ 7”	75.44	10.085	9’ 9”	558.51	74.66	20’ 9”	2529.60	338.16	29’ 9”	5199.90	695.13
3’ 8”	78.99	10.559	10’	587.52	78.54	21’	2591.00	346.36	30’	5287.70	706.86
3’ 9”	82.62	11.045	10’ 3”	617.26	82.52	21’ 3”	2653.00	354.66	30’ 3”	5376.20	718.69
3’ 10”	86.33	11.541	10’ 6”	640.74	86.59	21’ 6”	2715.80	363.05	30’ 6”	5465.40	730.62
3’ 11”	90.13	12.048	10’ 9”	678.95	90.76	21’ 9”	2779.30	371.54	30’ 9”	5555.40	742.64

To find the capacity of tanks greater than shown here, find a tank of one-half the size desired, and multiply its capacity by four, or find one one-third the size desired and multiply its capacity by 9.

Decimal Equivalents

1/64	.015625	9/64	.140625	17/64	.265625	25/64	.390625	33/64	.515625	41/64	.640025	49/64	.765625	57/64	.890625
1/32	.03125	5/32	.15625	9/32	.28125	13/32	.40625	17/32	.53125	21/32	.65625	25/32	.78125	29/32	.90625
3/64	.046875	11/64	.171875	19/64	.171875	27/64	.421875	25/64	.546875	43/64	.671875	51/64	.796875	59/64	.921875
1/16	.0625	3/16	.1875	5/16	.3125	7/16	.4375	9/16	.5625	11/16	.6875	13/16	.8125	15/16	.9375
5/64	.078125	13/64	.203125	21/64	.328125	29/64	.453125	37/64	.578125	45/64	.703125	53/64	.828125	61/64	.953125
3/32	.09375	7/32	.21875	11/32	.34375	15/32	.46875	19/32	.59375	23/32	.71875	27/32	.84375	31/32	.96875
7/64	.109375	15/64	.234375	23/64	.359375	31/64	.484375	39/64	.609375	47/64	.734375	55/64	.859375	63/64	.984375
1/8	.125	1/4	.250	3/8	.375	1/2	.500	5/8	.625	3/4	.750	7/8	.875		1.000

Circumferences and Areas of Circles

Diameter from 1/64 to 30, Advancing Chiefly by Eighths

Diam.	Circum.	Area
1/64	.04909	.00019
1/32	.09818	.00077
3/64	.14726	.00173
1/16	.19635	.00307
3/32	.29452	.00690
1/8	.39270	.01227
5/32	.49087	.01917
3/16	.58905	.02761
7/32	.68722	.03758
1/4	.78540	.04909
9/32	.88357	.06213
5/16	.98175	.07670
11/32	1.0799	.09281
3/8	1.1781	.11045
13/32	1.2763	.12962
7/16	1.3744	.15033
15/32	1.4726	.17257
1/2	1.5708	.19635
17/32	1.6690	.22166
9/16	1.7671	.24850
19/32	1.8653	.27688
5/8	1.9635	.30680
21/32	2.0617	.33824
11/16	2.1598	.37122
23/32	2.2580	.40574
3/4	2.3562	.44179
25/32	2.4544	.47937
13/16	2.5525	.51849
27/32	2.6507	.55914
7/8	2.7489	.60132
29/32	2.8471	.64504
15/16	2.9452	.6903
31/32	3.0434	.73708
1.	3.1416	.7854
1/16	3.3379	.8866
1/8	3.5343	.9940
3/18	3.7306	1.1075
1/4	3.9270	1.2272
5/16	4.1233	1.3530
3/8	4.3197	1.4849
7/16	4.5160	1.6230
1/2	4.7124	1.7671
9/16	4.9087	1.9175
5/8	5.1051	2.0739
11/16	5.3014	2.2365
3/4	5.4978	2.4053
13/16	5.6941	2.5802
7/8	5.8905	2.7612
15/16	6.0868	2.9483
2.	6.2832	3.1416
1/16	6.4795	3.3410
1/8	6.6759	3.5466
3/16	6.8722	3.7583
1/4	7.0686	3.9761
5/16	7.2649	4.2000
3/8	7.4613	4.4301
7/16	7.6576	4.6664
1/2	7.8540	4.9087
9/16	8.0503	5.1572
5/8	8.2467	5.4119
11/16	8.4430	5.6727
3/4	8.6394	5.9396

Diam.	Circum.	Area
2. 13/16	8.8357	6.2126
7/8	9.0321	6.4918
15/16	9.2284	6.7771
3.	9.4248	7.0686
1/16	9.6211	7.3662
1/8	9.8175	7.6699
3/16	10.014	7.9798
1/4	10.210	8.2958
5/16	10.407	8.6179
3/8	10.603	8.9462
7/16	10.799	9.2806
1/2	10.996	9.6211
9/16	11.192	9.9678
5/8	11.388	10.321
11/16	11.585	10.680
3/4	11.781	11.045
13/16	11.977	11.416
7/8	12.174	11.793
15/16	12.370	12.177
4.	12.566	12.566
1/16	12.763	12.962
1/8	12.959	13.364
3/16	13.155	13.772
1/4	13.352	14.186
5/16	13.548	14.607
3/8	13.744	15.033
7/16	13.941	15.466
1/2	14.137	15.904
9/16	14.334	16.349
5/8	14.530	16.800
11/16	14.726	17.257
3/4	14.923	17.721
13/16	15.119	18.190
7/8	15.315	18.665
15/16	15.512	19.147
5.	15.708	19.635
1/16	15.904	20.129
1/8	16.101	20.629
3/16	16.297	21.135
1/4	16.493	21.648
5/16	16.690	22.166
3/8	16.886	22.691
7/16	17.082	23.221
1/2	17.279	23.758
9/16	17.475	24.301
5/8	17.671	24.850
11/16	17.868	25.406
3/4	18.064	25.967
13/16	18.261	26.535
7/8	18.457	27.019
15/16	18.653	27.688
6.	18.850	28.274
1/8	19.242	29.465
1/4	19.635	30.680
3/8	20.028	31.919
1/2	20.420	33.183
5/8	20.813	34.472
3/4	21.206	35.785
7/8	21.598	37.122
7.	21.911	38.485
1/8	22.384	39.871
1/4	22.776	41.282

Diam.	Circum.	Area
7. 3/8	23.169	42.718
1/2	23.562	44.179
5/8	23.955	45.664
3/4	24.347	47.173
7/8	24.740	48.707
8.	25.133	50.265
1/8	25.525	51.849
1/4	25.918	53.456
3/8	26.311	55.088
1/2	26.704	56.745
5/8	27.096	58.426
3/4	27.489	60.132
7/8	27.882	61.862
9.	28.274	63.617
1/8	28.667	65.397
1/4	29.060	67.201
3/8	29.452	69.029
1/2	29.845	70.882
5/8	30.238	72.760
3/4	30.631	74.662
7/8	31.023	76.589
10.	31.416	78.540
1/8	31.809	80.516
1/4	32.201	82.516
3/8	32.594	84.541
1/2	32.988	86.590
5/8	33.379	88.664
3/4	33.772	90.763
7/8	34.165	92.886
11.	34.558	95.033
1/8	34.950	97.205
1/4	35.343	99.402
3/8	35.736	101.62
1/2	36.128	103.87
5/8	36.521	106.14
3/4	36.914	108.43
7/8	37.306	110.75
12.	37.699	113.10
1/8	38.092	115.47
1/4	38.485	117.86
3/8	38.877	120.28
1/2	39.270	122.72
5/8	39.663	125.19
3/4	40.055	127.68
7/8	40.448	130.19
13.	40.841	132.73
1/8	41.233	135.30
1/4	41.626	137.89
3/8	42.019	140.50
1/2	42.412	143.14
5/8	42.804	145.80
3/4	43.197	148.49
7/8	43.590	151.20
14.	43.982	153.94
1/8	44.375	156.70
1/4	44.768	159.48
3/8	45.160	162.30
1/2	45.553	165.13
5/8	45.946	167.99
3/4	46.339	170.87
7/8	46.731	173.78

Diam.	Circum.	Area
15.	47.124	176.71
1/8	47.517	179.67
1/4	47.909	182.65
3/8	48.302	185.66
1/2	48.695	188.69
5/8	49.087	191.75
3/4	49.480	194.83
7/8	49.873	197.93
16.	50.266	201.06
1/8	50.658	204.22
1/4	51.051	207.39
3/8	51.444	210.60
1/2	51.836	213.82
5/8	52.229	217.08
3/4	52.622	220.35
7/8	53.014	223.65
17.	53.407	226.98
1/8	53.800	230.33
1/4	54.193	233.71
3/8	54.585	237.10
1/2	54.978	240.53
5/8	55.371	243.98
3/4	55.763	247.45
7/8	56.156	250.95
18.	56.549	254.47
1/8	56.941	258.02
1/4	57.334	261.59
3/8	57.727	265.18
1/2	58.120	268.80
5/8	58.512	272.45
3/4	58.905	276.12
7/8	59.298	279.01
19.	59.690	283.53
1/8	60.083	287.27
1/4	60.476	291.04
3/8	60.868	294.83
1/2	61.261	298.65
5/8	61.654	302.49
3/4	62.047	306.35
7/8	62.439	310.24
20.	62.832	314.16
1/8	63.225	318.10
1/4	63.617	322.06
3/8	64.010	326.05
1/2	64.403	330.06
5/8	64.795	334.10
3/4	65.188	338.16
7/8	65.581	342.25
21.	65.973	346.36
1/8	66.366	350.50
1/4	66.759	354.66
3/8	67.152	358.84
1/2	67.544	363.05
5/8	67.937	367.28
3/4	68.330	371.54
7/8	68.722	375.83
22.	69.115	380.15
1/8	69.508	384.46
1/4	69.900	388.82
3/8	70.293	393.20

Diam.	Circum.	Area
22. 1/2	70.686	397.61
5/8	71.079	402.04
3/4	71.471	406.49
7/8	71.864	410.97
23.	72.257	415.48
1/8	72.649	420.00
1/4	73.042	424.56
3/8	73.435	429.13
1/2	73.827	433.74
5/8	74.220	438.36
3/4	74.613	443.01
7/8	75.006	447.69
24.	75.398	452.39
1/8	75.791	457.11
1/4	76.184	461.86
3/8	76.576	466.64
1/2	76.969	471.44
5/8	77.362	476.26
3/4	77.754	481.11
7/8	78.147	485.98
25.	78.540	490.87
1/8	78.933	495.79
1/4	79.325	500.74
3/8	79.718	505.71
1/2	80.111	510.71
5/8	80.503	515.72
3/4	80.896	520.77
7/8	81.289	525.84
26.	81.681	530.93
1/8	82.074	536.05
1/4	82.467	541.19
3/8	82.860	546.35
1/2	83.252	551.55
5/8	83.645	556.76
3/4	84.038	562.00
7/8	84.430	567.27
27.	84.823	572.56
1/8	85.216	557.87
1/4	85.608	583.21
3/8	86.001	588.57
1/2	86.394	593.96
5/8	86.787	599.37
3/4	87.179	604.81
7/8	87.572	610.27
28.	87.965	615.75
1/8	88.357	621.26
1/4	88.750	626.80
3/8	89.143	632.36
1/2	89.535	637.94
5/8	89.928	643.55
3/4	90.321	649.18
7/8	90.714	654.84
29.	91.106	660.52
1/8	91.499	666.23
1/4	91.892	671.96
3/8	92.284	677.71
1/4	92.677	683.49
5/8	93.070	689.30
3/4	93.462	695.13
30.	94.248	706.86

Viscosity Conversion Table

Kinematic Viscosity Centistokes =K	Seconds Saybolt Universal	Seconds Saybolt Furol	Seconds Redwood	Seconds Redwood Admiralty	Degrees Engler	Degrees Barbey
1.00	31	—	29.	—	1.00	6200
2.56	35	—	32.1	—	1.16	2420
4.30	40	—	36.2	5.10	1.31	1440
5.90	45	—	40.3	5.52	1.46	1050
7.40	50	—	44.3	5.83	1.58	838
8.83	55	—	48.5	6.35	1.73	702
10.20	60	—	52.3	6.77	1.88	618
11.53	65	—	56.7	7.17	2.03	538
12.83	70	12.95	60.9	7.60	2.17	483
14.10	75	13.33	65.0	8.00	2.31	440
15.35	80	13.70	69.2	8.44	2.45	404
16.58	85	14.10	73.3	8.86	2.59	374
17.80	90	14.44	77.6	9.30	2.73	348
19.00	95	14.85	81.5	9.70	2.88	326
20.20	100	15.24	85.6	10.12	3.02	307
31.80	150	19.3	128	14.48	4.48	195
43.10	200	23.5	170	18.90	5.92	144
54.30	250	28.0	212	23.45	7.35	114
65.40	300	32.5	254	28.0	8.79	95
76.50	350	35.1	296	32.5	10.25	81
87.60	400	41.9	338	37.1	11.70	70.8
98.60	450	46.8	381	41.7	13.15	62.9
110	500	51.6	423	46.2	14.60	56.4
121	550	56.6	465	50.8	16.05	51.3
132	600	61.4	508	55.4	17.50	47.0
143	650	66.2	550	60.1	19.00	43.4
154	700	71.1	592	64.6	20.45	40.3
165	750	76.0	635	69.2	21.90	37.6
176	800	81.0	677	73.8	23.35	35.2
187	850	86.0	719	78.4	24.80	33.2
198	900	91.0	762	83.0	26.30	31.3
209	950	95.8	804	87.6	27.70	29.7
220	1000	100.7	846	92.2	29.20	28.2
330	1500	150	1270	138.2	43.80	18.7
440	2000	200	1690	184.2	58.40	14.1
550	2500	250	2120	230	73.00	11.3
660	3000	300	2540	276	87.60	9.4
770	3500	350	2960	322	100.20	8.05
880	4000	400	3380	368	117.00	7.05
990	4500	450	3810	414	131.50	6.26
1100	5000	500	4230	461	146.00	5.64
1210	5500	550	4650	507	160.50	5.13
1320	6000	600	5080	553	175.00	4.70
1430	6500	650	5500	559	190.00	4.34
1540	7000	700	5920	645	204.50	4.03
1650	7500	750	6350	691	219.00	3.76
1760	8000	800	6770	737	233.50	3.52
1870	8500	850	7190	783	248.00	3.32
1980	9000	900	7620	829	263.00	3.13
2090	9500	950	8040	875	277.00	2.97
2200	10000	1000	8460	921	292.00	2.82

The viscosity is often expressed in terms of viscosimeters other than the Saybolt Universal. The formulas for the various viscosimeters are as follows:

Kinematic viscosity equals $\frac{\text{absolute viscosity}}{\text{specific gravity}}$

Redwood $K = .26\ t - \frac{188}{t}$ (British)

Redwood Admiralty $K = 2.39\,6 - \frac{40.3}{t}$ (British)

Saybolt Universal $K = .22\ t - \frac{180}{t}$ (American)

Saybolt Furol $K = 2.2\ t - \frac{203}{t}$ (American)

Engler $K = 1.47\,t - \frac{374}{t}$ (German)

t = Engler Degrees x 51.3

If viscosity is given at any two temperatures, the viscosity at any other temperature can be obtain by plotting the viscosity against temperature in degrees Fahrenheit on special log paper. The points for a given oil lie in a straight line.

Viscosity Conversion Table

Gardner-Holt Bubble Viscometer to Saybolt Seconds Universal

Gardner-Holt Tube Designation	Viscosity SSU	Centistokes	Gardner-Holt Tube Designation	Viscosity SSU	Centistokes
A	230	50	Q	1977	435
B	298	65	R	2136	470
C	388	85	S	2273	500
D	456	100	T	2500	550
E	568	125	U	2850	627
F	636	140	V	4018	884
G	750	165	W	4864	1070
H	909	200	X	5864	1290
I	1023	225	Y	8000	1760
J	1316	250	Z	10318	2270
K	1250	275	Z1	12273	2700
L	1364	300	Z2	16455	3620
M	1455	320	Z3	21045	4630
N	1545	340	Z4	28818	6340
O	1682	370	Z5	44773	9850
P	1818	400	Z6	67273	14800

Viscosity of Water

Temp.	Absolute Viscosity	Kinematic Viscosity		
° F	Centipoises	Centistokes	SSU	Ft^2/Sec
32	1.79	1.79	33.0	0.00001931
50	1.31	1.31	31.6	0.00001410
60	1.12	1.12	31.2	0.00001217
70	0.98	0.98	30.9	0.00001059
80	0.86	0.86	30.6	0.00000930
85	0.81	0.81	30.4	0.00000869
100	0.68	0.69	30.2	0.00000739
120	0.56	0.57	30.0	0.00000609
140	0.47	0.48	29.7	0.00000514
160	0.40	0.41	29.6	0.00000442
180	0.35	0.36	29.5	0.00000385
212	0.28	0.29	29.3	0.00000319

Properties of Water

Temp. ° F	Absolute Vapor Pressure PSI	Absolute Vapor Pressure Ft. Water	Specific Gravity (Water at 39.2° F = 1.000)	Temp. ° F	Absolute Vapor Pressure PSI	Absolute Vapor Pressure Ft. Water	Specific Gravity (Water at 39.2° F = 1.000)
60	0.26	0.59	0.999	205	12.77	30.6	0.961
70	0.36	0.89	0.998	206	13.03	31.2	0.960
80	0.51	1.2	0.997	207	13.30	32.0	0.960
85	0.60	1.4	0.996	208	13.57	32.6	0.960
90	0.70	1.6	0.995	209	13.84	33.2	0.959
100	0.95	2.2	0.993	210	14.12	33.9	0.959
110	1.27	3.0	0.991	211	14.41	34.6	0.958
120	1.69	3.9	0.989	212	14.70	35.4	0.958
130	2.22	5.0	0.986	213	14.99	36.2	0.957
140	2.89	6.8	0.983	214	15.29	37.0	0.957
150	3.72	8.8	0.981	215	15.59	37.7	0.957
151	3.81	9.0	0.981	216	15.90	38.4	0.956
152	3.90	9.2	0.980	217	16.22	39.2	0.956
153	4.00	9.4	0.980	218	16.54	40.0	0.956
154	4.10	9.7	0.979	219	16.86	40.8	0.955
155	4.20	9.9	0.979	220	17.19	41.6	0.955
156	4.31	10.1	0.979	221	17.52	42.5	0.955
157	4.41	10.4	0.978	222	17.86	43.3	0.954
158	4.52	10.7	0.978	223	18.21	44.2	0.954
159	4.63	10.9	0.978	224	18.56	45.0	0.953
160	4.74	11.2	0.977	225	18.92	45.9	0.953
161	4.85	11.5	0.977	226	19.28	46.8	0.953
162	4.97	11.7	0.977	227	19.65	47.7	0.952
163	5.09	12.0	0.976	228	20.02	48.6	0.952
164	5.21	12.3	0.976	229	20.40	49.5	0.951
165	5.33	12.6	0.976	230	20.78	50.5	0.951
166	5.46	12.9	0.975	231	21.17	51.4	0.951
167	5.59	13.3	0.975	232	21.57	52.5	0.950
168	5.72	13.6	0.974	233	21.97	53.5	0.950
169	5.85	13.9	0.974	234	22.38	54.5	0.950
170	5.99	14.2	0.974	235	22.80	55.5	0.949
171	6.13	14.5	0.973	236	23.22	56.6	0.949
172	6.27	14.9	0.973	237	23.65	57.8	0.948
173	6.42	15.2	0.973	238	24.09	58.8	0.948
174	6.56	15.6	0.972	239	24.53	59.8	0.948
175	6.71	15.9	0.972	240	24.97	61.0	0.947
176	6.87	16.3	0.972	241	25.43	62.1	0.947
177	7.02	16.7	0.971	242	25.89	63.3	0.946
178	7.18	17.1	0.971	243	26.36	64.5	0.946
179	7.34	17.4	0.971	244	26.83	65.6	0.946
180	7.51	17.8	0.970	245	27.31	66.8	0.945
181	7.68	18.3	0.970	250	29.83	73.2	0.943
182	7.85	18.7	0.970	260	35.44	87.4	0.938
183	8.02	19.1	0.969	270	41.87	103.6	0.933
184	8.20	19.5	0.969	280	49.22	122.8	0.927
185	8.38	20.0	0.969	290	57.57	144.0	0.923
186	8.57	20.4	0.968	300	67.0	168.6	0.918
187	8.76	20.9	0.968	310	77.7	197.0	0.913
188	8.95	21.4	0.967	320	89.7	228.4	0.908
189	9.14	21.8	0.967	330	103.0	264.0	0.902
190	9.34	22.3	0.966	340	118.0	305.0	0.896
191	9.54	22.8	0.966	350	134.6	349.0	0.891
192	9.75	23.3	0.965	360	153.0	399.2	0.886
193	9.96	23.8	0.965	380	195.8	517.7	0.874
194	10.17	24.3	0.965	400	247.3	663.9	0.861
195	10.38	24.9	0.964	420	308.8	842.4	0.847
196	10.60	25.4	0.964	440	381.6	1058.5	0.833
197	10.83	25.9	0.963	460	466.9	1318.0	0.818
198	11.06	26.6	0.963	480	566.1	1630.5	0.802
199	11.29	27.1	0.963	500	680.8	2000.1	0.786
200	11.53	27.6	0.963	520	812.4	2445.5	0.767
201	11.77	28.2	0.962	540	962.5	2980.4	0.746
202	12.01	28.8	0.962				
203	12.26	29.4	0.962				
204	12.51	30.0	0.961				

Electrical Usage Charts and Tables

Power Consumed Pumping 1000 Gallons of Clear Water at One Foot Total Head – Various Efficiencies

Overall Efficiency Pump Unit	Kwh per 1000 Gallons at One Ft. Total Head	Overall Efficiency Pump Unit	Kwh per 1000 Gallons at One Ft. Total Head	Overall Efficiency Pump Unit	Kwh per 1000 Gallons at One Ft. Total Head
32	.00980	51.5	.00609	71	.00442
32.5	.00958	52	.00603	71.5	.00439
33	.00951	52.5	.00597	72	.00435
33.5	.00937	53	.00592	72.5	.00432
34	.00922	53.5	.00586	73	.00430
34.5	.00909	54	.00581	73.5	.00427
35	.00896	54.5	.00575	74	.00424
35.5	.00884	55	.00570	74.5	.00421
36	.00871	55.5	.00565	75	.00418
36.5	.00860	56	.00560	75.5	.00415
37	.00848	56.5	.00555	76	.00413
37.5	.00837	57	.00550	76.5	.00410
38	.00826	57.5	.00545	77	.00407
38.5	.00815	58	.00541	77.5	.00405
39	.00804	58.5	.00536	78	.00402
39.5	.00794	59	.00532	78.5	.00399
40	.00784	59.5	.00527	79	.00397
40.5	.00775	60	.00523	79.5	.00394
41	.00765	60.5	.00518	80	.00392
41.5	.00756	61	.00586	80.5	.00389
42	.00747	61.5	.00510	81	.00387
42.5	.00738	62	.00506	81.5	.00385
43	.00730	62.5	.00502	82	.00382
43.5	.00721	63	.00498	82.5	.00380
44	.00713	63.5	.00494	83	.00378
44.5	.00705	64	.00490	83.5	.00375
45	.00697	64.5	.00486	84	.00373
45.5	.00689	65	.00482	84.5	.00371
46	.00682	65.5	.00479	85	.00369
46.5	.00675	66	.00475	85.5	.00367
47	.00667	66.5	.00472	86	.00365
47.5	.00660	67	.00468	86.5	.00362
48	.00653	67.5	.00465	87	.00360
48.5	.00647	68	.00461	87.5	.00358
49	.00640	68.5	.00458	88	.00356
49.5	.00634	69	.00454	88.5	.00354
50	.00627	69.5	.00451	89	.00352
50.5	.00621	70	.00448	89.5	.00350
51	.00651	70.5	.00445	90	.00348

Overall efficiency = true Input - Output efficiency of motor X pump efficiency.
Kwh/1000 gal. = K • H
Where K = Kwh/1000 gal. at one ft. head. H = Total Head.
Example: Overall efficiency = 72%. Total Head at the rated capacity = 150 ft.
Kwh/1000 gal. = .00435 X 150 = 0.653

Approximate Cost of Operating Electric Motors

Motor HP	*Average Kilowatts Input or Cost per Hour Based on 1 Cent per Kilowatt Hr.		Motor HP	*Average Kilowatts Input or Cost per Hour Based on 1 Cent per Kilowatt Hr.
	1-Phase	3-Phase		3-Phase
¼	.305	—	15	12.8
⅓	.408	—	20	16.9
½	.535	.520	25	20.8
¾	.760	.768	30	25.0
1	1.00	.960	40	33.2
1½	1.500	1.41	50	41.3
2	2.000	1.82	60	49.5
3	2.95	2.70	75	61.5
5	4.65	4.50	100	81.5
7½	6.90	6.75	125	102
10	9.30	9.00	150	122
			200	162

*For any other rate multiply by the rate:

Example: To determine cost of operating a 3/4 HP single phase motor at 3 cents per kilowatt hour multiply .760 X 3 = 2.280 cents or approximately 2¼ cents per hour.

ELECTRIC POWER

AC = Alternating current power

DC = Direct current

E = Volts = Electrical pressure (similar to head)

I = Amperes = Electrical current (similar to rate of flow)

W = Watts = Electrical power (similar to head capacity)

kW = Kilowatts = 1000 watts

Apparent Power = Volts x amperes = Voltamperes

Apparent Power - EI

Useful Power W = EI x P.F.

Power factor = ratio of useful power to apparent power

Power factor = PF = $\frac{W}{EI}$

kW Hr. = Kilowatt hour

Single phase power W = E x I x PF

3 Phase Power W = 1.73 x I x PF

Where E = Average voltage between phases

I = Average current in each phase

HORSEPOWER

1 HP equals. . .
.746 kilowatts or 746 watts
33,000 ft . lbs. per minute
550 ft. lbs. per second

WATER HORSEPOWER

$$= \frac{\text{GPM x 8.33 x Head}}{33{,}000} = \frac{\text{GPM x Head}}{3960}$$

GPM = Gallon per Minute
8.33 = Pounds of Water per Gallon
33,000 = Ft.-lb. per Minute in one HP

LABORATORY BHP

$$= \frac{\text{Head x GPM x Sp. Gr.}}{\text{3960 x Eff.}}$$

GPM = Gallon per Minute
Head = Laboratory Head (inc. column loss)
Eff. = Pump Only Efficiency

MOTOR INPUT HP

$$= \frac{\text{Laboratory BHP}}{\text{Motor Eff.}}$$

Total BHP from above
Motor Eff. from Manufacturer

UNIT EFFICIENCY

$$= \frac{\text{Water Horsepower}}{\text{Motor Input Horsepower}}$$

Water Horsepower from above
Input Horsepower from above

Single Phase Wire Size Selection Charts

115 Volts – 1 Phase

Amps	AWG Wire Size 14	12	10	8	6	4	2	0
2	595	946	1479					
3	397	630	986					
4	298	470	740	1161	1808			
5	238	378	592	926	1447			
6	198	315	493	774	1206	1842		
7	170	270	423	663	1033	1579		
8	149	236	370	581	904	1381		
9	132	210	329	516	804	1228	1871	
10	119	189	296	464	723	1105	1684	
12	99	158	247	387	603	921	1403	
14		135	211	332	517	789	1203	1622
16		118	185	290	452	691	1052	1420
18			164	258	402	614	935	1201
20			148	232	362	553	842	1136
22			134	211				
24			123	194				

Maximum Distance of Wire Run.

200 Volts – 1 Phase

Amps	AWG Wire Size 14	12	10	8	6	4	2	0
2	1035	1644						
3	690	1096	1715					
4	518	822	1287					
5	414	658	1029	1615				
6	345	548	858	1346	2097			
7	296	470	735	1154	1797			
8	259	411	643	1010	1573	2403		
9	230	365	572	897	1398	2136		
10	207	329	515	808	1258	1922	2928	
12	173	274	429	673	1048	1602	2440	
14		235	368	577	899	1373	2091	2821
16		206	322	505	786	1201	1830	2469
18			286	449	699	1068	1627	2194
20			257	404	629	961	1464	1975
22			234	367	572	874	1331	1795
24			214	337	524	801	1220	1646
26				311	484	739	1126	1519
28				288	449	686	1046	1411
30				269	419	641	976	1317
35				231	359	549	837	1129
40					315	481	732	988
45					280	427	651	878
50					252	384	586	790
55						349	532	718
60						320	488	658

Maximum Distance of Wire Run.

230 Volts – 1 Phase

Amps	AWG Wire Size 14	12	10	8	6	4	2	0
2	1190	1891						
3	794	1261						
4	595	946	1479					
5	476	756	1184	1858				
6	397	630	986	1548	2411			
7	340	540	845	1327	2067			
8	293	473	740	1161	1808	2763		
9	265	420	658	1032	1607	2456		
10	238	376	592	929	1447	2210	3367	
12	198	315	493	774	1206	1842	2806	
14		270	423	663	1033	1579	2405	3245
16		236	370	581	904	1381	2105	2839
18			329	516	804	1228	1871	2524
20			296	464	723	1105	1684	2271
22			269	422	658	1005	1531	2065
24			247	387	603	921	1403	1893
26				357	556	850	1295	1747
28				332	517	789	1203	1622
30				310	482	737	1122	1514
35				265	413	632	962	1298
40					362	553	842	1136
45					321	491	748	1009
50					239	442	673	909

Maximum Distance of Wire Run.

Three Phase Wire Size Selection Charts

230 Volts – 3 Phase

	AWG Wire Size							
Amps	**14**	**12**	**10**	**8**	**6**	**4**	**2**	**0**
2	1375	2184	3417					
3	916	1456	2278	3575				
4	657	1092	1708	2681				
5	550	873	1367	2145	3341			
6	458	728	1139	1788	2784			
7	393	624	976	1532	2386			
8	344	546	854	1341	2038	3190		
9	305	485	759	1192	1856	2836		
10	275	437	683	1073	1671	2552		
12	229	364	569	894	1392	2127	3240	
14		312	488	766	1193	1823	2777	
16		273	427	670	1044	1595	2430	3278
18			380	596	928	1418	2160	2914
20			342	536	835	1276	1944	2623
22			311	488	759	1160	1767	2884
24			285	447	696	1063	1620	2186
26				413	643	982	1495	2017
28				383	597	912	1389	1873
30				358	557	851	1296	1748
35				306	477	729	1111	1499
40					418	638	972	1311
45					371	567	864	1166
50					334	510	778	1049
55						464	707	954
60						425	648	874
65						393	598	807
70							555	749
75							518	699
80							486	656
85							457	617
90							432	583
95								552
100								525

Maximum Distance of Wire Run.

460 Volts – 3 Phase

	AWG Wire Size							
Amps	**14**	**12**	**10**	**8**	**6**	**4**	**2**	**0**
2	2749							
3	1833	2912						
4	1374	2184	3417					
5	1100	1747	2733					
6	916	1450	2278	3575				
7	785	1248	1952	3064				
8	687	1092	1708	2681				
9	611	971	1519	2383				
10	550	873	1367	2145	3341			
12	458	728	1139	1788	2784			
14		624	976	1532	2386	3646		
16		546	854	1341	2088	3190		
18			759	1192	1856	2836		
20			683	1073	1671	2552		
22			621	975	1519	2320	3535	
24			569	894	1392	2127	3240	
26				825	1285	1963	2991	
28				766	1193	1823	2777	
30				715	1114	1701	2592	3497
35				613	955	1458	2222	2997
40					835	1276	1944	2623
45					742	1134	1728	2331
50					668	1021	1555	2098
55						928	1414	1907
60						851	1296	1748
65						785	1196	1614
70							1111	1499
75							1037	1399
80							972	1311
85							915	1234
90							864	1166
95								1104
100								1049

Maximum Distance of Wire Run.

200 Volts – 3 Phase

	AWG Wire Size							
Amps	**14**	**12**	**10**	**8**	**6**	**4**	**2**	**0**
2	1195	1899	2971					
3	797	1266	1981	3109				
4	598	949	1486	2332	3632			
5	478	760	1188	1865	2905			
6	398	633	990	1554	2421			
7	341	543	849	1332	2075	3170		
8	299	475	743	1166	1816	2774		
9	266	422	660	1036	1614	2466		
10	239	380	594	933	1453	2219	3381	
12	199	316	495	777	1211	1849	2817	
14		271	424	666	1038	1585	2415	3258
16		237	371	583	908	1387	2113	2851
18			330	518	807	1233	1878	2534
20			297	466	726	1110	1690	2281
22			270	424	660	1009	1537	2073
24			248	389	605	925	1409	1900

Maximum Distance of Wire Run.

200 Volts – 3 Phase (continued)

	AWG Wire Size							
Amps	**14**	**12**	**10**	**8**	**6**	**4**	**2**	**0**
26				359	559	854	1300	1754
28				333	519	793	1207	1629
30				311	484	740	1127	1520
35				266	415	634	966	1303
40					363	555	845	1140
45					323	493	751	1014
50					291	444	676	912
55						404	615	829
60						370	563	760
65						341	520	702
70							483	652
75							451	608
80							423	570
85							398	537
90							376	507
95								480
100								456

Maximum Distance of Wire Run.

Materials

A BASIC UNDERSTANDING OF PLASTIC MATERIALS USED IN POOL AND SPA EQUIPMENT

The extensive use of many types of plastic materials in the pool and spa business requires us to have a basic knowledge of what the materials are, their strengths and limitations, and how to connect or bond the various materials together. This will not be a technical presentation on plastic materials, but a very practical one intended to help you to work with plastic components with a greater degree of understanding.

MATERIALS

Here are some commonly used plastic materials found in pool/spa components.

CHARACTERISTICS SUMMARY

Trade or Common Name	Technical Name	Strengths/ Advantages	Limitations/ Weaknesses	Typical Applications
ABS	Acrylonitrile-Butadiene-Styrene	High impact, molds well, bonds well.	Stress cracks, heat sensitive.	Skimmers, valves, main drains, fittings, filter internals, filter tanks.
CPVC	Chlorinated Polyvinyl Chloride	Good heat resistance, easily bonded, strong.	High cost, difficult to mold.	Pipe and fittings for hot water applications.
Lexan	Polycarbonate	High strength, very clear, heat resistant	Low chemical resistance, low UV resistance (some grades).	Trap lids, sight glasses, impellers.
Noryl	Modified PPO (polyphenylene oxide)	High strength, bondable, moderate chemical resistant.	Difficulty in molding, high cost, difficult to bond.	Pump bodies, impellers, traps.
Polyethylene	Polyethylene	Flexible, high impact, low UV resistance, cost effective.	High creep, low strength, low heat resistance. Cannot be glued.	Filter tanks, flex pipe, solar collectors.
Polypro	Polypropylene	Good heat & chemical resistance, good strength.	Moderate creep, low UV resistance in natural color.	D.E. grid cloth, separation tank bags, pump bodies and traps.
Polyester	Polyester	High strength and chemical resistance, high heat resistance.	Difficult to glue bond, difficult to mold.	Cartridge filter, media cloth.
PVC	Polyvinyl Chloride	Flexible, low cost, good bonding.	Moderate heat resistance, low UV resistance, moderate impact resistance.	Pipe, pipe unions, pool fittings, elbows and tees, etc.
Styrene	Polystyrene	Molds well, low cost, bonds well.	Moderate strength, low UV resistance, low heat resistance.	D.E. grids, trap baskets.
Vinyl	Vinyl	Flexible, chemical and UV resistant, good for thin sheeting.	Low strength, high creep. Bonded thermally only.	Pool liners, solar collectors, gaskets.

This brief summary chart of plastic materials does not take into consideration varying grades or blends of material within each general compound name. For instance, polyethylene may be used in high, medium or low density grades, each having different strengths and applications. ABS is a blend of three different polymers or plastic compounds, and the ratio of each will determine the characteristics of the material. This is why the term “engineering grade materials” is often used to signify that much fine-tuning goes into a plastic compound to give the desired performance in a specific application. Varying amounds of fiberglass mixed into the plastic resin can change or improve the properties of some plastic materials.

ENVIRONMENTAL FACTORS ON PLASTICS

While one of the principal benefits of plastics in the pool/spa environment, is corrosion resistance, there are a number of other factors which can harm plastic materials.

1. Sunlight/ultraviolet degradation
Ultraviolet light (sunlight), can over a period of time, cause plastics to become brittle, fade in color, and lose much of their physical strength. Manufacturers of resins can add compounds to the plastic formulas which inhibit the degrading effects of ultraviolet light. The most common and effective UV inhibitor is carbon black. This is why most pool pumps and other key pool components are colored black. In PVC, vinyl and ABS materials, other chemical UV inhibitors are added which do not change the resin color.

2. Heat
Thermoplastics common to the pool/spa industry are all sensitive to temperatures to some extent. This can come from solar heat (or ambient air temperature) or from the heat of the water. Some materials like Noryl and polypropylene have very good heat resistance, in excess of boiling water (212°F), before they begin to lose strength. Others like polyethylene, ABS and PVC begin to soften at temperatures only slightly above spa temperatures (110° - 125°F). PVC piping for hot water can be specially formulated for this application, and is known as CPVC.

3. Pressure
The affects of pressure on plastic becomes more critical the larger the pressure vessel (such as filter tanks) and with increased temzerature. This is known as creep/rupture tendency. When a plastic part begins to move, stretch, or distort under pressure and/or heat, it is described as “creep”. Each material has creep tendencies which can be measured and often controlled, as with the addition of chopped fiberglass to the resin compound. The materials with the greatest creep tendencies would be vinyl, polyethylene and PVC, which do not work well with glass reinforcement. If a plastic vessel containing pressure were to creep to its limits of strength, it would rupture or crack. In the pool/spa environment, because UV, heat and pressure are all powerful environmental factors, design engineers must be concerned with the creep/rupture properties of each material when selecting one for a specific plastic component.

INSTALLATION OF EQUIPMENT MADE OF PLASTICS

A. Equipment Selection and Application
Each piece of equipment, containing plastic parts or made entirely of plastic, has been designed for a specific purpose in the pool/spa environment. When products are installed in ways that are outside their intended usage, chances of product failure are significantly increased. When the proper application of equipment is in question, contact the manufacturer before making any installation.

B. Pipe Connections
There are two basic ways provided for attachment of piping to pool/spa equipment:

1. Threaded Piping Connections
National Pipe Thread (NPT) standards are used throughout the USA, which are tapered male and female connections with specific threaded pitch and diameters. BSP (British Standard Pipe) and DIN (Germany) standards apply in most foreign markets, and are not compatible with NPT. Because of the tapered design of NPT, engagement or overtightening of pipes in female ports of plastic equipment can result in cracked pipe ports, or threaded bosses, if they have not been properly designed or molded. Care should be taken to not overtighten threaded pipe nipples beyond the intended 3-4 thread engagement.

Use of thread sealant is normally required on pressure or vacuum connections on piping. The correct choice of thread sealant is critical on plastic components. The plumbing trades have traditionally used “pipe dope” for thread sealant on metal pipes and equipment. However, pipe dope and most teflon paste sealants have a vehicle or base material that is a petroleum product. Petroleum compounds will attack many platics used in pool/spa equipment and especially ABS, which is common in skimmers, valves and pool wall fittings, etc. The problem is called “stress cracking”. When a pipe is tightened into the female port of a component, the port is placed under mechanical stress. In this condition, petroleum-based sealants will attack the weakest part of the thread boss and quickly cause it to crack through and leak. Don’t be fooled by claims on the sealant can like “safe for plastics”. This usually means safe for PVC pipe, which is fairly resistant to petroleum sealants. Here is a list of thread sealants which we know have been reliable and safe for all plastic compounds:
Teflon Tape
Plasto-Joint Stick (Lake Chemical Co.)
Permatex #2 (Loctite Mfg. Co.)
Silicon RTV: (Room Temperature Vulcanizing)
a: General Electric RTV 60
b: Dow Corning Silastic 731, 732 and 738
c: Loctite Silicone (same as Dow 732)

It is also recommended that when connecting PVC pipe to components which generate heat, such as pumps or heaters, that CPVC pipe nipples be used for direct connection. There is less chance of material distortion and/or leaks to develop.

2. Solvent Welding
Solvent welding involves the gluing or chemical bonding of plastic pipe and components. The connection between male pipe and female socket is a slip fit, with the cement having solvents to soften and fuse the two parts together, and to fill any voids for a leak-free connection. The following are procedures for making secure solvent welded connections in a variety of combinations of plastic materials.

A. To consistently make good joints the following should be clearly followed:

1. The joining surfaces must be softened and made semi-fluid.
2. Sufficient cement must be applied to fill the gap between the plastic components being assembled.
3. Assembly of components must be made while the surfaces are still wet and fluid.

4. Joint strength develops as the cement dries. In the tight part of the joint, the surfaces will tend to fuse together, in the loose part, the cement will bond to both surfaces. In some cases clamp or hand pressure must be applied to obtain maximum strength joints. When assembling pipe, follow pipe preparation instructions and dimensional checks found on solvent cement containers. Areas of pipe and fittings to be softened and penetrated (as shown in Figure 2).

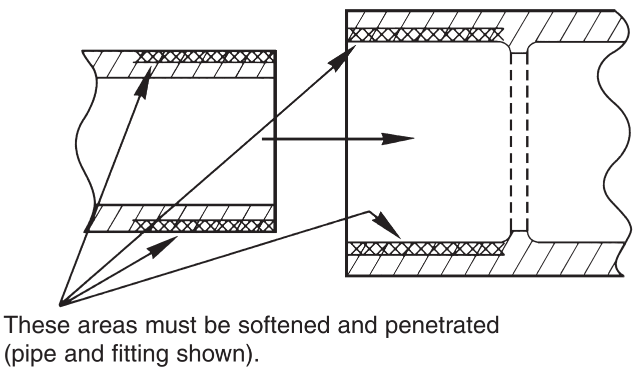


Figure 2

Penetration and softening can be achieved by the cement itself. In cold weather more time and additional applications are required.

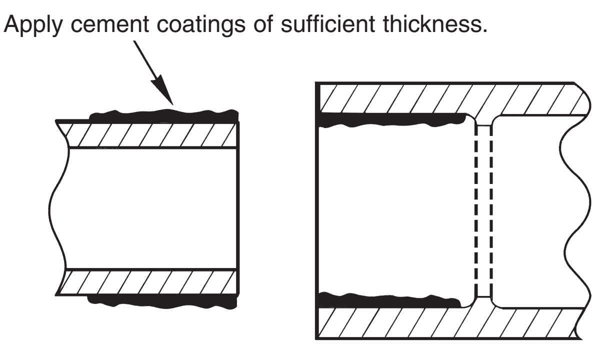


Figure 3

More than sufficient cement to fill the loose part of the joint must be applied. Besides filling the gap, adequate cement layers will penetrate the surfaces and also remain wet until the joint is assembled.

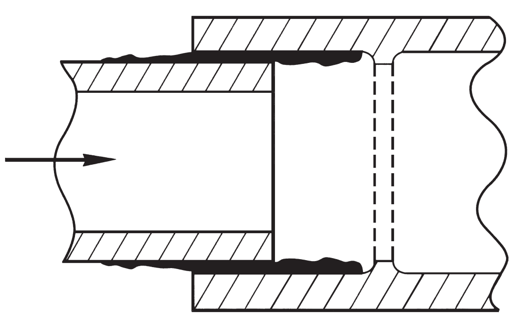


Figure 4

If the cement coatings on the pipe and fittings are wet and fluid when assembly takes place, they will tend to flow together and become one cement layer. Also, if the cement is wet the surfaces beneath them will still be soft, and these softened surfaces in the tight part of the joint will tend to fuse together. If possible, rotate the pipe 1/4 turn after it is inserted into the female socket.

Hardening of the adhesive (Figure 5).

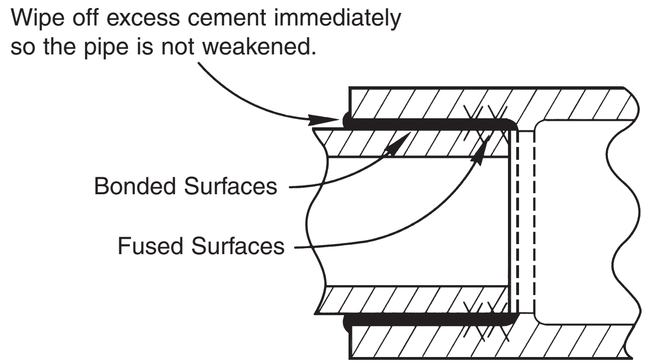


Figure 5

As the solvent dissipates, the cement layer and the softened surfaces will harden with a corresponding increase in joint strength. A good joint will take the required working pressure long before the joint is fully dry and final strength is obtained. In the tight (fused) part of the joint, strength will develop more quickly than in the looser (bonded) part of the joint. (It may in some cases be required to hold or fixture the joint for a short period of time to maintain its proper position).

B. The solvent welding of plastics and recommended solvents. The following are combinations of plastics normally encountered and the recommended solvents for bonding the materials. The solvents are listed in order of preference.

1. Cycolac (Brand ABS) to Cycolac (Brand ABS).

   Weld-On #1707 or #771 – a milky clear, semi-viscous, medium bodied, fast set cement normally applied by brush. Application temperatures – 40°F to 110°F.

   Weld-On #1591 or #773 – A black, semi-viscous, medium bodied, fast set cement normally applied by brush. Application temeratures – 40°F to 110°F.

   MEK (Methyl Ethyl Ketone) Weld-On #2354 – A watery solvent normally applied by dipping.

2. Cycolac (Brand ABS) to Rigid PVC.

   Weld-On #793 – A clear, semi-viscous, light bodied, very fast set cement normally applied by brush. Application temperatures – 40°F to 110°F. (**Not** recommended for Cycolac (ABS) to Cycolac (ABS) or PVC to 11z+'11z PVC).

   Weld-On #794 – A green colored, medium bodied, fast setting high strength cement. Application temperatures – 40°F to 110°F. (**Not** recommended for cycolac ABS) to Cycolac (ABS) or PVC to PVC).

3. Rigid PVC to Rigid PVC (Use P-70 primer or PVC components only).

   Weld-On #711 – A gray, semi-viscous, heavy bodied, fast set, high strength cement normally applied by brush. Excellent for poorly fitting joints. Application temperatures – 40°F to 110°F.

   Weld-On #717 – A gray, heavy bodied, medium set adhesive preferred in very humid weather.

4. Cycolac (ABS) to Lexan (polycarbonate).

   Methylene Chloride – Mixed with Lexan pellets to provide a semi-viscous solvent to insure voidless joints of poorly fitting parts. The solvent is mixed in a ratio of 4 parts solvent, by weight, to 1 part Lexan pellets, by weight.

   Weld-On #16 – A thick bodied solvent cement available in tubes and used when part fit is poor.

5. Lexan to PVC (Use P-70 primer on PVC component only).

   THF (Tetrahydrofurane) Weld-On #2010 – A watery solvent nromally applied by dipping.

   Methylene Chloride – Mixed with Lexan pellets to provide a semi-viscous solvent to insure voidless joints of poorly fitting parts. The solvent is mixed in a ration of 4 parts solvent, by weight, to 1 part Lexan pellets, by weight.

   Weld-On #16 – A thick bodied solvent cement available in tubes and used when part fit is poor.

6. Styrene to PVC (Use P-70 primer on PVC component only).

   Weld-On #792 or #1802 – A clear, semi-viscous, medium bodied cement normally applied by brush. Application temperatures – 40°F to 110°F.

7. Noryl to PVC (Use P-70 primer on PVC component only).

   Weld-On #792 or #1802 – A clear, semi-viscous, medium bodied cement normally applied by brush. Application temperatures – 40°F to 110°F.

8. Styrene to Cycolac (ABS).

   Weld-On #792 or #1802 – A clear, semi-viscous, medium bodied cement normally applied by brush. Application temperatures – 40°F to 110°F.

C. **Connecting ABS skimmer socket ports to PVC pipe** – The following pertains to the bond strength by solvent welding of PVC pipe to the ABS skimmer socket parts.

   The recommended solvent for bonding PVC to the ABS skimmer ports is Weld-On #793.

   Weld-On P-70 primer should be applied to the PVC pipe only prior to applying the #793 solvent to both parts at time of assembly and sufficient drying time is a must to prevent creep and eventual failure of the assembly.

Apply Industrial Polychemical Services P-70 primer to PVC pipe only – prior to appying Weld-On #793 to both the PVC pipe and socket port. Allow a minimum of four hours drying time, preferably 24 hours before pressure testing any solvent welded joint.

Exercises

1. What effect does sunlight have on PVC pipe?
   a. Causes pipe to become brittle.
   b. Causes pipe to lose its physical strength.
   c. Causes the pipe to lose its color.
   d. Ultra-violet light from the sun can cause all of the above.
2. PVC piping for hot water use is a special formula called?
   a. ABS
   b. CPVC
   c. NRA
   d. Styrene
3. Why is it important that the “sealant” used on threaded fittings **not** have a petroleum base?
   a. It is non-toxic to humans.
   b. Petroleum compounds cause stress-cracking and failures in many plastic materials.
   c. Non-petroleum sealants cost less.
   d. It reduces foreign oil imports.
4. What cement would you recommend to bond an ABS skimmer to PVC pipe?

Glossary

GLOSSARY OF SWIMMING POOL AND SPA TERMS

AAU – Amateur Athletic Union – A National organization with a division devoted to the athletic aspects of swimming.

ABRASION HAZARD – A sharp or rough surface that would scrape the skin upon chance or by normal use modes.

ACCESSIBLE – Easily exposed for inspection and the replacement of materials and/or parts with the use of tools.

AIR PUMP ASSIST BACKWASH – The compressing of a volume of air in the filter effluent chamber (by means of an air compressor or by the water pressure from the recirculating pump) which, when released, rapidly decompresses and forces water in the filter chamber through the elements in reverse, dislodging the filter aid and accumulated dirt, carrying it to waste.

AIR INDUCTION SYSTEM – A system whereby a volume of air (only) is induced into hollow ducting built into a spa floor, bench or other location. The air induction system is activated by a separate air power unit (blower).

ALGAE – Green, black or brown microscopic plant life which is nourished by sunlight.

ALGICIDE – A chemical or process for killing algae. An algistat is an agent for preventing their growth.

ALUM – A flocculating agent. Potassium and ammonium alum are the most common types used in the treatment of pool water. Aluminum sulphate is often used with gravity sand filters.

BACKWASH – The process of flow reversal to clean a filter and to restore it to the normal clean condition for filtering with a minimum resistance to flow through the media.

BACKWASH CYCLE – The operating time, after the filter cycle, required to completely clean the filter.

BACKWASH PIPING – the pipe extended from the backwash outlet of the filters to a terminus at the point of disposal.

BACKWASH RATE – The rate of application of water through a filter during the cleaning cycle expressed in gallons per minute per square foot of effective area.

BATHER – Any person using a pool, spa or hot tub and adjoining deck area for the purpose of water sports, recreation or related activities.

BEGINNERS AREA – Those water areas in pools, spas and hot tubs which are three feet (3) or less in water depth.

BODY FEED – the continuous addition of small amounts of filter aid during the operation of a diatomaceous earth filter.

BOOSTER PUMP SYSTEM – A system whereby one or more hydrojets are activated by the use of a pump which is completely independent of the filtration and heating system of a spa.

BROMIDE – A compound of bromine. Two of the salts, Sodium and Potassium Bromide, are sometimes used to produce a disinfectant or algaecide.

BROMINE – An element which is sometimes used in pool water purification. A dark, heavy, reddish-brown liquid in its normal state. Closely related to chlorine.

CARTRIDGE – A replaceable porous element.

Depth Type Cartridge: A filter cartridge with a medium not less than three-fourths inch (3/4”) thick that relies on penetration of particulates into the medium to achieve their removal.

Surface Type Cartridge: A filter cartridge with a medium less than three-fourths inch (3/4”) thick that relies on the retention of particulates on the surface of the cartridge to achieve their removal.

CASUAL CONTACT – Contact of any body part occuring by normal use modes.

CHEMICAL FEEDER – Any device to feed chemicals, but usually one feeding alum, acid, filter aid, algaecide, or soda ash. Included in this category are proportioning pumps, injector type feeders, pot type feeders, operating from a pressure differential, and dry type feeders.

CHLORINATOR – A devise to feed, regulate the flow, and measure the amount of chlorine gas introduced into the water being treated.

CHLORINE – An element, normally a gas, which is liquefied under pressure and stored in steel cylinders. Used as a disinfectant and algaecide when it is introduced in water solution into a pool or spa.

CORROSION – The etching or oxidation of a material by chemical action.

CORROSION RESISTANT MATERIAL – A material with exceptional resistance to the corrosion factors to which it is subjected.

CROSS CONNECTION – An unprotected connection between a domestic water system and any pool or other non-potable water whereby back flow to the domestic system could occur. Appropriate protection may be vacuum breakers, air gaps or other methods.

CYANURIC ACID – A chemical used for chlorine stabilization.

DECKS – those areas surrounding a pool, spa or hot tub that are specifically constructed or installed for use by bathers.

DEEP AREAS – Portions of a pool, spa or hot tub having water depths in excess of five feet (5’).

DESIGN RATE OF FLOW (DESIGN FILTER RATE) – The average rate of flow in a system which is used for design calculation (usually the flow in gallons per minute divided by the effective filter area in square feet).

DIATOMACEOUS EARTH (D.E.) – Porous silica from skeletal remains of one-celled plants, which when properly graded, acts as a precoat filter media for water filtration.

DIRECTIONAL INLET FITTING – An inlet fitting which provides adjustment in direction and flow rate to produce proper distribution of incoming water.

DISCHARGE HEAD – The total head, including static head and friction head, on the discharge side of the pump.

DISTRIBUTOR (TOP OR BOTTOM) – The device in a filter designed to divert the incoming water to prevent erosion of the filter media.

DIVING AREA – That area of a pool designed for diving. (NOTE: Diving Areas are defined in detail in various standards and regulations such as NSPI, Public and Residential Pool Standards, AAU, FINA, etc.).

DIVING BOARD – A board especially designed to produce diver spring action when properly installed on an anchor (base) and fulcrum. (The term diving board includes non-spring types).

DIVING PLATFORM – Usually used for the standard 5-meter and 10-meter official diving platform.

DIVING STAND – Any stand or supporting device for a springboard or diving board.

DIVING TOWER – This term is usually used for the 3-meter (10-ft.) springboard support.

DRAIN – An outlet at the deep p oint of a vessel or trough through which waste water passes.

EFFECTIVE FILTER AREA –

Permanent Medium Type: The effective filter area is the filter surface that is perpendicular to the flow direction.

Cartridge Filter: The total effective filter area shall be that cartridge area that is exposed to the direct flow of water. This excludes cartridge ends, seals, supports and other areas where flow is impaired.

EFFLUENT – The outflow of water from a filter or other device.

ELECTROLYSIS – Decomposition of metal due to flow of electrical current.

FACE PIPING – The piping with all valves and fittings which is used to connect the filter system together as a unit. This includes all valves and piping necessary for the filter plant to perform the functions of filtering or backwashing, either by the plant as a whole or any unit operating singly.

FACTOR OF SAFETY – The ultimate load divided by the safe load or the ultimate strength divided by the allowable stress.

FEET OF HEAD – A basis for indicating the resistance in a hydraulic system, equivalent to the height of a column of water that would cause the same resistance (100 feet of head equals 43 pounds per square inch). The total head is the sum of all resistances in a complete operating system. The principal factors affecting a head are vertical distances and the resistance caused by friction between the fluid and pipe walls.

FILTER – A device that separates solid particles from water by recirculating the water through a porous substance (a filter medium element).

Permanent Medium Filter: A filter that utilizes a medium that under normal use will not have to be replaced.

Diatomaceous Earth Filter: A filter that utilizes a thin layer of diatomaceous earth as its filter medium that periodically must be replaced.

Cartridge Filter: A filter that utilizes a porous cartridge as its filter medium.

FILTER AGITATION – The mechanical or manual movement to dislodge the filter aid and dirt from the filter element.

FILTER AID – A type of finely divided media used to coat a septum type filter, usually diatomaceous earth or volcanic ash. (NOTE: Alum, as used on the bed of a sand filter, is also referred to as a filter aid).

FILTER CARTRIDGE – A filter which operates through a disposeable cartridge. These are of two general types: The surface or area type where the suspended matter is removed at the surface, and the depth type in which the interstices vary from large to small in depth.

FILTER CYCLE – The operating time between cleaning or bachwash cycles.

FILTER DIATOMITE – One designed to filter water through a thin layer of filter aid such as diatomaceous earth or volcanic ash. Diatomite filters may be of the Pressure, Gravity, Suction or Vacuum type.

FILTER ELEMENT – A device within a filter tank designed to entrap solids and conduct water to a manifold, collection header, pipe or similar conduit. A filter element usually consists of a septum and septum support.

Permanent Filter Medium: A finely graded material (such as sand, anthracite, etc.) that removes filterable particles from the water.

Filter Aid: A type of fine medium used to coat a septum type filter; usually diatomaceous earth, processed perlite or similar material.

FILTER, GRAVITY-SAND – A filter with a layer of filter media (usually silica sand) supported on graded gravel through which water flows by gravity.

FILTER MEDIA – The finely graded material which entraps suspended particles (sand, anthracite, diatomaceous earth, etc.).

FILTER, PRESSURE-SAND – A sand filter enclosed in a tank to operate under pressure.

FILTER ROCK – Graded, rounded rock and/or gravel used to support filter media.

FILTER, SAND – A type of filter media composed of hard sharp silica, quartz, or similar particles with proper grading for size and uniformity.

FILTER SEPTUM – That part of the filter element consisting of cloth, wire screen or other porous material on which the filter cake is deposited.

FILTER, VACUUM (SUCTION) – A filter which operates under a vacuum or from the suction side of a pump.

FILTRATION FLOW – The rate of flow in volume per time (gpm, gph), through the filter system installed per manufacturer's instructions with a new, clean filter medium.

FILTRATION RATE – The rate of filtration of water through a filter during the filter cycle expressed in US gallons per minute per square foot of effective filter area.

FINA – The Federation Internationale de Natation Amateur – The governing body for intercollegiate competition including the Olympic games.

FLOCCULATING AGENT – A compound, such as one of the alums, which forms minute flakes in water which attract or enmesh small suspended particles.

FLOOR – Shall refer to the interior bottom surface of a pool or spa, ranging from a horizontal plane up to a maximum of a 45° slope.

FLOOR SLOPE – The slope in the pool floor, usually expressed in feet (or inches) of vertical rise in feet (or inches) of horizontal distance.

FREEBOARD – The clear vertical distance between the top of the filter medium and the lowest outlet of the upper distribution system in a permanent medium filter.

GALVANIC ACTION – Creation of an electrical current by electrochemical action.

GUTTER FITTING (GUTTER DRAIN) – A drainage fitting used in the overflow gutter.

HANDHOLD/HANDRAIL – A permanently installed device that can be gripped by a bather for the purpose of resting and/or steadying him/herself. Is not limited to but may be located within or without the pool, spa or hot tub or as part of a set of steps or deck-installed equipment.

HI-RATE PERMANENT MEDIA FILTER – A filter using high velocity flow made possible by uniform distribution and collection of incoming and outgoing water.

HOSE CONNECTOR – The fitting used to connect the hose to the vacuum wall fitting (usually a combination hose sleeve and nut).

HOT TUB – A spa constructed of wood with sides and bottom formed separately; and the whole shapes to join together by pressure from the surrounding hoops, bands or rods; as distinct from spa units formed from plastic, concrete, metal or other materials.

HYDROJETS – A fitting that bleeds air and water creating a high velocity, turbulent stream of air enriched water.

HYDROTHERAPY INLET FITTING – A special high velocity air entraining inlet fitting to produce a massage effect.

HYDROTHERAPY SPA OR HOT TUB – A unit that may have a therapeutic use which is not drained, cleaned or refilled for each individual. It may include, but not be limited to, hydrojet circulation, hot water and cold water mineral baths, air induction bubbles or any combination thereof. Industry terminology for a spa includes, but is not limited to, "therapeutic pool," "hydrotherapy pool," "whirlpool," "hot spa," etc.

Glossary

HYPOCHLORINATOR – A device used to feed, control and measure a solution of sodium or calcium hypochlorite into a water being treated. There are three general types: The positive displacement type which is usually a motor driven unit, the aspirator type actuated by a pressure differential created within the hydraulic system, and the metering type connected to the pump suction using an orifice which is opened and closed by a timing mechanism.

HYPOCHLORITE – A chemical compound commonly found in two forms for use with pools, spas and hot tubs: calcium hypochlorite is a chlorine carrier in both granular and solid form normally containing 70% to 80% available chlorine by weight; sodium hypochlorite is a liquid chlorine carrier normally containing 5% to 16% available chlorine by weight.

HYPOCHLORITE, CALCIUM – A compound of chlorine and calcium used in powder or granulated form usually containing 70% to 80% available chlorine by weight which is released in water solution to act as a germicide or algaecide.

HYPOCHLORITE, SODIUM – A compound usually containing 5% to 16%, or more, available chlorine by weight, in a caustic soda solution, which releases chlorine when added to pool water.

IMPELLER – The rotating vanes of a centrifugal pump.

INFLUENT – The inflow or entering water to a filter or other device.

INLET – The fitting through which the filtered water passes to the pool (filtered water inlet), or the fitting through which raw water passes to the pool (raw water inlet).

IODINE – An element related to chlorine and bromine used as a disinfectant, both in its natural solid form and in iodide compounds. When iodides are used, chlorine is normally employed to free the elemental iodine.

JTU (JACKSON TURBIDITY UNIT) – A visual means of measuring water clarity based upon the amount of light passing through a tube of water.

JUMP BOARD – A mechanism that has a coil spring, leaf spring or comparable device located beneath the board which is activated by the force exerted in jumping on the board.

LADDERS –

Deck ladder: A ladder for deck access from outside the pool, spa or hot tub.

Double Access Ladder: A ladder that straddles the pool wall of an aboveground pool and provides pool ingress and egress.

In-Pool, Spa or Hot Tub Ladder: A lader located in a pool, spa or hot tub to provide ingress and egress from the deck.

Limited Access Ladder: Any ladder with provision for making entry inaccessible when a pool, spa or hot tube is not in use (i.e., swing-up, slide-up or equivalent).

Portable Ladder: Any ladder that is intended to be removed easily when a pool, spa or hot tub is not in use.

LINER – That membrane that acts as a container for the water.

Expandable Liner: A liner that is constructed of a material that has the capability of stretching into a greater depth of irregular shape other than the original construction dimensions.

Hooper Liner: The liner that is used to obtain greater depth by geometrical pattern construction on the liner bottom or floor to fit a predetermined size and shape.

LOWER DISTRIBUTION SYSTEM (UNDERDRAIN) – Those devices used in the bottom of a permanent medium filter to collect the water during the filtering and to distribute the water during the backwashing.

MAIN OUTLET – The outlet fitting at the bottom of a swimming pool through which water passes to the recirculating pump (often erroneously referred to as the “main drain”.

MAKE-UP WATER – Fresh water used to fill or refill the pool, spa or hot tub.

MULTIPLE FILTER CONTROL VALVE – A multi-port valve with at least four positions for varous filter operations, which combines in one unit the function of two or more single direct flow valves (Dial Selector Valve).

MURIATIC ACID – A commercial name for hydrochloric acid. Used for lowering the pH and alkalinity of pool water.

NCAA – National Collegiate Athletic Association – The governing body for intercollegiate competition and the recording agent for college swimming records.

NONSWIMMING AREA – Any portion of a pool, spa or hot tub where water depth, offset ledges or similar irregularities would prevent normal swimming activities.

NTU (NEOPHELOMETRIC TURBIDITY UNIT) – An instrumental means of measuring water clarity based upon the intensity of light scattered by suspended particles.

ORIFICE PLATE – A disc, placed in a water flow line, with a concentric sharp-edged circular opening in the center, which creates a differential pressure to measure flow and to operate feeders and instruments or other hydraulic equipment.

OVERFLOW GUTTER – The gutter around the top perimeter of the pool which is used to skim the surface of the water and to carry off the waste, or to collect it for return to the filters (sometimes incorrectly referred to as “scum gutter” or “spit trough”).

OVERFLOW SYSTEM – Refers to removal of pool surface water through the use of overflows, surface skimmers and surface water collection systems of various design and manufacture.

pH – A value expressing the relative acidity or alkalinity of a substance, such as water, as indicated by the hydrogen ion cncentration.

PINCHING HAZARD – Any configuration of components that would pinch or entrap the fingers or toes of a bather.

POOL BOILER – A type of pool heater operating as an Indirect Type, but using steam instead of hot water in the closed system.

POOL DEPTH – The vertical distance between the floor level and the normal or operating water level when the pool is in use.

POOL FLOOR – That portioin of the pool interior which is horizontal or which is inclined 45° or less from horizontal.

POOL HEATER – A device through which pool water is circulated to increase the temperature of the water. In the Direct Type, the heat is transferred directly to the pool water circulating tubes. The Indirect Type utilizes a separate enclosed system which is directly exposed to heat generator and which heats the pool water by circulating the steam or hot water around the tubes of a heat exchanger through which the water circulates. The heat generator is considered part of every heater.

POOLS –

Aboveground/Portable Pool: A removable pool of any shape that is deeper than forty-two inches (42") or holds more than 2,500 gallons of water or has a water surface area in excess of 150 square feet. The aboveground pool frame is located entirely above ground and may be readily disassembled for storage and reassembled to its original integrity.

Inground Swimming Pool: Any pool, spa or hot tub whose sides rest in partial or full contact with the earth.

Non-Permanently Installed Pool: One that is so constructed that it may be readily disassembled for storage and reassembled to its original integrity.

On-Ground Swimming Pool: Any pool, spa or hot tub whose sides rest fully above the surrounding earth and that has a deep area below the ground level.

Permanently Installed Swimming Pool: A pool, spa or hot tub that is constructed in the ground or in a building in such a manner that it cannot be readily disassembled for storage.

Public Pool: Any pool, other than a residential pool, which is intended to be used for swimming or bathing and is operated by an owner, lessee, operator, licensee or concessionaire, regardless of whether a fee is charged for use. References to various types of public pools are defined by the following categories:

Class A – Competition – Any pool intended for use for accredited competitive aquatic events such as FINA, AAU, NCAA, N.F., etc. The pool may also be used for recreation.

Class B – Public Pool – Any pool intended for public recreational use.

Class C – Semi-Public Pool – Any pool operated solely for and in conjunction with lodgings such as hotels, motels, apartments, condominiums, etc.

Class D – Special Purpose Pool – Any pool operated for medical treatment, water therapy or nonrecreational functions.

Public Pools may be diving or nondiving. If diving, they shall be further classified into types as an indication of the suitability of a pool for use with diving equipment.

Type VI thru Type X – Public Pools suitable for the installation of diving equipment by type. Diving equipment classified at a higher type may not be used on a pool of lesser type (i.e., Type VIII equipment on a Type VI pool).

Residential Pool: A residential pool shall be defined as any constructed pool, permanent or nonportable, that is intended for noncommercial use as a swimming pool by not more than three-owner families and their guests and that is over twenty-four inches (24") in depth, has a surface area exceeding 250 square feet and/or a volume over 3,250 gallons.

Residential Pools shall be further classified into types as an indication of the suitability of a pool for use with diving equipment.

Type Q – Any residential pool where the installation of diving equipment is prohibited.

Type I thru Type V – Residential pools suitable for the installation of diving equipment by type. Diving equipment classified at a higher type may not be used on a pool of lesser type (i.e., Type III equipment on a Type II pool).

Wading Pool: A pool that may range in water depth from two feet (2') to zero feet (0') for wading.

POOL WALL – The sides of a pool above the floor which are vertical at the top and coved at the bottom, or which are inclined to the pool no more than 45° from the vertical.

POTABLE WATER – Any water, such as an approved domestic water supply, which is bacteriologically safe and otherwise suitable for drinking.

PPM (PARTS PER MILLION) – Unit used for the measurement of the concentration of a chemical or other substance in the pool, spa or hot tub water, where this concentration is expressed in terms of "n" molecules of substance per one million molecules of water.

PRECOAT – The coating of filter aid on the septum of a diatomite type filter at the beginning of each filter cycle.

PRECOAT FEEDER – A device used to feed a calculated amount of filter aid at the start of a diatomaceous earth filter cycle - following the cleaning operation.

PRESSURE DIFFERENTIAL – The difference is pressure between two parts of a hydraulic system (influent and effluent of a filter, suction and discharge of a pump, the up and down-stream sides of a venturi or orifice).

PSI – A n appreviation for "pounds per square inch" (see "Feet of Head").

PUMP STRAINER – A device, placed on the suction side of a pump, which contains a removable strainer basket designed to trap debris in the waterflow with a minimum of flow restriction (sometimes referred to in the past as a "Hair and Lint Trap").

PUNCTURE HAZARD – Any surface or protrusion that would puncture a bather's skin under casual contact.

QUATERNARY AMMONIA – A series of compounds of ammonia in solution used as algaecides and germicides which reduce the surface tension of the water.

RATED PRESSURE – That pressure that is equal to or less than the designed pressure and appears on the dataplate of the equipment.

RATE OF FLOW (GPM) – The measurement of the volume of flow per unit of time expressed in gallons per minute.

RATE OF FLOW INDICATOR – A device to indicate the rate of flow in a pipe line (sometimes referred to as a "rate-of-flow meter").

RECIRCULATING SYSTEM – The entire system including the suction piping, pump, strainer, filter, face piping and return piping.

REMOVABLE – Capable of being disassembled with the use of only simple tools such as a screwdriver, pliers or wrench.

RESIDUAL – Usually refers to chlorine residual, or the amount of measurable chlorine remaining after treating water with chlorine. Free residual differs from combined residual in that it is not combined with ammonia or other elements or compounds, and is a more effective disinfectant.

RETURN PIPING – That part of the pool, spa or hot tub piping between the filter and the vessel through which filtered water passes.

SAFETY LINE – A continuous line not less than 1/4 inch in diameter, which is supported by buoys and attached to opposite sides of a pool to separate the deep and shallow ends.

SEPTUM – That part of the filter element consisting of cloth, wire screen or other porous material on which the filter medium or aid is deposited.

SERVICE FACTOR – A factor indicating the degree to which an electric motor can be operated over a specified horsepower without danger of overload failure.

SILVER PROTEIN – A solution containing silver ions, such as Argyrol, used as a germicide.

SKIMMER WEIR – The horizontal surface over which the water flows to the circulating system (usually self-adjusting for water level changes).

SLIP RESISTING – A surface that has been so treated or constructed as to significantly reduce the chance of a bather from slipping. The surface should not be an abrasion hazard.

SLURRY – A suspension of diatomaceous earth in water used for body feeding in D.E. filters.

SLURRY FEEDER – a device to feed a variable amount of filter aid during the filter cycle.

SODIUM BISULFATE – A dry chemical commonly used to lower pH in water. Also called soda ash.

SODIUM CARBONATE – A dry chemical commonly used to raise pH in water.

SPA (SEE "HYDROTHERAPY SPA" OR "HOT TUB") – A hydrotherapy unit of irregular or geometric shell design.

Inground Spa/Hot Tub: Any spa or hot tub whose sides reside partially or fully below the natural ground level.

Nonpermanently Installed Spa/Hot Tub: Any such unit that is so constructed that it may be readily disassembled for storage and reassembled to its original integrity.

Permanently Installed Spa/Hot Tub: Any such unit that is constructed in the ground, or in a building, in such a manner that it cannot be readily disassembled for storage.

SPRAY RINSE, MECHANICAL – A fixed or mechanically movable spray system which directs a stream of water against the filter surface, causing the filter aid and accumulated dirt to dislodge into the empty tank.

SPRINGBOARD – A board especially designed to produce diver spring action when properly installed on an anchor (base) and fulcrum. (The term diving board includes non-spring types).

STATIC HEAD – The vertical distance between the free level of the source of the supply and the point of free discharge, or to the level of the free surface of the discharged water.

STEPS, RECESSED STEPS, LADDERS, AND RECESSED TREADS – A means of pool ingress and egress that may be used in conjunction with one another.

Steps: A riser/tread or series of risers/treads extending down from into the deck with the bottom riser/tread terminating at the pool, spa or hot tub wall, thus creating a "stairwell".

Ladders: A series of generally vertically separate treads or rungs connected by vertical rail members or independently fastened to an adjacent vertical pool wall (see "Ladders" for definitions of particular ladder types).

Recessed Treads: A series of vertically spaced cavities in the pool, spa or hot tub wall creating tread areas for step-holes.

SUCTION HEAD – The total head on the suction side of the pump, including suction lift and friction head.

SUCTION PIPING – That part of the pool, spa or hot tub piping through which water passes from the vessel to the pump.

SURFACE SKIMMER – Sometimes called a Recirculating Overflow. A deviced designed to continuously remove surface film and water and return it through the filter as part of the recirculation system, usually incorporating a self-adjusting weir, a collection tank and a means to prevent air lock of the pump (sometimes referred to as a "recirculation overflow," or a "mechanical" or "automatic skimmer").

SURFACE SKIMMER SYSTEM – This term encompasses perimeter type overflows, surface skimmers and surface water collection systems of various design and manufacture.

SURGE CHAMBER – A storage chamber within the pool recirculating system used to absorb the water displaced by bathers.

SWIMMING AREA – That area of a pool in excess of 3 feet in depth which is devoted to swimming.

TAMPERPROOF – Meaning that tools are required to alter or remove portions of the equipment.

TOXIC – Meaning that a given substance has an adverse physiological affect on man.

TREAD CONTACT SURFACE – Foot contact surfaces of a ladder, step, stair or ramp.

TURBIDITY – Cloudy condition of water due to the presence of finely divided microscopic materials in suspension that interfere with the passage of light.

TURNOVER – The period of time (usually in hours) required to circulate a volume of water equal to the pool, spa or hot tub capacity.

UNDERDRAIN – The distribution system at the bottom of the filter which collects the water uniformly during the filter cycle, and which distributes the backwash water uniformly during the cleaning operation. Normally applies to sand filters.

UNDERWATER LIGHTS – A light designed to illuminate a pool from beneath the water surface.

UPPER DISTRIBUTION SYSTEM – Those devices designed to distribute the water entering a permaent medium filter in a manner so as to prevent movement or migration of the filter medium. This system shall also properly collect water during filter backwashing unless other means are provided.

VERTICAL WALL – Shall refer to the wall up to a positive 11° angle towards the pool's interior from plumb.

WALLS – The interior pool wall surfaces consisting of surfaces from the plumb to a 45° slope.

WATER LINE – The water line shall be defined in one of the following ways:

Skimmer System: The water line shall be at the midpoint of the operating range of the skimmers.

Overflow System: The water line shall be at the top of the overflow rim.

WET NICHE – A watertight and water cooled unit submerged and placed in a niche in the pool wall.

DRY NICHE – A normal weatherproof fixture placed in an opening behind the pool wall which illuminates the pool through a watertight window in the pool wall.

VACUUM WALL FITTING – The fitting in the wall of the pool just below the water level to which is attached the hose for the underwater suction cleaner.

VELOCITY – The measurement of the motion of liquids, expressed in feet per second.

VENTURI TUBE – A tube, which has a constricted throat, which causes differences in pressure and can be used to operate feeding devices, instruments and to measure flow.

WADING AREA – That area less than 3 feet in depth devoted to activity of non-swimmers.

WALL SLOPE – The inclination from vertical in a pool wall, expressed in degrees or in feet (or inches) of horizontal distance in a given depth in feet (or inches).

Sta-Rite is a quality-conscious manufacturer of a complete selection of highly efficient commercial filtration systems, recirculating pumps and accessories necessary for original construction, renovation or operation of large swimming and aquatic facilities. An all-employee team is involved in the total quality effort, from the energy efficient designs, right through manufacturing and assembly to the final testing of each product prior to shipment. Every product is built to the highest possible standards every step of the way.

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Suggested specifications herein reflect those of various industry organizations, current at this printing. Sta-Rite assumes no repsonsibility for variants from governmental or association standards, since changes in these standards may occur at any time.

Reference

ORGANIZATION	ACTIVITY
American Alliance for Health, Physical Education, Recreation and Dance 1900 Association Drive Reston, VA 20091-1598 Phone: 703-476-3400, Fax: 703-476-9527	NAGWS Official Swimming and Diving Rules for Girls and Women
National Collegiate Athletic Association 700 W. Washington Street Indianapolis, IN 46206-6222 Phone: 317-917-6222, Fax: 317-917-6888	The National Collegiate Athletics Association is the organization through which the nation's colleges and universities speak and act on athletic matters at the national level.
National Federation of State High School Associations P.O. Box 690 Indianapolis, IN 46206 Phone: 317-972-6900, Fax: 317-822-5700	NFHS Swimming, Diving, Water Polo Rules NAGWA Sychronized Rules
National Sanitation Foundation (NSF) P.O. Box 130140, 789 N. Dixboro Road Ann Arbor, MI 48113-0140 Phone: 734-769-8010, 800-NSF-MARK Fax: 734-769-0109 Email: info@nsf.org Website: www.nsf.org	Standards on Circulation System Components for Swimming Pools, Spas or Hot Tubs
National Spa and Pool Institute (NSPI) 2111 Eisenhower Avenue Alexandria, VA 22314 Phone: 703-838-0083, Fax: 703-549-0493 Website: www.nspi.org	Standards for Public Swimming Pools and Spas
National Swimming Pool Foundation P.O. Box 495 Merrick, NY 11566 Phone: 516-623-3447, Fax: 516-867-2139 Email: lknspf@aol.com	Pool Design Compendium – A Comparision of Competitive Swimming and Diving Criteria and Standards
USA Swimming One Olympic Plaza Colorado Springs, CO 80909 Phone: 719-866-4578	Technical Rules and Codes of Regulations
United States Diving, Inc. 201 S. Capital Avenue, Suite 430 Indianapolis, IN 46225 Phone: 317-237-5252, Fax: 317-237-5257	United States Diving Rules and Regulations
United States Synchronized Swimming, Inc. 201 S. Capital Avenue, Suite 901 Indianapolis, IN 46225 Phone: 317-237-5700, Fax: 317-237-5705	Official Rules for United States Synchronized Swimming
United States Water Polo, Inc. 1685 W. Unitah Colorado Springs, CO 80904-2921 Phone: 719-634-0699, Fax: 719-634-0866	Official Water Polo Rules