CHAPTER 6

SIZING PUMPS, PIPES AND FILTERS

6.0 INTRODUCTION

If solar heat collectors are to be successfully used to meet a portion of the heating load for a commercial swimming pool (or a spa) their use should not reduce the rate of flow through the filtration system nor should it greatly increase the horsepower required to maintain that circulation. All code jurisdictions have maximum allowable turnover times for filtration and chlorination systems in pools. That time must not be exceeded because of the increased resistance to flow caused by the addition of piping and collector array. Excessive pumping horsepower unnecessarily reduces solar savings; this, too, is to be avoided. For simple installations, sizing the filters, pumps and pipe runs to adequately circulate, clean and heat the pool water successfully may be accomplished by following the instructions contained in the following sections. For large or complex installations, more-detailed manuals or a hydraulics specialist should be consulted.

A basic knowledge of the characteristics of a swimming pool's circulation system will be useful to solar designers and installers in selecting the components appropriate for the solar heating of a specific pool. It requires large enough pipe diameters to keep friction losses low, proper flow through the solar collectors to maximize heat collection yet minimize pressure drop, and adequate collector sizing to minimize the number of hours the pump must operate each day. Obviously, it is pointless to oversize the solar-related components to an extent that reduces the time required for heat collection below that required for acceptable filtration. (On most commerical pools the pump must run continously to meet community health standards.) It may be beneficial for the designer to obtain a pamphlet entitled Energy Efficient Sizing of Swimming Pool Pumps,Motors and Filters, (EAP-PF1) from the National Spa and Pool Institute, 2000 K Street, NW, Washington, DC 20006.

6.1 SIZING FILTRATION AND CIRCULATION SYSTEMS

Proper sizing of swimming pool filters, circulation pumps, and pipe runs may be accomplished by using the information provided in this section in conjunction with data routinely provided by manufacturers of those components.

6.1.1 Filter Sizing Graphs

Filter sizing is accomplished by using graphs such as Figure 6.1 provided by filter manufacturers. The following kinds of filters are those most often used to keep swimming pools cleans.

Sand, gravel, or anthracite filters are sometimes operated at a flow rate as high as 20 gallons per minute (gpm)/ft^2. It should be noted that some code jurisdictions limit the flow rate through these filters to three gpm/ft^2. Diatomaceous earth (DE) filters usually operate well at about two gpm/ft^2. Both sand and DE filters may be cleaned by back washing and discharging the dirty water into a sewer or other appropriate outlet. An air gap in the discharge line often is required to ensure against backflow contamination from the sewer. Cartridge filters usually are operated at a flow rate of about one gpm/ft^2 and may be reverse flushed and re-used. When the cartridges become excessively dirty they simply are replaced.

In pool filtration systems, the need for cleaning is indicated by high readings on a pressure gauge that is located between the filter and the

Filter manufacturers specify the readings at which they recommend maintenance The typical pressure drop using properly sized, clean filters is about five psi The back washing valve assembly on DE and sand filters may add another five psi.

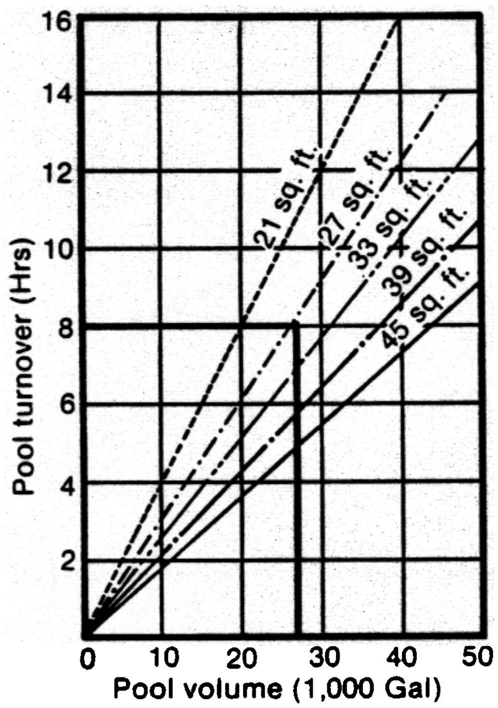

Figure 6.1

DE Filter Sizing Graph for Flow Rate of 2 Gpm/ft^2

6.1.2 Pump Sizing Graphs

To size the pumps it is necessary to establish a flow rate in gpm and then add up all the pressure drops which occur when water flows through the system at that rate. Figure 6.2 is a graph on which pressure drop flow rate are plotted for typical swimming pool ciruclation pumps

6.1.3 Sizing Connecting Piping

Connecting piping may be sized using pipe flow charts (Figures 6-4 and 6-5) Piping should be large enough to prevent excessively high flow rates which cause erosion of interior pipe and fitting surfaces Some code jurisdictions limit the rate of water flow through copper pipes to five feet per second Adequately sized piping and pumps help reduce maintenance and operating costs

6.2 SIZING A COMPLETE CIRCULATION SYSTEM

The following examples are intended to help clarify sizing procedures

The owner of a 20 foot x 40 foot motel swimming pool with an average depth of 4½ feet wants to be able to circulate the total pool volume through the filtration system in eight hours. (His turnover rate is one complete recirculation per eight hours.) He plans to use a DE filter and wants to know what size filter will be required and what size pumps will be required (1) with no heater, (2) with a gas heater, (3) with a solar heater and a gas heater for backup, and (4) with a solar heater without a backup The pump will be located so that the center of its impeller is three feet above the surface of the pool One hundred feet of pipe will be required unless solar collectors are used In that case, 200 feet of connecting pipe will be required. The high point of the solar collector array will be 12 feet above the center of the pump impeller The solar collectors will be connected to the circulation piping as shown in Figure 4.1b The owner also wants to know what size connecting pipe should be installed under any of the four alternative conditions

STEP 1. Determine the pool volume

Pool volume (gal) = 20' x 40' x 4.5' x 7.48 gal/ft^3 = 26,900 gal

STEP 2. Determine the DE filter cross sectional area if 2 gpm/ft^2 of filter is an acceptable flow rate through it, and the pool volume of 26,900 gallons must turn over every eight hours.

Figure 6.1 shows that a cross-sectional area between 27/ft^2 and 33/ft^2 be required. The filter that provides 33/ft^2 of cross-sectional area be the better choice because it will allow a turnover time of slightly less than eight hours

STEP 3 Determine the flow rate through the filtration system.

Because the entire volume must turn over once each eight hours,

$$\text{Flow rate} = \frac{26,900}{8} = 3360 \text{ gallons per hour (gph)}$$

$$\text{Flow rate} = \frac{3,360}{60} = 56 \text{ gpm}$$

STEP 4. If no heater is included in the system, determine the total pressure that the pump will be required to overcome at a flow rate of 56 gpm

Cause of Pressure Drop	Source of Information	Pressure Drop Lbs/In^2 (psi)	Pressure Drop Ft of Water (psi x 2.31)
100 ft 1½" schedule 40 plastic pipe	Figure 6.4	8	18.5
Fitting	About 1/2 of pipe drop	4	9.2
Valves	Manufacturer's specs.	5	11.6
Filter	Manufacturer's specs.	5	11.6
Lift head			3.
	TOTAL		54

Figure 6.2 shows that a one-hp pump (of the specific design covered by that graph) will circulate 56 gpm against a 57-foot head A 3/4-hp pump will circulate only 45 gpm against a 51-foot head, so the one-hp pump will be the safest choice

Discussion: It is interesting to note that if two-inch schedule 40 pipe is used, the' pressure drop in the pipe is only three psi or seven feet of water, so the total pressure drop is about 37 feet of water Figure 6.2 shows that a 3/4-hp pump is powerful enough to circulate 52 gpm against a total head of 37 feet of water. (Turnover time increases to 8.6 hours.) Figure 6.3 illustrates the relative magnitude of the pressure drops

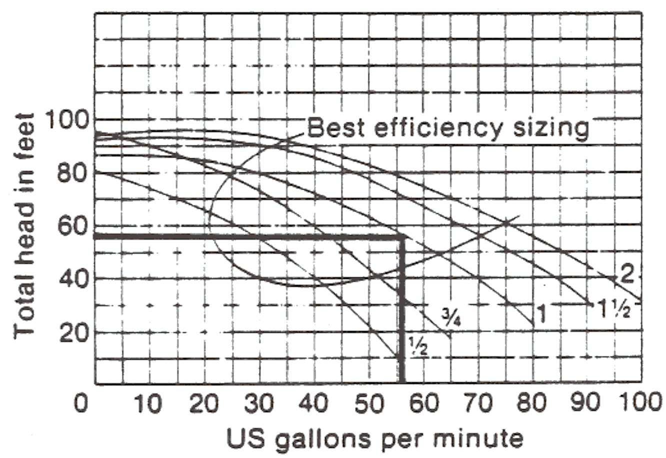

Figure 6.2 Pump Performance Curves

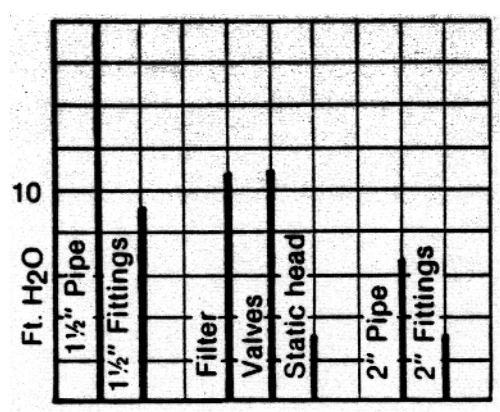

Figure 6.3 Magnitude of Pressure Drops

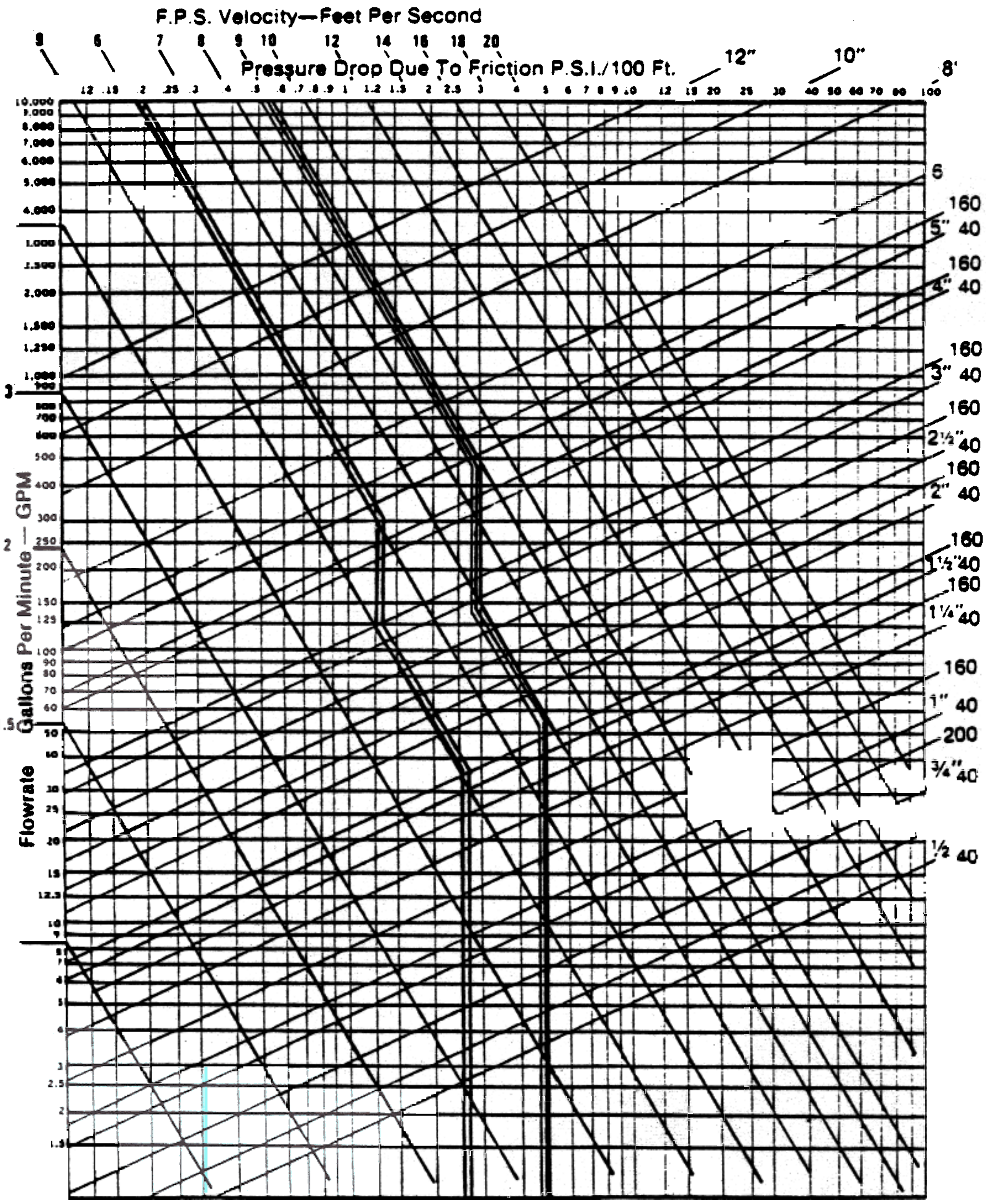

Figure 6.4

Pressure Drop in Plastic Pipe

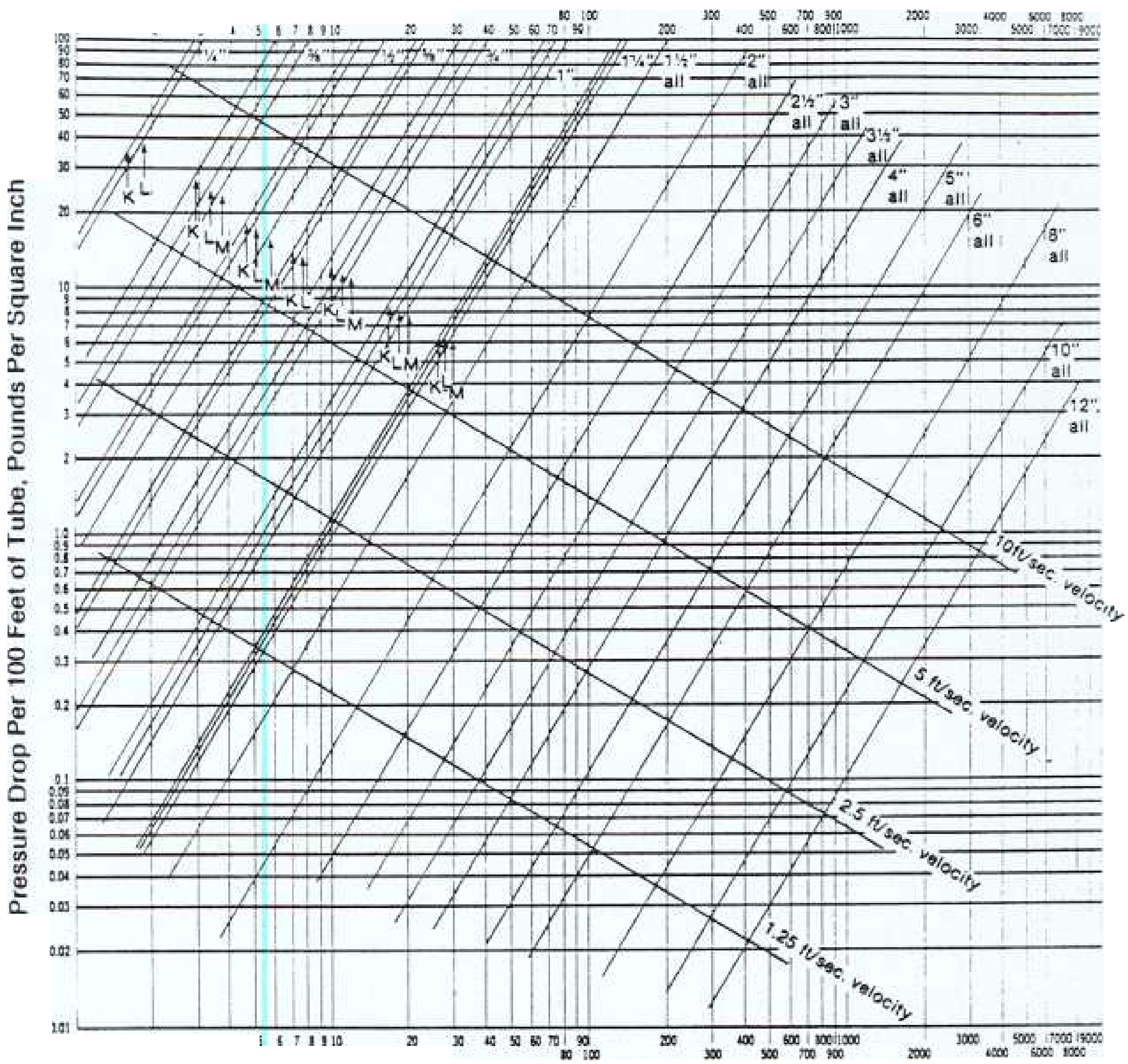

Figure 6.5

Pressure Loss and Velocity Relationships for Water Flowing in Copper Tube

(Note that the Axis Labeling is Different from Figure 6.4)

STEP 5 Determine the size pump which will be required if a gas-fired pool heater is added which causes an additional pressure drop of five psi

Cause of Pressure Drop	Pressure Drop Psi	Ft of Water
100 ft 1½" schedule 40 plastic pipe	8	18.5
Fittings	4	9.2
Valves	5	11.6
Filter	5	11.6
Pool heater	5	11.6
Lift head		3
Total		65

Figure 6.2 shows that a one-hp pump will pump about 50 gpm against 65 feet of water. This is probably close enough to the required volume for practical purposes. (The turnover time is a littler longer -- nine hours.)

Discussion Under these conditions, using two-inch pipe reduces the total pressure drop to about 50 feet of water but this does not allow us to use a 3/4-hp pump because the smaller pump will only circulate 46 gpm against a 50-foot head. (In this case the turnover time would be increased to 10 hours should the 3/4-hp pump be used.)

STEP 6 Determine the size pump which will be required if we add a solar collector system and a gas-fired backup heater. A pressure drop of two psi is expected across the solar collectors The system contains an extra 100 feet of pipe and a vacuum breaker located 12 feet* above the center of the pump's impeller

*As previously noted, relocating the vacuum breaker to the feeder line from the pool to the collector array can cause a balance of the static head pressure (flow down balances flow up) and reduce pump hp requirements by 15 ft of water head. This may be done in such a way as to permit complete system drainage. (See FSEC IN-13-83.)

Using 1½" and 2" Pipe

Cause of Pressure Drop		Pressure Drop Ft of Water
100 ft 1½" pipe	8	18.5
fittings	4	9.2
100 ft 2" pipe	3	6.9
fittings	1+	2.3+
Valves	5	11.6
Filter	5	11.6
Solar Panels	2	4.6
Gas heater	5	11.6
Static head (3'+12')		15
Total		92

Using Only 2" Pipe

Cause of Pressure Drop		Pressure Drop Ft of Water
200 ft 2" pipe	6	13.9
fittings	3	6.9
Valves	5	11.6
Filter	5	11.6
Solar Panels	2	4.6
Gas heater	5	11.6
Static head (3'+12')		15
Total		75

Figure 6.4 shows that if 100 feet of 1½-inch pipe and 100 feet of two-inch pipe are used to make the connections, a two-hp pump will move only 35 gpm against the 92-foot water head This increases the turnover time to about 13 hours, so a 2½-hp pump will be required If 200 feet of two-inch pipe is used, a 1½-hp pump will move 52 gpm against the 75-foot head. Again, in this example, 52 gpm will probably turn the pool volume over in an acceptable period of time (8.6 hr)

Discussion: Another option applicable to retrofitting a gas-heated pool piped initially with 1½-inch pipe and a one-hp pump is the addition second small pump installed as pictured in Figure 4.1d The additional pump will be required to overcome a static head of 12 feet of water and a friction head of 28 feet of water if 1½-inch pipe is used to connect the solar panels to the system The pressure loss across the panels will still be 4.6 feet of water The total pressure drop that the added pump will be required to overcome will be 12 + 28 + 4.6 or about 45 feet of water head Figure 6.2 shows that a 3/4-hp pump will circulate 49 gpm against a 45-foot head. It should be noted that the two pumps working in series will assist each other and in most cases the turnover times will be no more than eight hours

Two pumps require more maintenance than does one but the solar booster pump may be turned off when circulation through the panels is not desired. This reduces electrical consumption

A final option for pool heating is the addition of solar collectors without a fossil-fired backup system Referring to the immediately preceding piping options, the elimination of the gas-fired heater reduces the pressure drop from 92 to 80 feet of water if an additional 100 feet of 1½-inch pipe and 100 feet of two-inch pipe are used to make the connecions

Figure 6.2 shows that a two-hp pump will pump 54 gpm against an 80-foot head. (The turnover time is 8.3 hours.)

If two-inch connecting pipe is used throughout, the total pressure drop is reduced to about 63 feet and a one-hp pump will deliver 50 gpm against a 63-foot head (the turnover time is nine hours) A 1½-hp pump will circulate about 65 gpm against a 63-foot head (the turnover time is 7½ hours)

Table 6.1 presents each of the pool heating options and the corresponding pipe and pump sizes which yield the various pool turn-over time periods

Table 6.1
Pool Heating Options

Components	Pipe Size	Pump Size Required	Turnover Time
System with no heater	100 ft of 1½" schedule 40 plastic	1 hp	8 hr
	100 ft of 2" schedule 40 plastic	3/4 hp	8.6 hr
System with gas or oil heater (5 psi pressure drop)	100 ft 1½"	1 hp	9 hr
	100 ft 2"	1 hp	7.2 hr
System with gas and solar (15-ft static head)	100 ft 1½" plus 100 ft 2"	2½ hp	8 hr
	200 ft 1½"	2 pumps (1 hp + 3/4 hp)	8 hr
	200 ft 2"	1½ hp	8.6 hr
System with solar only (15-ft static head)	100 ft 1½" plus 100 ft 2"	2 hp	8.3 hr
	200 ft 2"	1 hp 1½ hp	9 hr 7.5 hr

None of the stated options alter the turnover rate of the pool sufficiently to require resizing the DE filter It should contain between 27/ft^2 and 33/ft^2 of filtration area

6.5 PRESSURE DROP ACROSS THE VALVES AND FITTINGS

Many swimming pool installers use the simple rules of thumb cited in the previous examples to determine pressure drops caused by the resistance to liquid flow of valves and fittings However, it is important for the solar installer to realize that the actual pressure drops vary with both rate and mechanical characteristics of specific valves and fittings Table 6.2 presents frictional losses expressed in equivalent lengths of pipe for commonly used fittings (Most fitting manufacturers supply similar tables.) The sum of the equivalent length of all the fittings on the circulation system may be added to the actual length of pipe in the system before the pressure drop is read from Figure 6.4 (plastic pipe) or Figure 6.5 (copper pipes). The pressure drop across the backwash valve assembly is accepted as being five psi in the example Actually, this pressure also varies with flow rate and the mechanical design of specific valves The variation from valve to valve is too great to make a generalized tabular presentation of pressure drop much more useful than the five psi -of-thumb value Most filter and backwash valve suppliers can make available accurate tables or graphs for their valves The information usually is given in psi which may be converted to feet of water head by multiplying by 2.31

Table 6.2 Friction Losses in Fittings

Type of Fitting	Material	1"	1¼"	1½"	2"	2½"	3"	3½"	4"	5"	6"	8"	10"	12"
Standard Tee with flow through branch	Steel	6	8	9	11	14	16	-	20	26	31	40	51	61
	Plastic	9	12	13	17	20	23	-	29	-	45	-	-	-
	Copper	6	8	9	11	14	16	18	20	26	31	40	-	-
90-deg Long Radius Elbow, or run of Standard Tee	Steel	1.7	2.3	2.8	3.6	4.2	5.2	-	6.8	8.5	10	14	17	20
	Plastic	3	4	5	7	8	10	-	12	-	17	-	-	-
	Copper	1.7	2.3	2.8	3.6	4.2	5.2	6.1	6.8	8.5	10	14	-	-
Adapter-slip/solder fitting to thread	Plastic	3	3	3	3	3	3	-	3	-	3	-	-	
	Copper	1	1	1	1	1	1	1	1	1	1	1	-	
Insert Coupling	Plastic	3	3	3	3	3	3	-	3	-	3	-	-	
Gate Valve (fully open)		0.60	0.80	0.95	1.15	1.4	1.6	1.85	2.1	2.7	3.2	4.3	5.3	6.4
Swing Check Valve		7	9	11	13	16	20	23	26	33	39	52	67	77
Ordinary entrance		1.5	2.0	2.4	3.0	3.7	4.5	5.2	6.0	7.3	9.0	12	15	17

Friction losses expressed as equivalent lengths of pipe (feet)