Water System Design

Continuing Education from *Plumbing Systems & Design*

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The objective in designing the water supply systems for any project is to ensure an adequate water supply at adequate pressure to all fi xtures and equipment at all times and to achieve the most economical sizing of the piping. There are at least six important reasons that proper design of water distribution systems is absolutely essential:

1. Health. This is of irrefutable and paramount importance. Inadequate or improper sizing can cause decreases in pressure in portions of the piping system, which in turn can cause contamination of the potable water supply by backfl ow or siphonage. There are too many well-documented deaths attributable to this cause.

2. Pressure. It is essential to maintain the required fl ow pressures at fi xtures and equipment or improper operation will result.

3. Flow. Proper and adequate quantities of fl ow must be maintained at fi xtures and equipment for obvious reasons.

4. Water Supply. Improper sizing can cause failure of the water supply due to corrosion or scale buildup.

5. Pipe Failure. Pipe failure can occur due to the relation of the rate of corrosion with excessive velocities.

6. Noise. Velocities in excess of 10 ft/sec will cause noise and increase the danger of hydraulic shock.

Of all the complaints resulting from improperly designed water systems, the two that occur most frequently are (1) lack of adequate pressure and (2) noise.

Noise may not be detrimental to the operation of a water distribution system but it is very defi nitely a major nuisance. The lack of adequate pressure, however, can have very serious repercussions in the operation of any water system.

FLOW PRESSURE

It is essential that the term fl ow pressure be thoroughly understood and not confused with static pressure. Flow pressure is that pressure that exists at any point in the system when water is fl owing at that point. It is always less than the static pressure. To have fl ow, some of the potential energy is converted to kinetic energy and additional energy is used in overcoming friction, which results in a fl ow pressure that is less than the static pressure.

When a manufacturer lists the minimum pressure required for the proper operation of a fl ush valve as 25 psi, it is the fl ow pressure requirement that is being indicated. The fl ush valve will not function at peak effi ciency (if at all) if the engineer has erroneously designed the system so that a static pressure of 25 psi exists at the inlet to the flush valve.

FLOW AT AN OUTLET

There are many times when the engineer must determine how many gallons per minute are being delivered at an outlet. This can easily be determined by installing a pressure gauge in the line adjacent to the outlet and reading the gauge while flow is occurring. With the flow pressure known, the following formula can be used:

(13-1)

$$q = 20d^2 p^{1/2}$$

where q = rate of flow at the outlet, gpm
d = actual inside diameter (ID) of outlet, in.
p = flow pressure, psi

Assume a faucet with a 3⁄8-in. supply and the flow pressure is 16 psi. Then:

$$q = 20 \times (3/8)2 \times (16)^{1/2}$$
$$= 20 \times 9/64 \times 4$$
$$= 11.25 \text{ gpm}$$

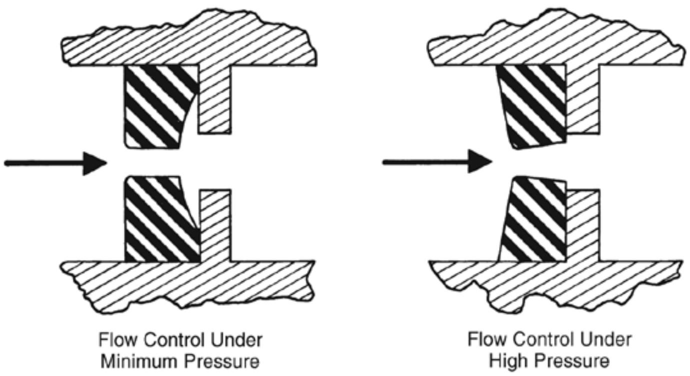
The flow for a ¼-in. and 1⁄8-in. supply at the same pressure would be 5 gpm and 1.25 gpm, respectively.

CONSTANT FLOW

Pressures in the various parts of the piping system are constantly fluctuating depending upon the quantity of flow at any moment. Under these conditions the rate of flow from any one outlet will vary with the change of pressure.

In industrial and laboratory projects there is some equipment that must be supplied with a fixed and steady quantity of flow regardless of line pressure fluctuations. This feature is also desirable in any type of installation.

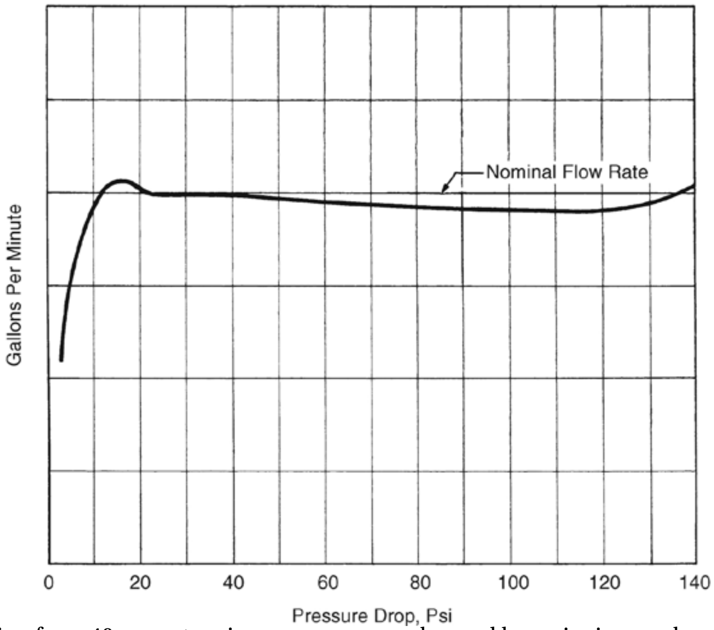
Figure 13-1 Flow Control



This criterion can easily be achieved by the utilization of an automatic flow-control orifice. A flow control is a simple, self-cleaning device designed to deliver a constant volume of water over a wide range of inlet pressures. (See Figures 13-1 and 13-2.) The automatic controlling mechanism consists of a flexible orifice that varies its cross-sectional area inversely with the pressure so that a constant flow rate is maintained under all conditions. Until the inlet pressure reaches the threshold pressure (12–15 psi), the flexible insert acts as a fixed orifice. When the threshold pressure is exceeded, the cross-sectional area of the orifice is decreased by the flexure of the insert. This causes a pressure drop that is equal to whatever pressure is necessary to absorb the energy not required to overcome system friction and to sustain the rated flow. The curve shown in Figure 13-2 is typical of most flow controls regardless of the rated flow, which is why no figures are shown for the gallons per minute axis. It is possible to approximate the flow of a specific flow control by using the line marked "Nominal Flow Rate" as the desired rate.

Assume a piece of equipment requires the fixed flow of 40 gpm and there is considerable line pressure fluctuation. A flow control would be specified to deliver 40 gpm. By use of the curve in Figure 13-2 the devia-

Figure 13-2 Flow Control Device Curve (Dole Valve)



tion from 40 gpm at various pressures can be read by assigning a value of 40 to the nominal flow rate line on the vertical scale and zero to the baseline. Standard flow controls are available in sizes from ¼ in. to 2½ in. and flow rates from ¼ to 90 gpm. They are ideal for use in limiting the maximum rate of flow to any fixture.

It is not unusual in a water distribution system to experience fluctuating discharges at fixtures and equipment due to other fixtures and equipment starting up or shutting down. Flow controls will minimize these problems because they automatically compensate for changes in the line pressure to hold the rate of water delivery from all outlets to a preselected number of gallons per minute. One very important word of caution—a flow control is not designed to perform the function of pressure regulation and should never be used where a pressure-regulating valve is required.

MATERIAL SELECTION

Before the type of material for the piping of a water distribution system can be selected, certain factors must be evaluated:

1. The characteristics of the water supply must be known. What is the degree of alkalinity or acidity? A pH above 7 is alkaline and below 7 is acidic. A pH of 7 represents neutral water. What is the air, carbon dioxide, and mineral content? The municipal water supply department can usually furnish all this information. If it is not available, a water analysis should be made by a qualified laboratory.

Table 13-1 Actual Inside Diameter of Piping, in Inches

Nominal Pipe Size, In.	Iron or Steel Pipe, Sch. 40	Brass or Copper Pipe	Copper Water Tube, Type K	Copper Water Tube, Type L
½	0.622	0.625	0.527	0.545
¾	0.824	0.822	0.745	0.785
1	1.049	1.062	0.995	1.025
1¼	1.380	1.368	1.245	1.265
1½	1.610	1.600	1.481	1.505
2	2.067	2.062	1.959	1.985
2½	2.469	2.500	2.435	2.465
3	3.068	3.062	2.907	2.945
4	4.026	4.000	3.857	3.905
5	5.047	5.062	4.805	4.875
6	6.065	6.125	5.741	5.845
8	7.981	8.001	7.583	7.725
10	10.020	10.020	9.449	9.625

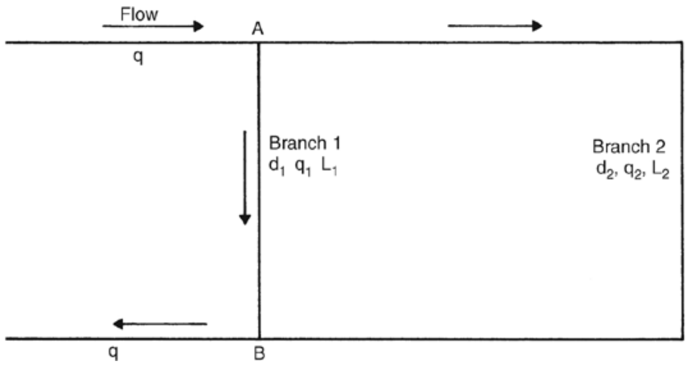
2. What are the relative costs of the various suitable materials?

3. Ease of replacement—can the material be obtained in a reasonable time or must it be shipped from localities that might delay arrival for months?

4. Actual inside dimensions of the same nominal size of various materials differ. This variation in ID can have a significant effect on sizing because of the variation in quantity rates of flow for the same design velocity. Table 13-1 shows the actual ID for various materials.

5. The roughness or smoothness (coefficient of friction) of the pipe will have a marked effect on pipe sizes.

Figure 13-3 Typical Parallel Pipe Circuit



PARALLEL CIRCUITS

There are many parallel pipe circuits in the water distribution system of any job. An arrangement of parallel pipe circuits is one in which flow from a single branch divides and flows in two or more branches which again join in a single pipe. Figure 13-3 illustrates a simple two-circuit system. The total flow entering point A is the same leaving point A with a portion flowing through branch 1 and the rest through branch 2. Flows q1 and q2 must equal q and the total pressure drop from A to B is the same whichever branch is traversed.

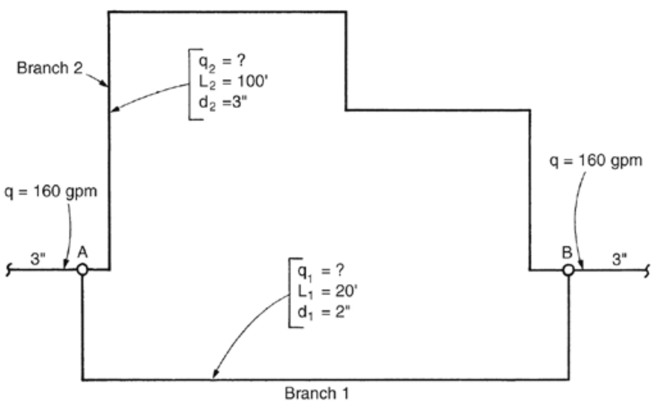
The rate of flow through each branch becomes such as to produce this equal pressure drop. The division of flow in each branch can then be expressed as:

(13-2)

$$\frac{q_1}{q_2} = \sqrt{\frac{L_2}{L_1}\left(\frac{d_1}{d_2}\right)^5}$$

Assume there is a flow in a 3–in. pipe of 160 gpm entering point A and leaving point B as shown in Figure 13-4. The length of branch 1 is 20 ft and branch 2 is 100 ft. The size of branch 1 is 2 in. and branch 2 is 3 in. To determine the quantity of flow in each branch, the basic formula is applied, and:

Figure 13-4 Example of Division of Flow in a Parallel Pipe Circuit



$$\frac{q_1}{q_2} = \sqrt{\frac{100}{20}\left(\frac{2}{3}\right)^5}$$
$$= \sqrt{5\ (.66)^5}$$
$$= \sqrt{5 \times 0.125}$$
$$= 0.79$$
$$q_1 = 0.79q_2$$

since $q_1 + q_2 = 160$

then $0.79q_2 + q_2 = 160$

$$1.79q_2 = 160$$
$$q_2 = 89.4 \text{ gpm}$$

and $q_1 = 160 - 89.4 = 70.6$ gpm

or $q_1 = 0.79 \times 89.4 = 70.6$ gpm

INADEQUATE PRESSURE

As previously noted, lack of adequate pressure is one of the most frequent complaints and could be the cause of serious troubles. The pressure available for water distribution within a building can come from various sources. Municipalities usually maintain water pressure in their distribution mains within the range of 35–45 psi. There are localities where the pressure maintained is much less or greater. The local utility will furnish the information as to their minimum and maximum operating pressures. When utilizing only the public water main pressure for the water distribution system within a building, it is very important to determine the pressure available in the mains during the summer months. Huge quantities of water are used during this period for sprinkling of lawns and for air-conditioning cooling tower makeup water, which usually cause excessive pressure loss in the mains. Future growth of the area must also be analyzed. If large housing, commercial, or industrial development is anticipated, the pressure available will certainly decrease as these loads are added to the public mains. It is good practice to assume a pressure available for design purposes as 10 psi less than the utility quotes.

If the pressure from the public mains is inadequate for building operation, other means must be provided for increasing the pressure to an adequate level. There are three basic methods available:

1. Gravity tank system
2. Hydropneumatic tank system
3. Booster pump system

Each system has its own distinct and special advantages and disadvantages. All three should be evaluated in terms of capital expenditure, operating costs, maintenance costs, and space requirements. Depending upon which criteria are the most important, this will dictate which system is selected.

FLOW DEFINITIONS

Maximum flow or maximum possible flow is the flow that will occur if the outlets on all fixtures are opened simultaneously. Average flow is that flow likely to occur in the piping under normal conditions. Maximum probable flow is the maximum flow that will occur in the piping under peak conditions. It is also called peak demand or peak flow.

DEMAND TYPES

Some outlets impose what is called a continuous demand on the system. They are differentiated from outlets that impose an intermittent demand. Outlets such as hose bibbs, lawn irrigation, air-conditioning makeup, water cooling, and similar flow requirements are considered to be continuous demands. They occur over an extended period of time. Plumbing fixtures draw water for a relatively short period of time and are considered as imposing an intermittent demand.

Each fixture has its own singular loading effect on the system, which is determined by the rate of water supply required, the duration of each use, and the frequency of use. The water demand is related to the number of fixtures, type of fixtures, and probable simultaneous use.

ESTIMATING DEMAND

The basic requirements for estimating demand call for a method that

1. Produces estimates that are greater than the average demand for all fixtures or inadequate supply will result during periods of peak demand.
2. Produces an accurate estimate of the peak demand to avoid oversizing.
3. Produces estimates for demand of groups of the same type of fixtures as well as for mixed fixture types.

DESIGN LOADS

Arriving at a reasonably accurate estimate of the maximum probable demand is complicated due to the intermittent operation and irregular frequency of use of fixtures. Different kinds of fixtures are not in uniform use. Bathroom fixtures are most frequently used on arising or retiring and, not surprisingly, during television commercials. Kitchen sinks find heavy usage before and after meals. Laundry trays and washing machines are most likely to be used in the late morning. During the period from midnight to 6 P.M. there is very little fixture use. Luckily, fixtures are used intermittently and the total time in operation is relatively small so it is not necessary to design for the maximum potential load. Maximum flow is therefore of no real interest to the designer. Average flow is also of no concern, for if a system were designed to meet this criterion it would not satisfy the conditions under peak flow. It is therefore necessary to consider only the maximum probable demand (peak demand) imposed by the fixtures on a system.

Two methods have evolved in the United States that, when used where applicable, have proven to give satisfactory results. They are the empirical method and method of probability. The empirical method is based upon arbitrary decisions arrived at from experience and judgment. It is useful only for small groups of fixtures. The method of probability is based upon the theory of probabilities and is most accurate for large groups of fixtures.

In the past, certain demand rates became generally accepted as standard. These rates are tabulated in Table 13-2 for the common types of fixtures and the average pressure necessary to deliver this rate of flow. The actual pressure for a specific fixture will vary with each manufacturer's design, some requiring a greater or lesser pressure than others.

Although the flow rates shown in Table 13-2 have been used by engineers, they are hopelessly outdated. Water conservation measures being mandated by federal regulations and model codes make the flow rates shown in Table 13-2 unreasonable for use in the design of systems. The federal Energy Policy Act (EPACT92) established the following criteria for water use by fixture:

Table 13-2 Demand at Individual Fixtures and Required Pressure

Fixture	Flow Pressure, psi	Flow Rate, gpm
Ordinary lavatory faucet	8	3.0
Self-closing lavatory faucet	12	2.5
Sink faucet, ⅜ in.	10	4.5
Sink faucet, ½ in.	5	4.5
Bathtub faucet	5	6.0
Laundry tub faucet, ½ in.	5	5.0
Shower head	12	5.0
Water closet flush tank	15	3.0
Water closet flush valve, 1 in.	10–25	15–45
Urinal flush valve, ¾ in.	15	15.0
Hose bibb or sill cock, ¾ in.	30	5.0

Water closets: 1.6 gal/flush
Urinals: 1.5 gal/flush
Showers: 2.5 gpm
Lavatories: 2.5 gpm
Sinks: 2.5 gpm

Manufacturers offer fixtures meeting these and more stringent requirements. Lavatories with 0.5 gpm flow rates and urinals with 1.0 gal/flush have been installed in thousands of buildings with satisfactory results. However, there is a need for research to determine the actual minimum flow required, for each type of fixture, to satisfy psychological requirements of the user and provide the necessary sanitary requirements.

WATER SUPPLY FIXTURE UNITS

A standard method for estimating the water demand for a building has evolved through the years and has been accepted almost unanimously by plumbing designers. It is a system based on weighting fixtures in accordance with their water supply load-producing effects on the water distribution system. The National Bureau of Standards has published report BMS 65, Methods of Estimating Loads in Plumbing Systems, by the late Dr. Roy B. Hunter, which gives tables of load-producing characteristics (fixture unit weights) of commonly used fixtures, along with probability curves that make it possible to apply the method easily to actual design problems.

The method of probability should not be used for a small number of fixtures. Although the design load, as computed by this method, has a certain probability of not being exceeded, it may nevertheless be exceeded on rare occasions. When a system contains only a few fixtures, the additional load imposed by one fixture more than has been calculated by the theory of probability can easily overload the system. When a system contains a large number of fixtures, one or several additional fixture loadings will have an insignificant effect on the system.

In developing the application of the theory of probability to determine design loads on a domestic water distribution system, Hunter assumed that the operation of the fixtures in a plumbing system could be viewed as purely random events. He then determined the maximum frequencies of use of the fixtures. He obtained the values of the frequencies from records collected in hotels and apartment houses during the periods of heaviest usage. He also determined characteristic values of the average rates of flow for different fixtures and the time span of a single operation of each.

If only one type of fixture were used in a building, the application of the theory of probability would be very simple and straightforward. When dealing with systems composed of various types of fixtures that must be combined, the process becomes extremely involved and too complicated to be of any practical use. Faced with this dilemma, Hunter devised an ingenious method to circumvent the problem by a simple process which yields results within ½% accuracy of the more involved and laborious calculations required. He conceived the idea of assigning "fixture loading factors" or "fixture unit weights" to the different kinds of fixtures to represent the degree to which they loaded a system when used at their maximum assumed frequency. A fixture unit weight of 10 was arbitrarily assigned by Hunter to a flush valve, and all other fixtures were assigned values based on their load-producing effect in relation to the flush valve. All fixtures have been converted, in essence, to one fixture type and the application of the theory of probability is greatly simplified.

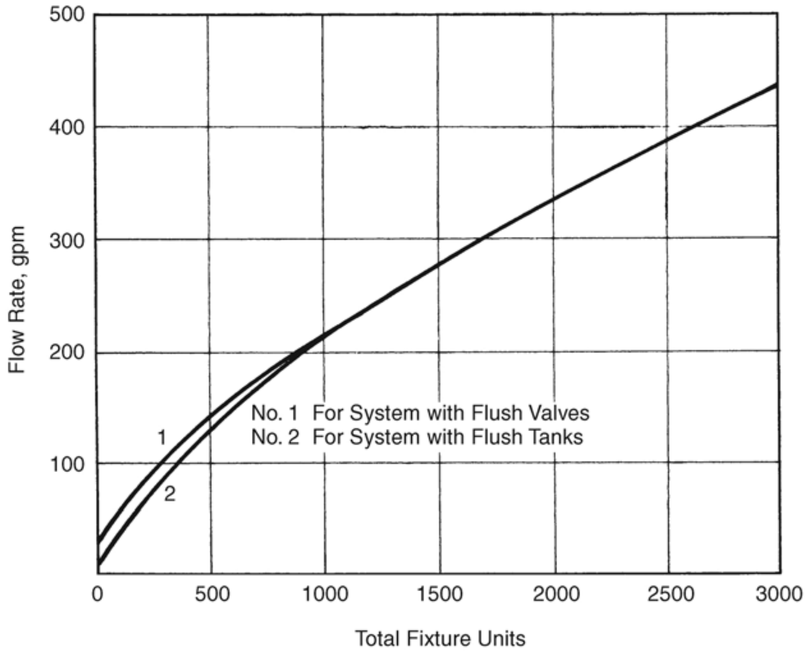
Table 13-3 Demand Weight of Fixtures, in Fixture Units

Fixture or Group	Occupancy	Type of Supply Control	Fixture Units		
			Hot	Cold	Total
Water closet	Public	Flush valve	—	10	10
Water closet	Public	Flush tank	—	5	5
Pedestal urinal	Public	Flush valve	—	10	10
Stall or wall urinal	Public	Flush valve	—	5	5
Stall or wall urinal	Public	Flush tank	—	3	3
Lavatory	Public	Faucet	1.5	1.5	2
Bathtub	Public	Faucet	3	3	4
Shower head	Public	Mixing valve	3	3	4
Service sink	Office, etc.	Faucet	3	3	4
Kitchen sink	Hotel or restaurant	Faucet	3	3	4
Water closet	Private	Flush valve	—	6	6
Water closet	Private	Flush tank	—	3	3
Lavatory	Private	Faucet	.75	.75	1
Bathtub	Private	Faucet	1.5	1.5	2
Shower head	Private	Mixing valve	1.5	1.5	2
Bathroom group	Private	Flush valve W.C.	2.25	6	8
Bathroom group	Private	Flush tank W.C.	2.25	4.5	6
Separate shower	Private	Mixing valve	1.5	1.5	2
Kitchen sink	Private	Faucet	1.5	1.5	2
Laundry tray	Private	Faucet	2	2	3
Combination fixture	Private	Faucet	2	2	3

Table 13-4 Conversion of Fixture Units to Equivalent gpm

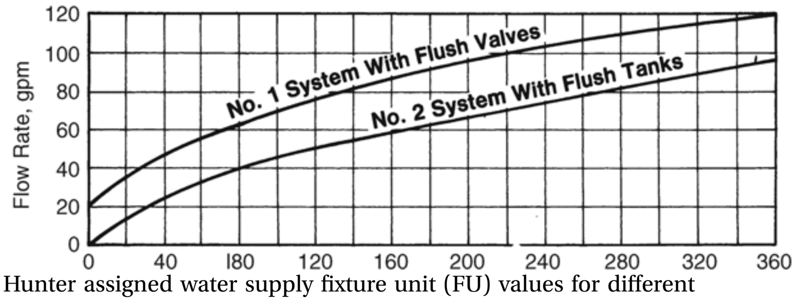
Demand (Load) Fixture Units	Demand (Load), gpm System with Flush Tanks	Demand (Load), gpm System with Flush Valves
1	0	—
2	1	—
3	3	—
4	4	—
5	6	—
6	5	—
8	6.5	—
10	8	27
12	9	29
14	11	30
16	12	32
18	13	33
20	14	35
25	17	38
30	20	41
35	23	44
40	25	47
45	27	49
50	29	52
60	32	55
70	35	59
80	38	62
90	41	65
100	44	68
120	48	73
140	53	78
160	57	83
180	61	87
200	65	92
225	70	97
250	75	101
275	80	106
300	85	110
400	105	126
500	125	142
750	170	178
1,000	208	208
1,250	240	240
1,500	267	267
1,750	294	294
2,000	321	321
2,250	348	348
2,500	375	375
2,750	402	402
3,000	432	432
4,000	525	525
5,000	593	593
6,000	643	643
7,000	685	685
8,000	718	718
9,000	745	745
10,000	769	769

Figure 13-5 Conversion of Fixture Units to gpm



See enlarged scale of lower portion of curves (Figure 13-6).

Figure 13-6 Conversion of Fixture Units to gpm (enlarged scale)



Hunter assigned water supply fixture unit (FU) values for different kinds of fixtures, which are given in Table 13-3. Conversion of fixture unit values to equivalent gallons per minute, based on the theory of probability of usage developed by Hunter, is given in Table 13-4. A graphic representation of this table is shown by Figures 13-5 and 13-6 (Hunter's Curve). Figure 13-7 gives a graphic representation of the conversion from fixture units to gallons per minute for a mixed system. An examination of the curves and tables reveals that demand for a system utilizing flush valves is much greater than that for flush tanks for small quantities. The difference in demand for each system decreases as the fixture unit load increases until 1,000 FUs are reached. At this loading and beyond, the demand for both types of systems is the same.

For hot water piping and where there are no flush valves on the cold water piping, the demand corresponding to a given number of fixture units is determined from the values given for the flush tank system.

The accuracy of Hunter's curve, however, has come into serious question. Results utilizing the curve have proven to be as much as 100% inflated in some instances. The consistent overdesign, however, should in no way be interpreted as indicating that Hunter's basic research and approach are incorrect.

His method is demonstrably accurate, but it must be remembered that his basic assumptions and criteria were promulgated more than 60 years ago. Many things have changed, and changed drastically, in the interim. Improvements have been made in flush valve design as well as in faucets and fixtures. Social customs and living patterns have changed. The public emphasis on water and energy conservation has altered many basic criteria. It is now necessary to change some of Hunter's basic assumptions (but not his concept).

It has been demonstrated by thousands of projects operating satisfactorily that it is safe to reduce the values obtained by use of Hunter's curve by 40%. It is stressed again that this reduction can be applied only for systems with a large number of fixtures. The opposite is true for water use in toilet facilities where large numbers of people gather, such as sport facilities and auditoriums. In these types of facilities, demand flow rates will exceed those determined by Hunter's curve because many people will use the toilet rooms during breaks in the game or performance. The student is again warned to use the table of fixture unit values in the code applicable to the locality of the project. The values vary slightly from code to code.

The student is also alerted to the fact that water supply fixture units are not the same as drainage fixture unit values. The discharge rates of certain fixtures are entirely different from the rate at which water is supplied, e.g., bathtubs. The loading effect is therefore different on the drainage system than it is on the water supply system for specific fixtures.

For supply outlets that are likely to impose continuous demands, estimate the continuous demand separately from the intermittent demand and add this amount in gallons per minute to the demand of the fixtures in gallons per minute.

It should be kept in mind when calculating maximum probable demands that, except for continuous demands, fixture unit values are always added, never gpm values. For example, if the maximum probable demand for two branches is required and one branch has a load of 1250 FU and the other 1750 FU, it would be wrong to add 240 gpm + 294 gpm to obtain 534 gpm for the total demand. The correct procedure is to add 1250 FU + 1750 FU to obtain a total FU value of 3000 and then from Table 13-4 determine the correct peak demand as 432 gpm. The 432 gpm value reflects the proper application of the theory of probability.

The following example illustrates the procedure for sizing a system.

Example 13-1

Determine the peak demands for hot and cold and total water for an office building that has 60 flush valve water closets, 12 wall hung urinals, 40 lavatories, and 2 hose bibbs and requires 30 gpm for air-conditioning water makeup.

From Table 13-3 determine the FU values:

	Hot Water	Cold Water	Total (Hot & Cold)
60 WC x 10	—	600	600
12 UR x 5	—	60	60
40 Lavs x 2	—	—	80
40 Lavs x 1.5	60	60	—
	60 FU	720 FU	740 FU

From Table 13-4 or Figure 13-5:
60 FU = 32 gpm hot water demand
720 FU = 174 gpm cold water demand
740 FU = 177 gpm total water demand

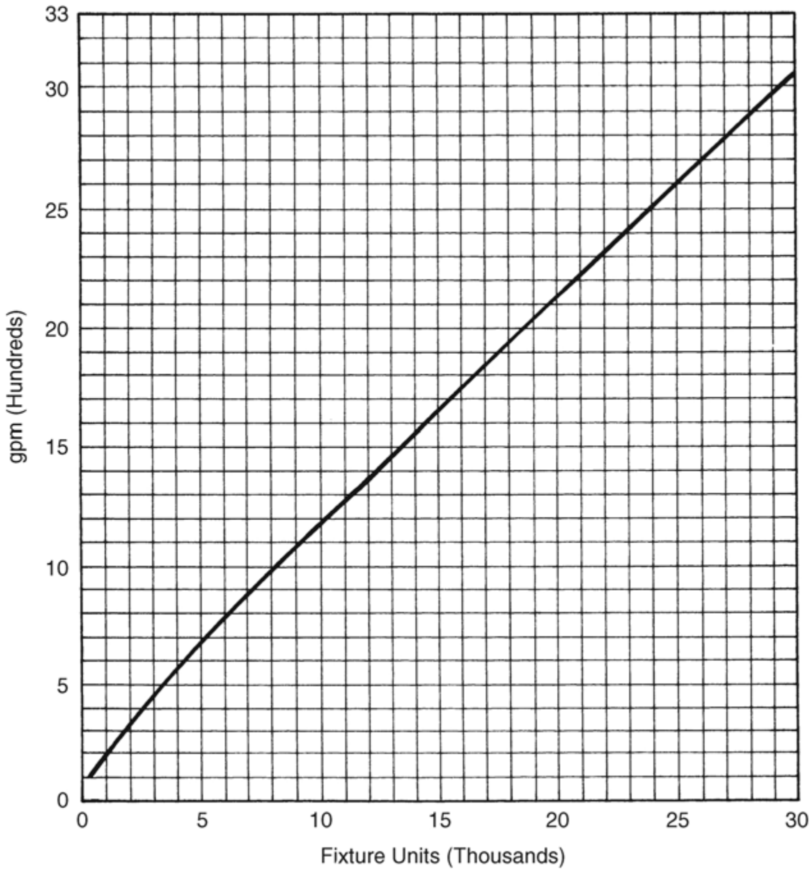
To the cold water and total water demand must be added the continuous demand:

2 hose bibbs × 5 (from Table 13-2) = 10 gpm
Air-conditioning makeup = 30 gpm
40 gpm

Then:
Hot water demand: = 32 gpm
Cold water demand: 174 + 40 = 214 gpm
Total water demand: 177 + 40 = 217 gpm

The conversion of fixture unit loads to equivalent gallons per minute demand was obtained from Table 13-4 using straight line interpolations to obtain intermediate values. Total water demand is required for sizing the water service line for the building and also for the cold water piping inside the building up to the point where the connection is taken off to the hot water heater supply.

Figure 13-7 Conversion of Fixture Units to gpm (Mixed System)



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Note: In determining your answers to the CE questions, use only the material presented in the corresponding continuing education article. Using information from other materials may result in a wrong answer.

About This Issue's Article

The May 2011 continuing education article is "Water System Design," Chapter 13 of *Engineered Plumbing Design II.*

The objective in designing the water supply systems for any project is to ensure an adequate water supply at adequate pressure to all fixtures and equipment at all times and to achieve the most economical sizing of the piping. This chapter discusses how to accomplish this, focusing on flow in piping, material selection, piping layouts, estimating demand, dealing with pressure problems, and sizing the system.

You may locate this article at psdmagazine.org. Read the article, complete the following exam, and submit your answer sheet to the ASPE office to potentially receive 0.1 CEU.

CE Questions — "Water System Design" (PSD 177)

1. Improper sizing of a water system can cause ________.
- a. inadequate pressure
- b. contamination of the water supply
- c. failure of the water supply
- d. all of the above

2. ________ pressure is the pressure that exists at any point in a system when water is moving at that point.
- a. static
- b. flow
- c. residual
- d. constant

3. What is the rate of flow at the outlet for a faucet with a ¼-inch supply and 16-psi flow pressure?
- a. 1.25 gpm
- b. 5 gpm
- c. 11.25 gpm
- d. none of the above

4. What is the actual inside diameter of 3-inch brass pipe?
- a. 3.068 inches
- b. 3.062 inches
- c. 2.907 inches
- d. 2.945 inches

5. ________ can be used to increase pressure to an adequate level.
- a. automatic flow-control orifice
- b. gravity tank system
- c. booster pump system
- d. both b and c

6. ________ is the flow that will occur if the outlets on all fixtures are opened simultaneously.
- a. average flow
- b. maximum possible flow
- c. maximum probable flow
- d. peak flow

7. Which of the following is considered a continuous demand?
- a. lawn irrigation
- b. air-conditioning makeup
- c. water cooling
- d. all of the above

8. A fixture's loading effect is determined by what?
- a. rate of water supply required
- b. duration of each use
- c. frequency of use
- d. all of the above

9. When designing a system, it is necessary to consider only the ________ imposed by each fixture on the system.
- a. average flow
- b. maximum flow
- c. peak demand
- d. none of the above

10. What is the fixture unit value of a public flush valve wall urinal?
- a. 2 FUs
- b. 3 FUs
- c. 4 FUs
- d. 5 FUs

11. 70 fixture units equal ________ gpm in a system with flush tanks.
- a. 35
- b. 59
- c. 38
- d. 62

12. It is safe to reduce the values obtained by use of Hunter's curve by ________ percent.
- a. 10
- b. 30
- c. 40
- d. 50

PSD 177

Plumbing Systems & Design Continuing Education Application Form

This form is valid up to one year from date of publication. The *PS&D* Continuing Education program is approved by ASPE for up to one contact hour (0.1 CEU) of credit per article. Participants who earn a passing score (90 percent) on the CE questions will receive a letter or certification within 30 days of ASPE's receipt of the application form. (No special certificates will be issued.) Participants who fail and wish to retake the test should resubmit the form along with an additional fee (if required).

1. Photocopy this form or download it from www.psdmagazine.org.
2. Print or type your name and address. Be sure to place your ASPE membership number in the appropriate space.
3. Answer the multiple-choice continuing education (CE) questions based on the corresponding article found on *www.psdmagazine.org* and the appraisal questions on this form.
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PS&D Continuing Education Answer Sheet

Water System Design (PSD 177)

Questions appear on page 8. Circle the answer to each question.

Q 1.	**A**	**B**	**C**	**D**
Q 2.	**A**	**B**	**C**	**D**
Q 3.	**A**	**B**	**C**	**D**
Q 4.	**A**	**B**	**C**	**D**
Q 5.	**A**	**B**	**C**	**D**
Q 6.	**A**	**B**	**C**	**D**
Q 7.	**A**	**B**	**C**	**D**
Q 8.	**A**	**B**	**C**	**D**
Q 9.	**A**	**B**	**C**	**D**
Q 10.	**A**	**B**	**C**	**D**
Q 11.	**A**	**B**	**C**	**D**
Q 12.	**A**	**B**	**C**	**D**

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Appraisal Questions

Water System Design (PSD 177)

1. Was the material new information for you? ❑ Yes ❑ No
2. Was the material presented clearly? ❑ Yes ❑ No
3. Was the material adequately covered? ❑ Yes ❑ No
4. Did the content help you achieve the stated objectives? ❑ Yes ❑ No
5. Did the CE questions help you identify specific ways to use ideas presented in the article? ❑ Yes ❑ No
6. How much time did you need to complete the CE offering (i.e., to read the article and answer the post-test questions)?