Design of Potable Water Plumbing Systems

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DESIGN OF POTABLE WATER PLUMBING SYSTEMS

This course is divided into four parts:

- PART I - Estimating Potable Water Demand
- PART II - Estimating Non-Residential Water Demand
- PART III - Water Distribution System
- PART IV - Regulatory and System Reliability Considerations

PART I ESTIMATING POTABLE WATER DEMAND

A fundamental consideration in the sizing of a plumbing water system or its components is an estimate of the amount of water expected to be used by the customers.

Estimating demand depends on the water usage patterns and is usually unique for a particular system. For instance, a difference can exist for a residential and a non-residential system. A water usage pattern may also be unique because of the individuality of consumers on the system and their expectations to use water whenever and however they wish.

Water demand estimation is complex and involves consideration of a number of factors:

1. Climatic influences (evaporation, vapor transpiration, temperature, precipitation, winds, etc.); Climate has a significant impact on water use. For instance, in areas where freezing temperatures are prevalent, water use should be closely evaluated. Some systems may see higher demands as users allow faucets to run to prevent freezing.
2. Socioeconomic influences (property values, economic status, residential densities); Demographics change with the nature of a development. Population densities are different for single family and multi-family residences; for housing provided for families and housing provided for singles or senior citizens/retirees; and for individual lots and mobile home park type developments.
3. Property lots; Housing sizes are usually directly linked to the income levels of the residents. Middle-income residents typically occupy 1,500 to 3,000 square foot homes with moderate sized lawns. Higher income residents occupy homes larger than 3,000 square feet. With respect to water use, the greatest impact of income level is probably the extent of landscaping. The major factor in water use related to larger lot sizes is in the irrigable area, such as lawns, gardens, and other agricultural uses.
4. Recreational or seasonal uses; Water use and demand at public places, such as amusement parks, vary and can be different. Recreational areas usually experience peak demands during summer holiday weekends such as Memorial Day, Independence Day, and Labor Day.

5. Extent of metering or pricing schedules; Water pricing structure may vary from place to place. Some systems may use a water meter that tends to price on actual use; others may have 'flat rates' fixed on property size.
6. Historic water log sheets; Places like airports, hotels, hospitals and public buildings see more or less consistent overall demand. The only design variable involved for the facility is the volume of traffic.
7. Land use; The purpose of a facility should be assessed. Commercial, industrial and public facility demands are much different from residential demand. Water use associated with the services of cleaning, landscaping, and farming need to be assessed carefully.
8. Conservation practices; Areas that have acute or scarce water resources resort to mandatory conservation measures. Mandatory conservation practices include, but are not limited to, alternate day watering schedules, installation of low water use fixtures, water closet tank displacement devices, leak detection, rainwater harvesting, and use of treated effluent water for landscaping. Unaccounted water demand reduction programs also exist. Community covenants, bylaws or local ordinances may exist to support water conservation practices. It is very important to determine if water use restrictions are enforceable.

Why Plumbing Codes?

It is nearly impossible to predict the consumer mind-set or socioeconomic ethics on water use. There is usually insufficient data to account for all the factors that may influence the water demands of a particular water system.

Defined design criteria are laid out in the ASHRAE guide and the Uniform Plumbing Code (UPC). Both criteria focus on the use of probability theory with a safety factor to compensate for unknown variables. Required flow rates are defined based on a "Fixture Count" method that is determined after appropriate research and analysis of controlling variables. Among a host of other factors, these variables are fixture types, people use factors for structure types, and people socioeconomic factors.

There is no substitute for reliable and accurate meter records of water usage for estimating future demand. An historic data approach allows a designer to use metered water use data from an existing facility to estimate the demand of a new system.

Model Plumbing Codes

The model universal plumbing codes list minimum requirements for potable water systems based on probability theory.

The five model plumbing code agencies in the United Sates are:

1. Uniform Plumbing Code (UPC); adopted mainly in the western U.S.
2. Standard Plumbing Code (SPC); adopted mainly in the southern U.S.
3. BOCA Plumbing Code (BOCA); adopted mainly in the eastern U.S.
4. International Plumbing Code (IPC).
5. CABO Plumbing Code (CABO); exclusively for residential construction.

Salient features of these codes are:

- The IPC is relatively new code originating in 1995 as a joint effort of the three major model code groups (UPC, SPC and BOCA).
- The CABO, also derived from these three major codes, is designed exclusively for plumbing of one and two family residential dwellings.
- The provisions of the above codes are essentially consistent, but contain somewhat different requirements to address factors that are unique to local conditions. For instance, the UPC contains information that considers the earthquake prone western U.S. region. In many cases, a local municipality or jurisdictional authority will add addenda to deal with a specific situation of an area.
- All of the model plumbing codes require water supply systems to be designed to deliver a specified flow rate (gallons per minute) within certain pressure limits.
- Each code lists procedures for calculating design flow rates that are directly related to the number of plumbing fixtures within the building. (Check UPC-

1997, Appendix A; SPC-1997, Appendix F; IPC-1995, Appendix E; CABO-1995, Sect 3409).

- The model codes require a minimum inlet nominal diameter of water supply piping to be at least ¾ inch. (Check UPC-1997, Sect. 610.8; SPC-1997, Sect. 608.2; IPC-1995, Sect. 604.1; CABO- 1995, Sect 3403.4)

Estimating Potable Water Demand

Theoretically all plumbing system (pipes) should be sized for a maximum flow rate that is capable of serving the fixtures simultaneously. In practice the chances of their simultaneous use are remote and the plumbing (piping) design criteria may be relaxed to some degree. Plumbing water distribution systems shall be designed based on the idea of the most probable peak demand loading, which reflects the worst-case scenario for a system.

There are two methods that have been proposed to aid in the design of plumbing water systems. Currently, the plumbing industry uses **Hunter's** method for approximating peak demand loadings on a building's water distribution system. This method was developed in the 1940's and presented in the National Bureau of Standards published report BMS 65, "Methods of Estimating Loads in Plumbing Systems". It is still the most widely used procedure and forms the basis for model plumbing codes (e.g. The International Plumbing Code, The Uniform Plumbing Code and ASHRAE guide).

Another method, which is not cited in any major U.S. plumbing codes, has been developed by the American Water Works Association (AWWA). The "fixture value method" was introduced in 1975 and presented in AWWA's M22 Manual. This method is an empirical approach based on data obtained from water meter data loggers. This method is not recommended for sizing the plumbing water branches, laterals or risers and is primarily used for sizing for water service lines only. Both procedures are separately discussed in the following paragraphs.

Before we proceed further let's define a few important terms:

1. **Fixture -** A fixture is any device for the distribution and use of water in a building. Example: shower, urinal, fountain, shower, sink, water faucet, tap, hose bibs, hydrant etc.
2. **Maximum flow** – Maximum flow or maximum possible flow is the flow that will occur if the outlets on all fixtures are opened simultaneously. Since most plumbing fixtures are used intermittently and the time in operation is relatively small, it is not necessary to design for the maximum possible load. Maximum flow is therefore of no real interest to the designer.
3. **Average flow –** Average flow is flow likely to occur in the piping under normal conditions. Average flow is also of little concern to the designer, for if a system was designed to meet this criterion, it would not satisfy the conditions under peak flow. Average flow is typically used for determining the storage tank volume factoring the hours of storage required.
4. **Maximum probable flow –** Maximum probable flow is the flow that will occur in the piping under peak conditions. It is NOT the total combined flow with all fixtures wide open at the same time, but is proportional to the number of fixtures that may be expected to be in use simultaneously. It is also called peak demand or maximum expected flow. *The plumbing water system is designed based on maximum probable flow.*
5. **Continuous demand** - Some outlets impose continuous demand on the system; for example; hose bibs, lawn irrigation, air-conditioning makeup, water cooling, and similar flow requirements are considered to be continuous demand. They occur over an extended period of time.
6. **Intermittent demand** – Plumbing fixtures that draw water for relatively short periods of time are considered an intermittent demand. The examples include bathroom fixtures, kitchen sinks, laundry trays and washing machines. 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.

What is the Fixture Unit Count?

The fixture unit concept is a method of calculating maximum probable water demand within large buildings based on theory of probability. The method is based on assigning a fixture unit (f/u) value to each type of fixture based on its *rate of water consumption*, on the *length of time* it is normally in use and on the *average period between successive uses*. All the above factors, together, determine the rate of flow with a plumbing pipe.

Hunter's Method of Estimating Loads in Plumbing Systems

Hunter's method of estimating loads in plumbing systems is based on assigning a fixture unit weight (f/u) to the plumbing fixtures and than converting these to equivalent gallons per minute, based on the theory of probability of usage.

Hunter observed that all fixtures are not used simultaneously. The durations of use are different and times between uses are different. He estimated the flow rates through various fixtures by capturing average flow and the time span of a single operation for different fixtures. For example, a flush valve was considered to operate over a 9-second period providing an average volume of 4 gallons. This yields a design flow of 27gpm [(4/9)*(60) = 26.6gpm]. Similarly for flush tanks, he found that it takes approximately 60 seconds to deliver 4 gallons. This yields a design flow of 4gpm [(4/60)*(60) = 4gpm].

Hunter also found an average time between successive usages (frequency of use) from records collected in hotels and apartment houses during the periods of heaviest usage. This was important to evaluate "how many fixtures could be operated simultaneously" since it is less likely that all the fixtures in the building will be operated simultaneously. Consider a building with 20 flush valves and 20 flush tanks. Hunter applied the probability theory to determine how many of these 20 fixtures will be operated at any given instant with the condition that this occurrence won't exceed more than one percent of the time. He observed that the probability of using more than 3 flush valves and 8 flush tanks simultaneously is less than 1%.

Therefore, the peak design flow is worked out to be 3 * 27 = 81gpm for flush valve and 8 * 4 = 32gpm for flush tanks.

Therefore, the pipe capacity shall be (3 *27) + (8 *4) = 113gpm.

Hunter realized that the probability theory could be greatly simplified, if a common fixture loading unit is applied to the plumbing fixtures. Hunter arbitrarily assigned a singular base fixture unit weight of 10 to the flush valve, and other fixture types were then given a fixture unit weight in terms of their comparative flow rate and time-usage factor in relation to the base fixture (flush valve). He obtained a weight of 5 for the flush tank and 4 for the bathtub which corresponds to a demand ratio of 1:2:2.5 between the three common fixture types (flush valves, flush tanks, and bathtubs, respectively). All fixtures are thus converted, in essence, to one fixture type. In other words, each unit of flush valve corresponds to 10 fixture units; each unit of flush tanks has 5 fixture units and each unit of bathtub has 4 fixture units.

Table 1 lists the demand weights in "fixture units" as determined by the National Bureau of Standards. It is used in conjunction with Figure 1 or Table 2 in determining the expected normal peak flow for any number or combination of fixtures.

TABLE – 1

Demand Weights of Plumbing Items in Fixture Units

Fixture or Group	**Occupancy**	**Cold Water (CW) only**	**Hot Water (HW) only**	**Total Building Supply HW & CW**
Water Closet (Flush Valve)	Public	10	--	10
Water Closet (Flush Tank)	Public	5	--	5
Pedestal Urinal (Flush Valve)	Public	10	--	10
Stall or Wall Urinal (Flush valve)	Public	5	--	5
Stall or Wall Urinal (Flush Tank)	Public	3	--	3
Lavatory (Faucet)	Public	1-1/2	1-1/2	2
Bathtub (Faucet)	Public	3	3	4
Shower Head (Mix valve)	Public	3	3	4
Service Sink (Faucet)	Office	2-1/4	2-1/4	3
Kitchen Sink (Faucet)	Hotel/ Restaurant	3	3	4
Water Closet (Flush valve)	Private	6	--	6
Water Closet (Flush tank)	Private	3	--	3
Lavatory (Faucet)	Private	¾		1
Bathtub (Faucet)	Private	1-1/2	1-1/2	2
Shower Head (Mix valve)	Private	1-1/2	1-1/2	2
Bathroom Group (Flush valve)	Private	8.25	2.25	8
Bathroom Group (Flush tank)	Private	5.25	2.25	6

Fixture or Group	Occupancy	Cold Water (CW) only	Hot Water (HW) only	Total Building Supply HW & CW
Shower (Mix valve)	Private	1-1/2	1-1/2	2
Kitchen Sink (Faucet)	Private	1-1/2	1-1/2	2
Laundry Trays (Faucet)	Private	2-1/4	2-1/4	3
Combination Fixture (Faucet)	Private	2-1/4	2-1/4	3
Washer	Private	3	3	4

(Source: National Bureau of Standard Report: BMS 65 by Late Dr. R. B. Hunter)

From the tabulated fixture units Table 1, the designer can assign fixture unit weights to the specific fixtures of concern in his design. When these are added, their total gives a basis for determining the maximum probable flow that may be expected in a water pipe.

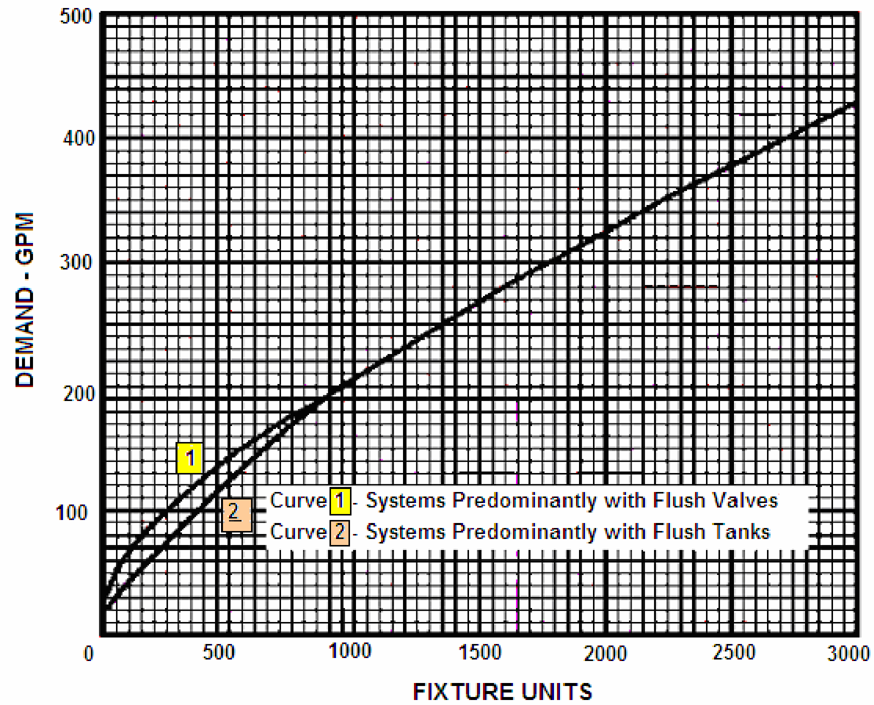
Both hot and cold water service will be required within the building. As a general rule, separate hot and cold water demands can be taken as ¾ of the total shown; for example, a bathtub faucet would be counted as 1½ fixture unit on the cold water system, and 1½ fixture unit on the hot water. Supply piping would be calculated accordingly, while the total figure of the two fixture units would be used to design the drainage piping.

Note: The fixture unit loading method is used to quantify intermittent demand and could be applied to any of the residential or non-residential facilities. The other continuous water usage requirements such as hose bibs, air conditioning cooling tower makeup, gardening or process cooling requirements, etc. need to be carefully added to determine the peak water demand.

Fixture Unit – Flow Relationship

It is obvious that as the number of fixtures increases, the probability of their simultaneous use decreases. Figure 1 below shows the graphic representation of probability of flow as a function of fixture unit count, also commonly referred to as "Hunter's Curve"

FIGURE - 1



The figure above shows two separate curves; one for flush valve (Curve 1) and the other for flush tanks (Curve 2). The curves show slight discrepancies from 0 to 1,000 fixture units. The flush tank curve has slightly larger flow rate values within this range. The reason for different flow rate values has to do with sudden instantaneous draw rate of the flush valve water closet. The difference in demand for each system decreases as the fixture unit load increases until 1,000 f/u's are reached. At this loading and beyond, the demand for both types of systems is the same.

The enlarged view of Figure 1 is also presented below for the benefit of smaller buildings utilizing lesser number of fixtures.

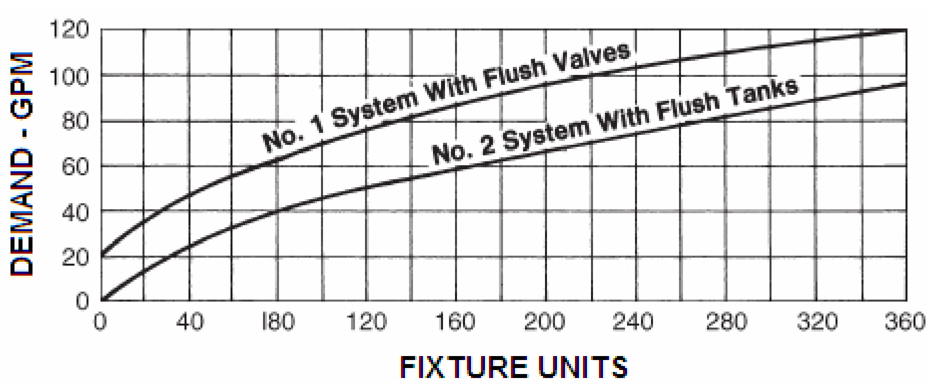


FIGURE – 1 (Enlarged View)

It is customary engineering practice to employ Curve 2 for hot water service pipe sizing and for cold water service when flush tanks are involved.

The flush valve Curve 1 is used only for cold water and total service water flow estimation. Quite often it will be compared to the actual flush valve manufacturer's recommendations.

Curve 1 is seldom used for hot water side sizing. Reason**:** "Instantaneous maximum or peak probable flow is not expected to appear except at very infrequent intervals and is expected to be of short duration".

The conversion of fixture unit loads to equivalent gallons per minute demand is also available in a tabulated form as indicated in Table 2 below:

TABLE – 2

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	-
10	8	27
20	14	35
30	20	41
40	25	47
50	29	52
60	32	55
70	35	59
80	38	62
90	41	65
100	44	68
140	53	78
180	61	87
200	65	92
250	75	101
300	85	110
400	105	126
500	125	142
750	170	178
1000	208	208
1250	240	240

Demand (Load) Fixture Units	Demand (Load), gpm system with Flush Tanks	Demand (Load), gpm system with Flush Valves
1500	267	267
1750	294	294
2000	321	321
2500	375	375
3000	432	432
4000	525	525
5000	593	593
10000	769	769

Note that the relationship between gallons per minute (gpm) and fixture unit is not constant, but varies with the number of fixture units. For example, 1000 FU is equivalent to 208 gpm, but 2000 FU is not double that, but is only 1.5 times as much, or 321 gpm. As the number of fixture units is increasing, the flowrate is not increasing linearly. This reflects the proper application of the theory of probability.

<u>Caution</u>:

 # 1: The Hunter's method of probability is accurate for large groups of fixtures only and its use may be inaccurate for small applications. For example, consider a branch is serving 5 water closets fitted with flush valves in a public restroom. If the hypothetical probability of use is set at 1%, this implies that the system will overload only one percent of the time and only two fixtures need to be "on" for the system. If three or more fixtures are in operation simultaneously, the system is automatically overloaded, and Hunter's method "fails". When a system contains a large number of fixtures, one or several additional fixture loadings will have an insignificant effect on the system. A judicial discretion is advised.

 # 2: Even for large applications, the estimate design flow may be construed as low for some situations. One may wonder that in a crowded environment, for example in sport facilities and auditoriums, the demand flow rates may exceed those determined by Hunter's curve because many people will use the toilet rooms during breaks in the game or performance.

 # 3: It should be kept in mind when calculating maximum probable demands, fixture unit values are always added and NOT the gpm values. For example, if the maximum probable demand for two branches is required and one branch has a load of 1000 f/u's and the other 2000 f/u's, it would be improper to add 208 gpm + 321 gpm to obtain 529 gpm for the total demand. The correct procedure is to add 1000 f/u's + 2000 f/u's to obtain a total f/u's value of 3000 and then from Table 2 determine the correct peak demand as 432 gpm. This value reflects the proper application of the theory of probability.

 # 4: 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.

 # 5: Hunter's method provides a design demand value for a specified number of fixtures but it does not tell us how many fixtures should be provided. The required number of fixtures is dependent on the peak occupancy rate which is governed by local regulations.

 # 6: One disadvantage of utilizing Hunter's curve is the elapsed time between its conception and the technological changes. Over the past sixty years new technologies and ideologies have been developed regarding the design of plumbing distribution systems. An example is the movement of the industry towards low-demand fixtures. For example, a flush valve (Hunter's Type fixture) in the 1940's had a flow rate of 27 gpm, flow time of 9 seconds, and a recurrence time of 300 seconds. The probability of use of this fixture type was 9/300 = 0.03. Contemporary flush valves are currently restrained to a flow volume of 1.6 gallons over a period of 4 seconds. The reduction in flow time causes a decrease in the probability of use to 4/300 = 0.013, and decrease in flow rate to 24 gpm. <u>The reader is advised 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.</u>

Example:

What is the hot, cold and total water flow rate for a group of plumbing fixtures in a small hotel building consisting of 52 flush valve water closets, 30 flush valve urinals, and 40 lavatories? The hotel requires 30 gpm for air-conditioning water makeup and 10 gpm for each of the 3 hose bibs.

Solution

From Table 1, determine the FU values:

Fixture Type	Qty.	Fixture demand weight	Hot Water	Cold Water	Total (Hot & Cold)
WC (flush valve)	52	@ 10	-	520	520
Urinals	30	@ 5	-	150	150
Lavatories	40	@ 2	-	-	80
Lavatories	40	@ 1.5	60	60	
Total			60 f/u	730 f/u	750 f/u

From Table 2 or Figure 1:

- 60 f/u = 32 gpm hot water demand (for hot water demand read flush tank column)
- 730 f/u = 175 gpm cold water demand (read flush valve column and interpolate)
- 750 f/u = 178 gpm total water demand (read flush valve column and interpolate)

The continuous demand must be added to the cold water and total water demands:

<u>Continuous Demand:</u>

- Hose bibs = 30 gpm
- Air-conditioning makeup = 30 gpm
- Total = 60 gpm

Then:

- Hot water demand: = 32 gpm
- Cold water demand: 174 + 60 = 234 gpm
- Total water demand: 178+ 60 = 238 gpm

Note that the 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.

Residential Demand Estimating Procedure

Most plumbing codes have similar requirements for sizing the plumbing water system. These requirements are designed to ensure that water fixtures will have an adequate supply of water under normal household use. A step-wise estimating approach is:

1. Determine the local plumbing code adopted by the area (UPC, SPC, BOCA, IPC or CABO). Check the applicability of the model codes to the design or alternatively, for the applicability of local municipality or jurisdictional authority standards. A conservative approach is to use the more stringent of the two codes during the conceptual phase, and depending on the economics, adopt the more lenient code, if feasible, during the detailed phase.

2. Begin by making a list of the type and number of fixtures that will be installed. Determine other water usage, such as fire sprinklers and/or outdoor bibs for cleaning or gardening. A reduction in the required flow rate can be considered if the fire sprinkler and/or outdoor service bibs can be isolated from the potable water plumbing system.

3. Refer to the sizing tables provided by the code authority having jurisdiction, or the sizing tables of the applicable plumbing code (Table 3 below), or use Table 1 to assign the fixture unit count. Following the steps above in order, will result in a conservative design.

4. Using the tables, find the water supply fixture units (wsfu) rating for each fixture and add these individual ratings to obtain a total wsfu for each house or facility.

5. Use the total wsfu rating to find the required minimum flow rate (gallons per minute) from the curve (Figure 1 above), or directly from the tables. (Interpolate Table 4 below).

6. If the home is equipped with fire sprinklers that cannot be isolated from the potable water plumbing system, add an additional water demand of 26 gallons per minute in accordance with the requirements of NFPA 13D-1994, Section 4-1. (NFPA recommends 13 gallons per minute of flow for the simultaneous operation of two sprinklers).

7. If the home is equipped with hose bibs that cannot be isolated from the potable water plumbing system, assume a water demand of 10 gallons per minute for one nozzle hose bib operation at a time. For gardening or irrigational use, an additional flow of 10 gallons per minute should be added to the calculated peak hour demand (PHD) for each acre of land use.
8. Since a hose bib does not result in a consistent demand, add 10 gallons per minute to the value calculated in Step 5 to obtain the peak water requirements and appropriate pump sizing.
9. Since firewater is not a consistent demand, use a minimum of 26 gallons per minute, or the maximum valve calculated in Step 8, to obtain the minimum water requirements and appropriate pump sizing.

Illustration: Plumbing Flow Estimation using model codes

Step # 1

Determine the total number of water supply fixture units for all water fixtures to be supplied by the plumbing system. Use Table 3 below:

TABLE – 3

Fixture Units as Defined by Plumbing Codes

	UPC Codes	**CABO Codes**	**SPC & IPC Codes**
Type of Fixtures	**Fixture Units** **Combined hot & cold**	**Fixture Units** **Combined hot & cold**	**Fixture Units** **Combined hot & cold**
Bathtub (with/without overhead shower	4.0	1.4	1.4
Shower Stall	2.0	1.4	1.4
Lavatory	1.0	0.7	0.7
Water Closet (tank type)	2.5	2.2	2.2
Kitchen Sink	1.5	1.4	1.4
Dishwasher	1.5	1.4	1.4
Clothes washer	4.0	1.4	1.4
Hose Bibb (outdoor faucet)	2.5	2.5	Designer's Discretion
Hose Bibb-each additional	1.0	-	-

Step # 2

After summing the fixture units of the individual water fixtures, use Table 4 below to find the minimum required flow rate.

TABLE – 4

Fixture Unit V/s Probable Flow Rate

	UPC Codes	CABO Codes	SPC & IPC Codes
Total Fixture Units	**Required Water GPM**	**Required Water GPM**	**Required Water GPM**
7.5	6.0	-	-
8	-	-	12.8
9	-	7.2	-
10	8.0	7.7	14.6
12	-	9.0	16.0
14	-	10.4	17.0
15	11.5	-	-
16	-	11.6	18.0
18	-	12.7	18.8
20	15.0	14.0	19.6
25	17.5	16.8	21.5
30	20.0	19.5	23.3

Source of Data:

1. Fixture Units- UPC Table 6-4, 1997 edition, & values based on individual dwelling
2. Flow Rate- UPC, Chart A-3, Appendix C, 1997 edition, section A2.1
3. Fixture Units- CABO Table 3409, 1995 edition
4. Flow Rate- CABO Table 3409, 1995 edition
5. Fixture Units- SPC Table F101B, 1997 edition, & IPC Table E101B, 1995 edition
6. Flow Rate- SPC Table F102, 1997 edition, & IPC Table E102 1995 edition

PART II ESTIMATING NON-RESIDENTIAL WATER SYSTEM DEMAND

Industrial, commercial, or other nonresidential water demands should be separated from residential demands.

Non-residential water demand can include:

1. Small-scale buildings that are not typical single-family houses but comprised of buildings such as apartments, condominiums, motels, and trailer parks.
2. Commercial facilities including hotels, shopping centers, retail/wholesale businesses, restaurants, public and office buildings.
3. Industrial customers that require process water.
4. Public facilities such as schools, public hospitals, governmental offices, parks, landscaped roads, and cemeteries.
5. Landscaping such as farms, gardens, horticulture, irrigated crops etc.
6. Recreational users including campgrounds, RV parks, seasonal rental units, etc.

American Water Works Association – "Fixture Value Method"

AWWA method is typically used in sizing the water service lines for non-residential demands. Also known as the "Fixture Value Method", this method is presented in the AWWA M22 Manual titled, "Sizing Water Service Lines and Water Meters".

This method is an empirically derived approach that rely on the actual measured data; both the independent variable (fixture value) and the dependent variable (average peak flow rate) for specific building categories. Using the mechanical data loggers, the AWWA was able to compile peak flow measurements for different customer classes including the small scale buildings, hotels, hospitals, commercial, and public buildings. Peak demand graphs were created by plotting the measured average peak flow rates per customer class versus the cumulated fixture value. The resulting pair of graphs represents "Probable customer peak water demands vs. Fixture values". These curves depict "low-range" (under 1,300 combined fixture values) and "high-range" (up to 13,000 combined fixture values) conditions. Various classes are shown on different curves and allow the fixture value method to account for the diverse water usage characteristics of different customer types.

The M22 manual also states that these values "represent the peak flow in gallons per minute of each fixture or appliance when it is operated without the interference of other fixtures at 60 psi". This approach yields fixture values that are specific to each fixture type and are represented in gallons per minute. For example, the M22 Manual suggests a fixture value of 35 gpm and 4 gpm for water closets with flush valves and flush tanks, respectively. Designers can also modify fixture values based on personal preference. The application of fixture values to peak demand loadings is quite different than Hunter's technique.

Procedures for Estimating Non-Residential Demands using M22 Manual

The M22 Manual lists the following procedure estimating customer demand:

1) Required system characteristics:

   - Pressure at the water meter outlet
   - Type of customer (i.e. customer class)
   - Number and type of fixtures

2) Determine combined fixture value:

   - Total the number of similar fixtures and multiply by their respective fixture values
   - Sum all fixture values for each type of fixture in the system

3) Determine "Probable customer peak water demand" using the applicable low-range or high-range graph at the water meter outlet.
4) If the design pressure at the meter is above or below the 60 psi design value, a pressure correction factor must be used. Simply multiply the peak water demand by the pressure factor.
5) Add any continuous demands to the domestic loading to find the total customer peak demand. Special considerations, such as outdoor watering needs, process cooling or fire protection requirements, should also be taken into account.

Most of the information shall be available from the building lead usually an architect. While conceptualizing, it is possible that the exact information on the fixture quantity may not be available. In the absence of preliminary information, the water estimation could be carried out from standard tables published by AWWA (Refer to Table 5).

TABLE – 5

Guide for Non-Residential Water Demand

Type of Establishment	**Water Used** **(Gallons per day, GPD)**
Airport (per passenger)	3 - 5
Apartment, multiple family (per resident)	50
Bathhouse (per bather)	10
Boardinghouse (per boarder) Additional kitchen requirements for nonresident boarders	50 10
Camp: Construction, semi permanent (per worker) Day, no meals served (per camper) Luxury (per camper) Resort, day and night, limited plumbing (per camper) Tourist, central bath and toilet facilities (per person)	 50 15 100 - 150 50 35
Cottage, seasonal occupancy (per resident)	50
Club: Country (per resident member) Country (per nonresident member present)	 100 25
Factory (gallons per person per shift)	15 - 35
Highway rest area (per person)	5
Hotel: Private baths (2 persons per room) No private baths (per person)	 50 50
Institution other than hospital (per person) Hospital (per bed)	75 - 125 250 - 400
Lawn and Garden (per 1000 sq. ft.) Assumes 1-inch per day (typical)	600
Laundry, self-serviced (gallons per washing [per customer]	50

Type of Establishment	**Water Used** **(Gallons per day, GPD)**
Livestock Drinking (per animal): Beef, yearlings Brood Sows, nursing Cattle or Steers Dairy Dry Cows or Heifers Goat or Sheep Hogs/Swine Horse or Mules	 20 6 12 20 15 2 4 12
Livestock Facilities Dairy Sanitation (milk room) Floor Flushing (per 100 sq. ft.) Sanitary Hog Wallow	 500 10 100
Motel: Bath, toilet, and kitchen facilities (per bed space) Bed and toilet (per bed space)	 50 40
Park: Overnight, flush toilets (per camper) Trailer, individual bath units, no sewer connection (per trailer) Trailer, individual baths, connected to sewer (per person)	 25 25 50
Picnic: Bathhouses, showers, and flush toilets (per picnicker) Toilet facilities only (gallons per picnicker)	 20 10

Type of Establishment	**Water Used** **(Gallons per day, GPD)**
Poultry (per 100 birds): Chicken Ducks Turkeys	 5 - 10 22 10 - 25
Restaurant: Toilet facilities (per patron) No toilet facilities (per patron) Bar and cocktail lounge (additional quantity per patron)	 7 - 10 2-1/2 - 3 2
School: Boarding (per pupil) Day, cafeteria, gymnasiums, and showers (per pupil) Day, cafeteria, no gymnasiums or showers (per pupil) Day, no cafeteria, gymnasiums or showers (per pupil)	 75 - 100 25 20 15
Service station (per vehicle)	10
Store (per toilet room)	400
Swimming pool (per swimmer) Maintenance (per 100 sq. ft.)	10
Theater: Drive-in (per car space) Movie (per auditorium seat)	 5 5
Worker: Construction (per person per shift) Day (school or offices per person per shift)	 50 15

Source: Design and Construction of Small Water Systems: A Guide for Managers, American Water Works Association, 1984, and Planning for an Individual Water System. American Association for Vocational Instructional Materials, 1982

Comparison of Hunter's Method V/s AWWA Fixture Value Method

There are four major differences between Hunter's method and the AWWA empirical approach:

1. First, the Hunter curve takes into consideration the random usage of plumbing fixtures, while the AWWA fixture value method incorporates empirical data obtained at the water meter. Hunter's approach is the integration of empirically derived fixture use data with a theoretical probability model, namely the binomial distribution. His procedure is based on "congested use", which is reflected in his choice of a 1% failure rate. AWWA M22 method is purely an empirical approach based on water meter data points representing average peak flows.
2. Second, the AWWA fixture value method presents different graphs for varying customer types. It includes diverse range of building classes; whereas, the Hunter's method does not directly provide values for different customer class types. It can be argued that Hunter's method does present indirectly a classification scheme. Commercial and industrial applications will typically be dominated by flush valve fixtures. Residential systems are commonly flush tank depending on their size.
3. Third, the AWWA method includes a provision for adjusting demand based on varying pressure (at the water meter). The Hunter method does not include any such pressure adjustment option. Fixture unit values were derived for constant fixture supply rates. Note that the constant supply rates work reasonably well for flush valves due to valve mechanics and pressure regulators, but for other fixtures, supply rates rely heavily on individual usage preferences and flow pressures.
4. Finally, it is important to note that the AWWA method was developed primarily to size service water lines only. This is apparent by citing the experimental procedures used to acquire flow data. Measurements were taken at the water meter, and not at the individual supply lines or fixtures within the distribution system. Sizing smaller branches becomes a problem due to the poor resolution of the "low-range" curve for smaller numbers of fixture values. This is not to say that the AWWA's fixture value method cannot be used for smaller branch applications, but its accuracy may be

suspect. Even though Hunter's method is also a suspect in smaller applications, the Hunter curve and tables do provide flowrates for the smallest branches and display flowrate values for f/u count as small as one. However, designer discretion is advised on special cases.

Choosing the right method….

Both the Hunter method and the AWWA M22 method produce peak demand flow and have their optimal applications. The Hunter's fixture unit method was developed specifically for sizing plumbing water distribution systems. When the objective is to size plumbing water distribution systems, which are comprised of laterals, branches, and riser, the Hunter's method is the preferred choice. The best use for the AWWA fixture value method is primarily for water service lines only.

To start, always get hold of the local plumbing codes for the area in which the project is to be built. Local jurisdictions may require local code stipulations, and thus, they would govern the design. Any specific water demand estimates that the Department of Environment has prepared should be consulted to see if any of these estimates reflect adjustments for conservation practices or regional demographic changes.

PART III WATER DISTRIBUTION SYSTEM

The potable water systems must achieve the following basic objectives:

1. Deliver an adequate volume of water to the most hydraulically remote fixture during minimum pressure and maximum flow conditions;
2. Provide adequate water pressure to the to the most hydraulically remote fixture during minimum pressure and maximum flow conditions; and
3. Prevent excessive water velocity during maximum flow conditions.

A very common complaint in most of the buildings is that the lowest floors have the high pressures while the floors at higher elevations have scarce water or inadequate pressures. On the face of it, the solution to the problem looks simple; the system should be designed such that the water main's pressure must be great enough to overcome all resistance due to friction in pipe length, wall irregularities, number of fittings and net vertical distance traveled while still delivering the required pressure at the remote outlet. It sounds well theoretically; however, the actual design is not that simple.

Pressures

Water supply pressure in a residential or commercial building should not fall below 20 psi at the point of use. When pressures drop below this point, common appliances and plumbing fixtures will no longer function properly. When water pressure is inadequate, means for increasing the pressure shall be provided.

At the most favorable point of use, the pressure should not exceed 80 psi. Pressures beyond this point may lead to:

- Excessive flows at fixtures with a resultant waste of water
- High velocities with a resultant noisy piping system
- Water hammer with a resultant noise and destructive effect on the piping and fixtures
- Leakages
- Failure of piping joints, fixtures and appliances.

The installation of a pressure regulator shall be considered when the residual pressure at fixtures exceeds 80 psi. The regulator is usually installed just downstream of the main water shutoff valve so that if you have to work on the regulator, you can shut the water off. Incidentally, the warranties of some appliances and water heaters are voided if the pressure is above 80 psi.

Flow Pressure V/s Static Pressure

Flow pressure is that pressure that exists at any point in the system when water is flowing at that point. Once water starts to flow, the water moving through the pipe uses some of its energy to push past the pipe surface, no matter how smooth the pipe is. This consumes energy and reduces the pressure available to push water out the end of the pipe. This pressure loss due to friction occurs at every point along the pipe. When water starts to flow through a pipe, the pressure is highest at the source and decreases every inch along that pipe. The pressure would be lowest right at the tap. If we wanted to move 3 gallons per minute (gpm) through 1/2-inch-diameter pipe, 100 feet long, we might lose about 7 psi of pressure. If the pressure at the beginning of the pipe is 60 psi, the pressure at the end would be 53 psi. Flows (or flow rates) are measurements of the volume of water that comes out of the tap every minute. To summarize, as water is flowing through a pipe, the flow pressure drops as it moves along the pipe but the flow remains constant.

Static pressure is the pressure exerted by the water on the walls of the pipe when no water is flowing. There will be no flow as long as the taps are closed. Assuming that the pipe is horizontal, no matter where you measure the static pressure along that pipe, you would have the same pressure reading. If that pressure was 60 psi (pounds per square inch) where the pipe first came into the house, it would also be 60 psi right at the back of the house.

Note that the flow pressure is always less than the static pressure. When a manufacturer lists the minimum pressure required for the proper operation of a flush valve as 25 psi, it is the flow pressure requirement that is being indicated. The flush valve will not function at peak efficiency (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.

Pressure V/s Flow

"Flow" is a measure of volume of water delivered in a period of time. The poor shower is caused by low flow. "Pressure" is a measure of the force of the water, and it is measured when no water is flowing ("static" pressure). The flow and pressure are related by the following equation:

$q = 20d^2 p^{½}$

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" supply and the flow pressure is 16 psi. Then:

$q = 20 \times (3/8)^2 \times (16)^{½}$

$= 20 \times 9/64 \times 4$

= 11.25 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.

It is true that for a given plumbing system, the higher the pressure, the better the flow. However, there is a practical limit to increasing pressure to improve flow. The amount of water available at the tap depends on several things including:

1. How big the pipe is.
2. How smooth the inside of the pipe is.
3. How straight the pipe is.
4. How hard it is being pushed from behind (what's the static pressure?)
5. How much water we are trying to move (what flow are we looking for, in gallons per minute?)
6. How high the elevation is (what's the building height?)

Fundamentals of Pipe Sizing

In Part-1 of this course, we learned that the potable water demands are essentially intermittent. The intermittent demand volumes are much less than the total demand of plumbing systems; hence, smaller diameter pipes can be used for design. However, knowledge of the intermittent demand is essential. Based on this fact, Hunter proposed a probabilistic demand approach for designing plumbing water distribution systems. He suggested taking the design demand value as the aggregate demand that can be exceeded with only 1% probability. As a consequence, plumbing pipes in general have diameters less than 1 inch for most buildings up to 5 to 7 stories high. For buildings taller than 7 stories, the structures are divided into zones of about 7 stories each, and each zone's plumbing system is designed independently.

The flow requirement established by the fixture unit count is related to pipe size by pressure drop and flow velocity considerations. Pipe sizing can be based on one of the following four approaches:

1. <u>Pressure drop restriction only with no velocity limitation:</u> This approach will lead to conservative sizing toward the far end of the system. Risers will tend to be larger than sizes established by other approaches, and the beginning pipe main's size will tend to be smaller. The allowable pressure drop is usually specified on the order of 5 psi per 100 feet of pipe length or lower.

2. <u>Pressure drop and velocity restriction:</u> In this approach, risers will be of the same size as mentioned above, with the beginning pipe main's size being one to two nominal pipe sizes larger. The allowable pressure drop is usually specified on the order of 5 psi per 100 feet of pipe length or lower, with the flow velocity restricted to 6 to 8 feet per second (fps).

3. <u>Maximum velocity restriction:</u> This design approach will orient sizing toward the near end, or start of the distribution main. The beginning portion of the main's size will tend to be large, while the risers and far ends of the distribution main will tend to be one to two nominal pipe sizes smaller compared to sizes established by a pressure drop limitation. The maximum allowable flow velocity is generally on the order of 6 to 8 fps.

4. No design limitation and piping sized to use up available street static pressure: Given excessive street (source) static pressure availability, the flow friction loss design rate can become very elevated. The resulting smaller size distribution piping can then generate high mix flow changes at showerheads. This is because of pressure drop changes in the HW and CW piping as respective HW and CW flow rates change.

Apparently, all of the above stated design approaches with their assigned design limitations, except for number 4, have worked satisfactorily. This may be true simply because of pipe over-sizing introduced by the unreliability of flow demand statements and the unknowns concerning pipe tuberculation.

It is customary engineering practice to establish limitations based on maximum allowable pipe friction loss rate and a maximum allowable design velocity. This is because of the concern for flow noise and the possible effect of high distribution piping pressure drop on hot and cold water mix flow stability.

In general, it seems best to orient the sizing exercise toward the terminal end of the main and toward the risers by use of the limitations stated in design approaches 1 and 2 above. This will tend to reduce possible noise generation in riser piping adjacent to occupied spaces.

Probability Flow Rates and Pipe Sizing

“Make the piping big enough” is an old plumber’s axiom.

It’s obvious that the bigger the pipe, the more water you can move through it. What’s not so obvious is how dramatic this is. For example, changing the pipe diameter from 1/2-inch to 3/4-inch can make a very large difference. You can calculate that the 3/4-inch diameter pipe is 225 percent of a 1/2-inch-diameter pipe in cross-sectional area. In practice, the difference is even more dramatic than the cross-sectional area would suggest. If you consider 100 feet of 1/2-inch-diameter pipe, you will lose 10 psi of pressure running 3.5 gpm through the pipe. For 3/4-inch-diameter pipe, you will lose 10 psi when you flow 9.4 gpm through it. The cross-sectional area of a 3/4-inch-diameter pipe is 225 percent of a 1/2-inch-diamater pipe, but the flow through a 3/4-inch-diameter pipe is 270 percent of the flow of a 1/2-inch-diameter pipe with the same pressure loss.

The larger the pipe diameter, the better will be the water pressure. Any attempt to reduce the pipe sizes to save cost needs to be carefully evaluated. It must be noted that the cost savings for 1" pipe or tube as compared to 1¼ inch is minimal. Cost savings would seem low in comparison with implied risk factors because of the four times pressure drop increase associated with a one size reduction for any given flow rate.

<u>Caution</u>

It is not always good to over-design the system. In a plumbing network, the cold-water branch lines are susceptible to variations in pressure and flow due to the sudden instantaneous draw rate associated with flush valves; whereas, the hot water distribution lines are particularly NOT subject to wide variations. This presents insurmountable control problems for the mixing fixtures, as the resultant outlet temperature will change if the cold-hot water ratio is altered.

Showerhead temperature stability requires:

a. Stable hot and cold water temperatures and

b. Stable mix ratio of hot and cold water

The expression below determines the relationship between temperature and mix ratio:

$$\text{Ratio \% HW} = \frac{\text{Mix (deg F)} - \text{CW (deg F)}}{\text{HW (deg F)} - \text{CW (deg F)}}$$

The ratio percentage of 140 °F required for mix with 40 °F CW to provide 100 °F mixed temperature can be established by the formula indicated below:

$$\text{Ratio \% HW} = \frac{100 - 40}{140 - 40} = 60\%$$

The most obvious problem concerning showerhead temperature stability is temperature control of the entering hot service water to the mix point.

It is apparent that a combined fluctuation of both HW supply temperature and the flow mix ration can cause significant variation in mix temperature. Fortunately, these are not usually simultaneous problems.

HW heater temperature control is generally associated with light load demands while the distribution piping pressure drop change flow mix stability problem will be associated with high load demands. As one problem increases, the other moderates.

The design of mix water application should be carefully evaluated in consultation with an experienced plumber.

Pipe Materials

The two most common materials currently used for potable water supply lines are copper and plastic.

Copper: Copper is used most often in plumbing piping because it offers numerous advantages:

- Corrosion resistance and low friction loss
- Smaller in diameter and can be used in tight places
- Inhibits bacterial growth, and therefore, the water is safe to drink
- More resistant to flame than PVC pipes
- More prone to withstand earthquakes
- Provide better form fitting than PVC pipe
- Life expectancy indefinite unless unusual water conditions or manufacturing defects are present

The disadvantage of copper pipes is higher cost, condensation concerns, heat conductivity, system noise and tube kinking.

<u>Standard Copper tubes:</u>

- K type**:** thickest, available in straight runs or coils
- L type**:** Most common medium thick, available in straight lengths or coils
- M type**:** thinnest, available in straight lengths only, used at low pressure service.

<u>Recommended Copper tubing:</u>

- Copper Tubing: ASTM B 88, Type ‘K’ water tube. For tubing up to 2” diameter, use ‘soft’ copper (annealed temper).
- Copper Tubing: ASTM B 88, Type ‘K’ water tube. For tubing with diameters larger than 2”, use ‘hard’ copper.

Plastic: The two most common types of plastic pipes for potable water service are: polyethylene (PE) and chlorinated poly vinyl chloride (CPCV). PE piping uses press-on fittings and CPCV uses solvent welded or glued fittings. Plastic pipes offer many advantages over copper.

- Plastic pipes ar easy to work with and connections can be made without soldering;
- It is the most lightweight that makes it easier to install;
- Has lower cost
- Can withstand higher water pressure than the copper
- Non-conductive, will not rust, and is not as conducive to condensation
- Less noisy at higher water pressure levels
- Self-insulating which means it can handle hotter temperature water

Disadvantages: Plastic pipes are bulky and often do not fit in tight places as well as copper. Fitting failures and leakage may occur because of poor workmanship. Plastic pipes contain volatile compounds which are harmful to the environment. Even though they can withstand hot water temperatures, they are less flame resistant which is one of the biggest disadvantages.

Note - Polybutylene piping was removed from the Uniform Plumbing Code in the U.S. in 1989 as an approved water distribution material.

Sizing Auxiliaries

Where the water pressure in the public water main or individual water supply system is insufficient to supply the minimum pressures and quantities, the supply shall be supplemented by an elevated water tank, booster pump or an expansion system.

Booster Pump Sizing

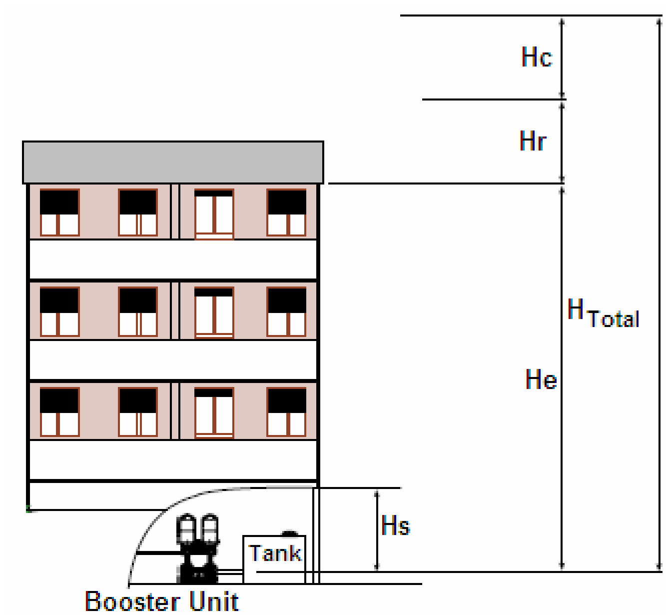
Pump selection is based on two parameters:

1. **Flow Rate (gpm):** Pumps are selected for the peak flow rate. The peak flow rate is the sum of the higher flow out of the maximum probable demand (as estimated by fixture count) and the additional demand expected from fire protection or hose bib. The maximum probable demand is calculated as outlined in Part 1 of this course.

2. **Total Dynamic Head (TDH):** The head of the pump is the pressure drop summation of:

   - Friction drop in piping and fittings up to the remotest point; plus
   - Static pressure drop due to highest located fixture; plus
   - Terminal pressure (usually 30 psi) added for the faucet outlet.

Calculating Total Dynamic Head



The Total Dynamic Head (TDH) for your booster application is calculated as follows:

TDH = He + Hr + Hc – Hs

Where:

- He is the vertical height difference between the booster discharge and the highest point of use.
- Hr is the friction losses of all of the piping, valves, elbows, etc. of the system.
- Hc is the desired discharge pressure at the top of the system.
- Hs is any suction pressure coming into the booster from the water supply line.

Example:

The highest tap in a building is 70 feet above the pump. Friction losses from piping add up to 30 feet. The user wants 50 psi (116 feet) available and there is 25 psi (58 feet) of suction pressure at the pump.

TDH = (He) + (Hr) + (Hc) – (Hs)

TDH = 70 + 30 + 116 – 58

TDH = 158 feet

The important key considerations are:

1. Municipalities usually maintain water pressure in their distribution mains within the range of 35 to 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. It is a good practice to assume a pressure available for design purposes to be 10 psi less than the utility quotes.
2. Utility street pressure often varies widely within a 24-hour day, as well as from month to month. The installation of pumps is required if at any time the street pressure can be expected to be lower than the pressure drop anticipated in the system. As a standard engineering practice, a minimum terminal pressure of 8 psi is desired at faucet outlets.
3. Potable water pumps are desired along with a storage tank even if the street pressure is normally high (although this is not guaranteed all the time, plus there exists a possibility for supply interruptions).
4. Booster pumps are generally referred to as online pumps. The use of booster pumps in plumbing systems should be carefully evaluated. Utility companies do not allow the installation of booster pumps within their system because of hydraulic network balancing problems.

5. The pump should be provided with a pressure reducing provision to restrict the maximum discharge pressure to 80 psi.
6. At a minimum, the pump shall be provided with a local recirculation provision, or on-off mechanism with the expansion tank, to protect pump internals during no-flow conditions.

Storage Tank

The storage tank volume sizing is typically based on the average probable water demand factored by the hours of storage required. Generally the owner (utility service customer) optionally elects to size the storage tank for 12 hours, 24 hours or higher, based on his knowledge of the reliability of the utility supply and the criticality of his operations.

Expansion Tank

The expansion tank is generally provided downstream of the booster pumps. The expansion tank used for residential or tertiary facilities is a portable factory charged bladder or diaphragm type vessel. It comes with factory-set pressure settings usually 10 to 12 psig below the system pressure. Large plumbing systems may employ site-fabricated hydro-pneumatic tanks.

The primary purposes of an expansion tank are as follows:

- Absorbs the water demand fluctuations as a result of sudden draw of water
- Compensates the pressure surges in the piping network
- Provides a cushion for peak demand
- Prevents frequent starting of pumps

The tank should be located in the discharge piping downstream from the check valves.

PART IV REGULATORY AND SYSTEM RELIABILITY CONSIDERATIONS

Heightened environmental awareness and rising water use and its associated energy costs, are resulting in greater legal mandates for efficient plumbing fixtures. The amount of water traditionally equated with one fixture unit is becoming less.

The following are other regulatory requirements to consider when analyzing or estimating water demands:

Water Rights: Projected water demands consistent with the level of intended service should be compared against water rights held by the purveyor.

Utility customers can no longer expect the capability of using water whenever and however they wish. The term *"In stream Flow"* is quite familiar; it implies a legal right for water to remain in the stream to protect the natural environment.

It is acceptable to install pumping equipment capable of producing flows in excess of current water right limits; however, pump discharges must be flow-restricted such that permitted withdrawal rates are not exceeded.

Water Conservation: Although 80% of the earth's surface is covered with water, less than 1% of that water is available for potable consumption. Drinking Water Regional Offices detail water conservation planning requirements. Purveyors must have an approved conservation program as part of their compliance with the "Conservation Planning Requirements". The conservation plan includes water use data collection, identification of conservation objectives, evaluation of conservation measures, identification of selected conservation measures chosen for implementation, and target water savings projections. These are incorporated into the water demand forecast used to justify the need for additional water. In addition to those listed above, ecological considerations may also play a role in determining the requirements for obtaining water rights.

The Washington State 1993 Plumbing Code Standards has introduced mandatory conservative practices. For instance, the code requires that:

- General public lavatories, excluding handicap stations, must have spring valve self-closing faucets;
- Urinals or water closets with continual flushing not be permitted; and
- Two to three gpm restrictive flow shower heads be used.

The design engineer must address all regulatory requirements which apply to the water system that ensure system reliability, including sufficient source and storage capacity, pumping capacity and hydraulic capacity criteria.

System Reliability Recommendations

The following presents a brief summary of recommendations that are intended to promote high levels of system reliability for service to customers:

1. Water system source, treatment, and storage facilities must be designed such that, together, they provide the maximum day demand (MDD) for the system.
2. Larger storage tanks, with corresponding greater residence times of stored water, are more susceptible to water quality problems such as stale water, warmer water in the summer, and biological growth. When a system relies on storage to meet MDD, the impact on system users will be significantly greater if the volume of storage constructed is underestimated. It should also be noted that the more a utility relies on storage rather than source to meet MDD, the longer it will take the utility to replenish storage once it is depleted.
3. Fire protection authorities generally recommend the ability to replenish fire suppression storage within an 8 to 24-hour period once it is depleted. This may not be possible during periods of high demand if the source cannot provide flow rates equal to or exceeding the MDD. It is important to check with local authorities on whether a dedicated storage is needed for firewater service.
4. An additional flow of 10 gallons per minute should be added to the calculated peak hour demand (PHD) for cleaning service bibs and an additional 10 gpm for each acre to be irrigated, in excess of the base value.
5. If irrigation is not permitted on more than 2.5 acres per connection, or if additional management controls are instituted, then such information should be noted on restrictive covenants, water user agreements, or other legally enforceable agreement between the lot owner (or water customer) and the water system. It is important to present this information when requesting system approval.
6. In the event the largest pump is out of service, multiple pumps should be installed with such capacity that the MDD of the service area could be provided.

7. Provision of a minimum of 20 psi at the intake of the pumps under fire flow plus MDD-rate conditions, must be ensured.
8. Provision for an automatic shut-off should be in place when the intake pressure drops below 10 psi.
9. Separate power connections from two independent primary public power sources, or provision of in-place auxiliary power, should be available if the pumps provide fire flow or are pumping from ground-level storage.
10. An alarm system should be included that notifies the operator(s) of overflows or drops in storage levels below the point where the emergency storage volume is depleted.
11. Designs should result in pipeline velocities that do not exceed 8 feet per second.
12. Designs should allow all pipelines to be efficiently flushed at a flow velocity of at least 2.5 fps.
13. Only utilize pipe material recommended for potable water use such as copper, galvanized iron or approved HDPE. Provide all mains and distribution lines with appropriate internal and external corrosion protection. Guard against corrosion of metal piping due to galvanic reaction with buried metals in moist subsoil as a result of de-icing salts percolating into the soil, high or low pH groundwater, fertilizers, or large roots of dead trees.
14. Conduct hydraulic analysis for systems with designed fire flow capability to ensure adequacy of system flows and pressures.
15. Great care must be taken when sizing pipe for flush valve water closets to guard against high CW piping pressure drop changes.
16. There is little point to the maintenance of a set HW temperature, if its pressure drop is so high as to cause a flow ratio change and consequently a temperature change at the showerhead. Consequently, HW side temperature control (three-way mix valve pressure drop) should be minimized.
17. Showerhead pressure drop is an important factor in terms of stabilized mixed flow ratios and temperatures. High showerhead pressure drop, by way of a mixing valve sized optimally at 20 psi, will provide increased flow ratio mix sensitivity to distribution line pressure drop changes.

18. Underground piping must be a minimum of 12" below the frost line (the depth will vary with locale).
19. Distribution piping must be 12" above and 12" laterally from underground clay sewer lines.
20. All below-grade piping should be placed at least 10 feet (3 meters) from electrical discharges of nearby ground rods.
21. Reductions in the service pipe size to the inlet side of water softeners should NOT be made.
22. The minimum nominal service pipe size should be ¾".
23. A backflow preventer (double check valve assembly) should be provided where the possibility of contaminated water or reverse flow exists.
24. Water pressures in excess of 80 psi must be regulated.
25. An accessible strainer must be installed upstream of regulators.
26. Measures to prevent excessive backpressure, bypass, etc. should be implemented.
27. Hot and cold pipes should be spaced at least 6 inches (15 centimeters) apart or have insulation placed between them to prevent heat exchange.
28. Every length of pipe should be,
    - Protected from freezing;
    - Pitched slightly to promote positive drainage;
    - Provided with ample chase and riser space to allow movement due to thermal expansion;
    - Supported frequently enough to prevent sags between supports;
    - Included in dead load tabulations of structural calculations; and
    - Accessible for maintenance and future upgrades.

Course Summary

This course presents the basic understanding of the fundamental concepts of plumbing water systems.

Model codes such as UPC, SPC, and IPC provide a simplified basis of estimating potable water demand based on the number of plumbing fixtures.

The estimation of potable water demand is based on a probability theory that has been developed to predict the mind-set or socioeconomic ethics of consumer water use.

The estimation of non-residential water demand is based on historical data published by the American Water Works Association.

The recommended sizing of a piping system is based on pressure drop-velocity criteria. A standard engineering practice in pipe sizing is based on restricting the pressure drop to 5 psi per 100 feet of equivalent length pipe in conjunction with a flow velocity not exceeding 8 fps.

The selection and sizing of the various ancillary plumbing components, such as pumps and storage tanks, should be based on the peak demand and maximum average daily demand.

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