CMGT 235 – Electrical and Mechanical Systems

Discussion No. 12 **Unit 2 - Plumbing Systems** **Fall 2022**

Water Supply Fixture Unit (WSFU) and Sizing Water Supply Piping

Water Consumption

Estimates vary, but, on average, each person uses about 80-100 gallons of water per day, for indoor home uses.

2016 California Plumbing Code

Table 1. Maximum Installed Flush or Flow Rates

Fixture or fitting	2016 CA Plumbing Code	EPAct 1992 Federal Standard	WaterSense®
Flush Fixtures			
Flushometer-Valve Toilet (Water Closet)	1.28 gpf	1.6 gpf	1.28 gpf
Tank Toilet (Water Closet)	1.28 gpf	1.6 gpf	1.28 gpf
Urinal (Wall Mounted)	0.125 gpf	1.0 gpf	0.5 gpf
Urinal (Floor Mounted)	0.5 gpf	1.0 gpf	0.5 gpf
Flow Fixtures			
Residential Lavatory Faucet	1.2 gpm @ 60 psi	2.2 gpm @ 60 psi	1.5 gpm @ 60 psi
Public lavatory (restroom) faucet	0.5 gpm @ 60 psi	0.5 gpm @ 60 psi	
Kitchen Faucet	1.8 gpm @ 60 psi	2.2 gpm @ 60 psi	
Showerhead	2.0 gpm @ 80 psi	2.5 gpm @ 80 psi	2.0 gpm @ 60 psi
Pre-Rinse Spray Valve	1.6 gpm @ 60 psi	1.6 gpm @ 60 psi	1.28 gpm @ 60 psi

LEED Baseline Daily Water Consumption (Residential)

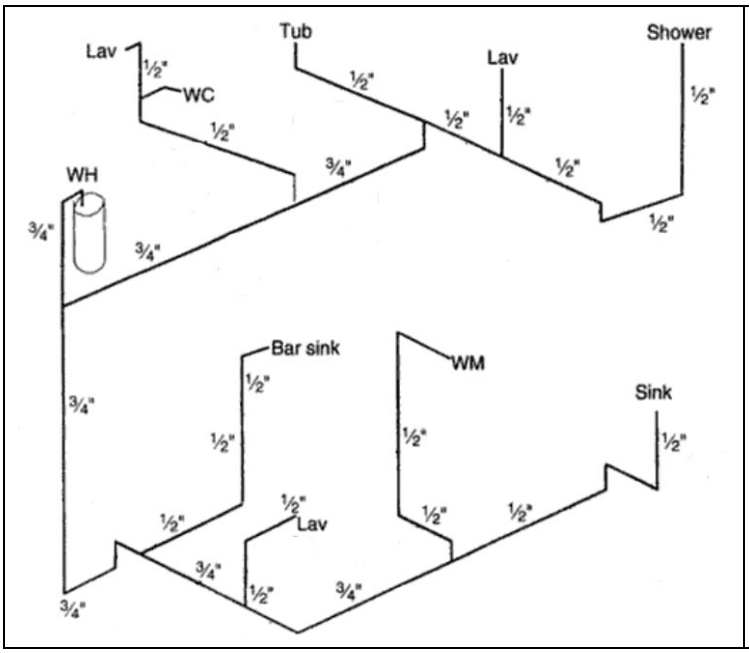
Activity	Fixture Flush/Flow Rate	Duration	Uses per Day	Water Consumed (gal)
Water Closet	1.6 GPF	1	5	8
Lavatory, Private	2.2 GPM	60 sec	5	11
Shower	2.5 GPM	480 sec	1	20
Kitchen Sink	2.2 GPM	60 sec	4	8.8
Total				47.8 gal

WC = 1.6 GPF x 1 F x 5 uses = 8 gal
LAV = 2.2 gpm x 60 sec x 1 min / 60 sec x 5 uses = 11 gal
SHW = 2.5 gpm x 480 sec x 1 min / 60 sec x 1 use = 20 gal
KS = 2.2 gpm x 60 sec x 1 min / 60 sec x 4 uses = 8.8

Water Demand
The instantaneous peak demand for water in a pipe serving a number of plumbing fixtures or serving an entire building is referred to as the demand load.

Demand Load
- ❑ Maximum probable or peak instantaneous demand for domestic water by a group of fixtures. The demand load is typically expressed in gpm (or L/min or L/sec).
- ❑ Depends on the number and type of fixtures installed and the operation of the fixtures.
  Continuous flow: faucets, hose bibb, and shower
  Intermittent flow: water closets and urinals

It is highly unlikely that every sink, dishwasher, water closet, bathtub, shower, clothes washer, and garden hose in a building be operated at one time. Totaling fixture flow rates for all fixtures in an entire building distribution system would give the total demand for water usage only if all fixtures were used at one time. In most instances, totaling fixture requirements provides a very high estimate that results in overdesign of the piping.



Fixture	Flow Rate (GPM)	Total (GPM)
1 – SHW	2.5	2.5
3 – LAV	2.2	6.6
1 – TUB	5.0	5.0
1 – WC	3.0 (refill tank)	3.0
1 – BS	2.2	2.2
1 – CW	4.0	4.0
1 – LS	2.2	2.2
		25.5 gpm

Demand Load = 25.5 gpm

Simple Empirical Design Method
Piping is sized with rules of thumb based upon observation and experience.
Branch pipes can be sized from minimum branch requirements cited in the building code.

- Up to three ½ in branches can be served by a ¾ in main.
- Up to three ½ in branches or up to six ¼ in branches can be served by a 1 in main.
- Up to five ¾ in branches or up to ten ½ in branches can be served by a 1 ¼ in main.

The empirical approach is used in design of plumbing systems for residences and similar buildings with simple plumbing systems. Typically, a qualified plumber does design during rough in of the piping. This approach can lead to system problems in complex piping arrangements.

Water Supply Fixture Unit (WSFU)

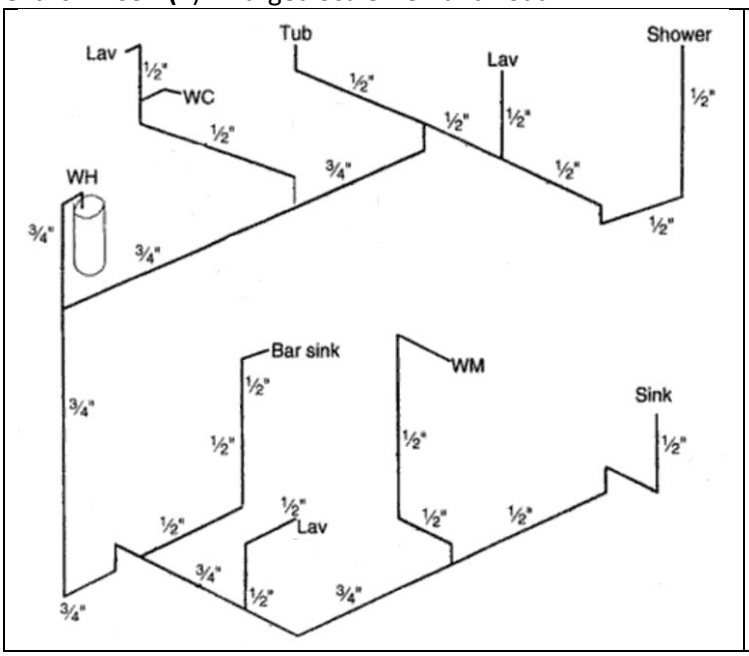
- ❑ Arbitrarily chosen measure that allows all types of plumbing fixtures to be expressed in common terms.
- ❑ Purpose is to make it possible to calculate the design load on a system composed of different types of fixtures, each having different flow rates.
- ❑ Fixture unit values are assigned to the different types of fixtures.
- ❑ The total number of fixture units is used to establish the maximum probable water supply load.

The *Water Supply Fixture Unit (WSFU)* is an arbitrarily chosen measure that represents each fixture connected to the water supply system.

2016 California Plumbing Code

Table 610.3 Water Supply Fixture Units (WSFU) and Minimum Fixture Branch Pipe Sizes

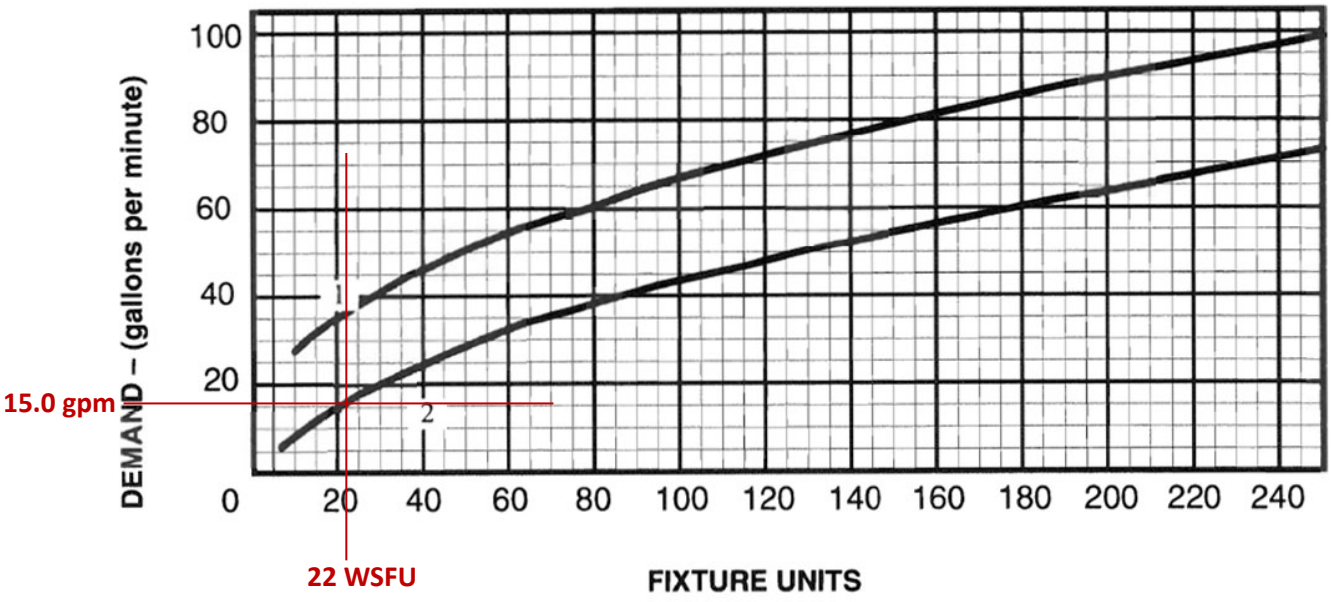
Chart A 103.1(2) Enlarged Scale Demand Load



Fixture	WSFU	Total WSFU
1 – SHW	2.0	2.0
3 – LAV	1.0	3.0
1 – TUB	4.0	4.0
1 – WC	2.5	2.5
1 – BS	1.0	1.0
1 – CW	4.0	4.0
1 – LS	1.5	1.5
		22 WSFU

Demand Load = 15 gpm

CHART A 103.1(2)
ENLARGED SCALE DEMAND LOAD



For SI units: 1 gallon per minute = 0.06 L/s

2016 CPC Chart A 105.1 (3) – Friction Loss in Fairly Rough Pipe

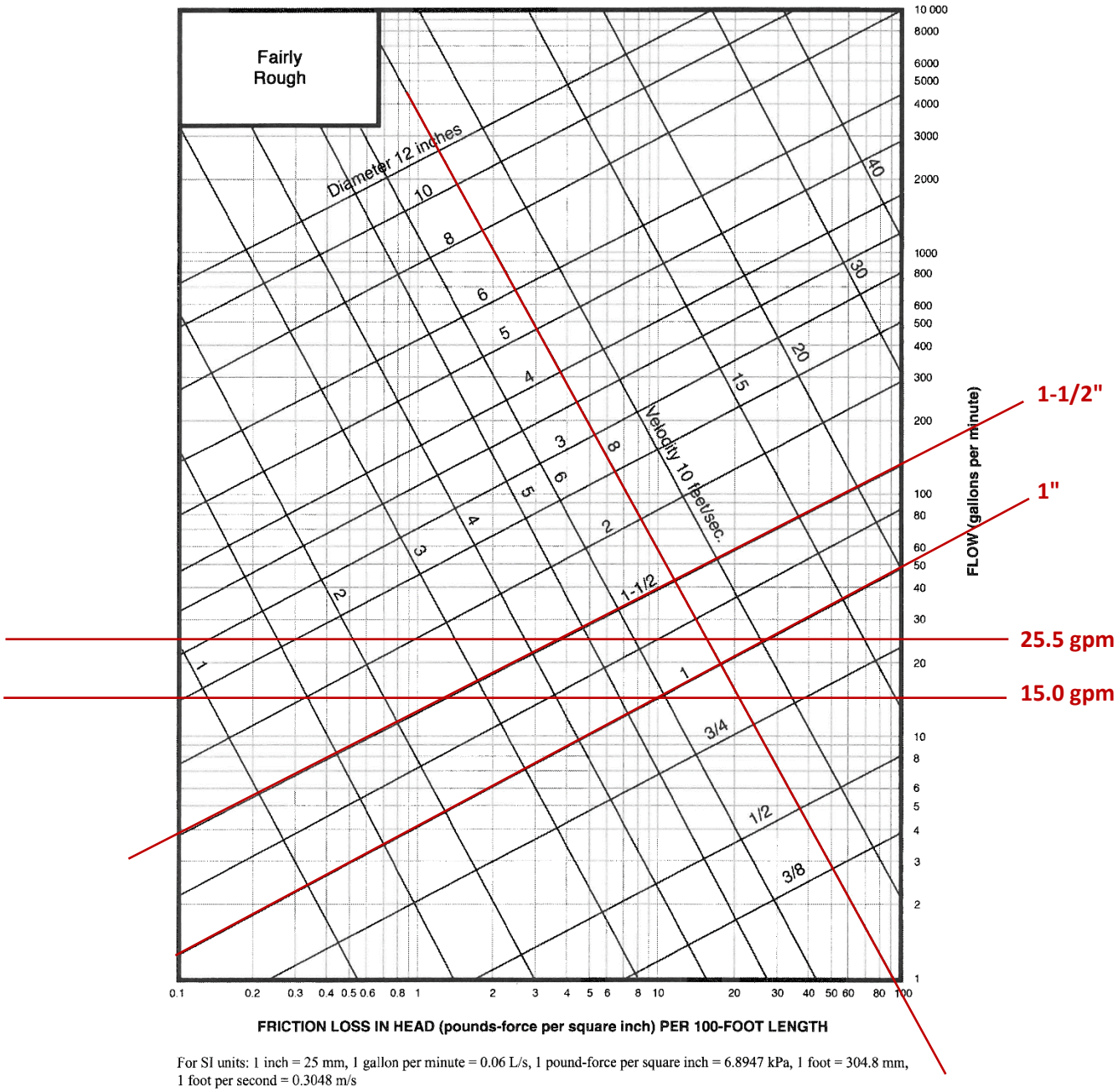
Assume a maximum velocity of 8 feet/sec (fps)

Plot on the graph where our demand (25.5 gpm and 17 gpm) meets this velocity.

From that point, you select the nearest pipe size to the left of the 8-fps velocity curve.

APPENDIX A

CHART A 105.1(3)



FRICTION LOSS IN HEAD (pounds-force per square inch) PER 100-FOOT LENGTH

For SI units: 1 inch = 25 mm, 1 gallon per minute = 0.06 L/s, 1 pound-force per square inch = 6.8947 kPa, 1 foot = 304.8 mm, 1 foot per second = 0.3048 m/s

Velocity Design Method

- ❑ The *velocity design method* entails selecting the smallest pipe diameter without exceeding a pre-established maximum velocity for the demand load in the pipe.
- ❑ It works well in preliminary design of a plumbing system provided system layout is reasonably symmetrical.
- ❑ This method does require an investigation of pressure loss to ensure that the residual pressure at the most remote fixture is adequate.

Procedure

1. Sum the total number of Water Supply Fixture Units (WSFU) for hot water and cold water combined.
2. Determine the maximum probable demand in gpm.
3. Based upon the maximum desired velocity (8 ft/sec) and demand load (Q), solve for the minimum diameter ($D_{i\text{-}min}$):
   In U.S. customary units

   $D_{i\text{-}min} = \sqrt{0.409\ Q / v}$ inch

4. Select a pipe size (from design tables) with an inside diameter equal to or greater than the minimum required diameter, $D_{i\text{-}min}$.

Q (gpm)	v (fps)	$D_{i\text{-}min}$	Copper Tube: Type M	Copper Tube: Type L
25.5	8	1.142	1-1/4"	1-1/4"
15.0	8	0.876	1"	1"

TABLE 2c. Dimensions and Physical Characteristics of Copper Tube: TYPE M

Nominal or Standard Size, inches	Nominal Dimensions, inches			Calculated Values (based on nominal dimensions)				
	Outside Diameter	Inside Diameter	Wall Thickness	Cross Sectional Area of Bore, sq inches	Weight of Tube Only, pounds per linear ft	Weight of Tube & Water, pounds per linear ft	Contents of Tube per linear ft	
							Cu ft	Gal
3/8	.500	.450	.025	.159	.145	.214	.00110	.00826
1/2	.625	.569	.028	.254	.204	.314	.00176	.0132
3/4	.875	.811	.032	.517	.328	.551	.00359	.0269
1	1.125	1.055	.035	.874	.465	.843	.00607	.0454
1 1/4	1.375	1.291	.042	1.31	.682	1.25	.00910	.0681
1 1/2	1.625	1.527	.049	1.83	.940	1.73	.0127	.0951
2	2.125	2.009	.058	3.17	1.46	2.83	.0220	.165
2 1/2	2.625	2.495	.065	4.89	2.03	4.14	.0340	.254
3	3.125	2.981	.072	6.98	2.68	5.70	.0485	.363
3 1/2	3.625	3.459	.083	9.40	3.58	7.64	.0653	.488
4	4.125	3.935	.095	12.2	4.66	9.83	.0847	.634
5	5.125	4.907	.109	18.9	6.66	14.8	.131	.982
6	6.125	5.881	.122	27.2	8.92	20.7	.189	1.41
8	8.125	7.785	.170	47.6	16.5	37.1	.331	2.47
10	10.125	9.701	.212	73.9	25.6	57.5	.513	3.84
12	12.125	11.617	.254	106	36.7	82.5	.736	5.51

https://www.plumbersstock.com/plumbing/pipe/copper.html

1" Type M – 5′ $27.40/ea
1-1/4" Type M – 5′ $25.65/ea

1" Type L – 5′ $23.65/ea
1-1/4" Type L – 5′ $78.65/ea

Example 1.

A. Using the 2016 CPC Table 610.3 and Chart A 103.1(2) Enlarged Scale Demand Load, determine the total WSFUs and total demand load for the one-bedroom home shown. Each side of the house has a hose bibb.

Fixture Type	WSFU
2-LAV	2.0
1-SHW	2.0
1-WC FT	2.5
1-BT	4.0
1-CW	4.0
1-LT	1.5
1-KS	1.5
1-DW	1.5
4-HB	5.5
TOTAL	24.5

Demand Load = 17.0 gpm

B. Using the velocity design method, determine the minimum required size for the main water supply pipe. Use a maximum velocity of 8 ft/sec. Assume a system with flush tanks and Type L copper tube.

$D_{i\text{-}min} = \sqrt{0.409\ Q / v}$ inch

$D_{i\text{-}min} = \sqrt{0.409 \times 17\ GPM / 8\ FPS}$ inch

$D_{i\text{-}min} = 0.932$

A 1 inch Type L Copper Tube with an inside diameter of 1.025 is adequate for the main water supply pipe.

Sizing Water Supply Pipes
2016 CPC Chapter 6 Water Supply and Distribution
610.0 Procedure

Determining the required meter and pipe work sizes is a four-step process:
Step 1. Calculate the Available Water Pressure
Step 2. Find the Effective Maximum Developed Length (DL) of pipe
Step 3. Calculate the Total WSFU
Step 4. Use Table 610.4 Fixture Unit Table for Determining Water Pipe and Meter Sizes

Example (JLC Article)

Sizing Water Supply Pipes

To size the main water distribution pipe:

1. **Find the pressure loss:**

Municipal water service pressure		70 psi
minus pressure loss from equipment (water softener)	–	5 psi
minus pressure loss from elevation (22' x 0.5)	–	11 psi
Adjusted pressure	**0.433**	**54 psi**

2. **Find the developed length of pipe:**
Length of pipe to farthest fixture times 1.2 (to account for pressure loss due to fittings)
37' x 1.2 = 45'-0"
1.5

3. **Find the fixture-unit values:**

Full-bath group w/ bathtub	3.6	(hot and cold)
Half-bath group	2.6	(hot and cold)
Kitchen group	2.5	(hot and cold)
Laundry group	2.5	(hot and cold)
Hose bibb	2.5	(cold only)
Total fixture-unit value	**13.7**	

4. **Use code tables (figure 3) to determine pipe size**

2016 CPC Table 610.4

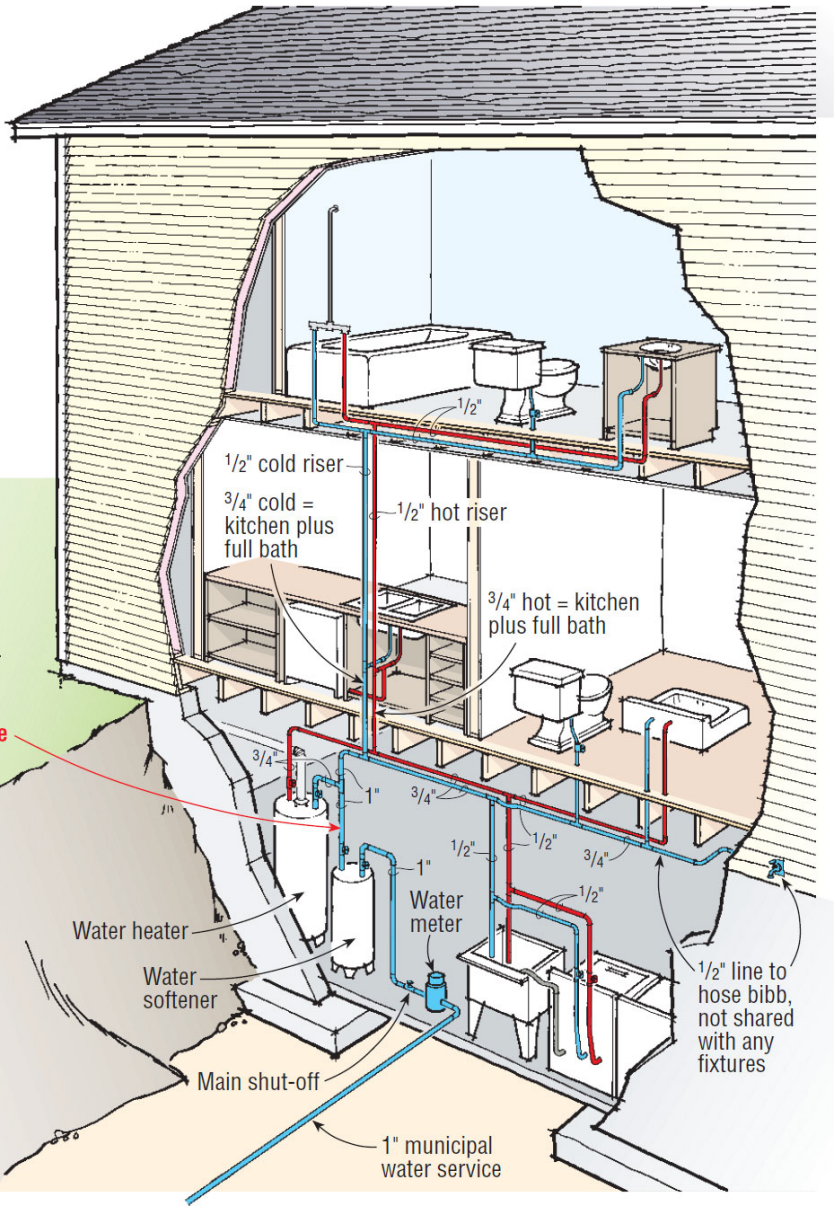


Figure 4. When sizing the main distribution pipe, add up all the fixture groupings in the whole house (see table in Figure 2). After the cold and hot lines divide, use separate hot and cold fixture groupings to size branch lines.

Example 2. Determine the meter and pipe work sizes for the standard 1-story, two-bath home shown below. The home has a main meter, backflow preventer, water heater, water softener, and dishwasher. Assume a minimum daily static service pressure available (MDSSPA) of 80 psi. A hose bibb is installed on each outside wall. Assume an 8 psi loss through the meter, 5 psi loss through the backflow preventer, and a 15 psi loss through the water softener. The highest water outlet in the building is 10 feet above the source of supply. The length of the piping between the source of supply and the fixture in the building that's the farthest away is 130 feet. Use the 2016 California Plumbing Code, Chapter 6 – 610.0

PLAN No. 1806-0111

2-BEDROOM 1-STORY

2 BEDROOM, 2 BATHROOM, 1-KITCHEN
1-DINING AREA, 1-FAMILY ROOM
1-STUDY, AND 2 CAR GARAGE

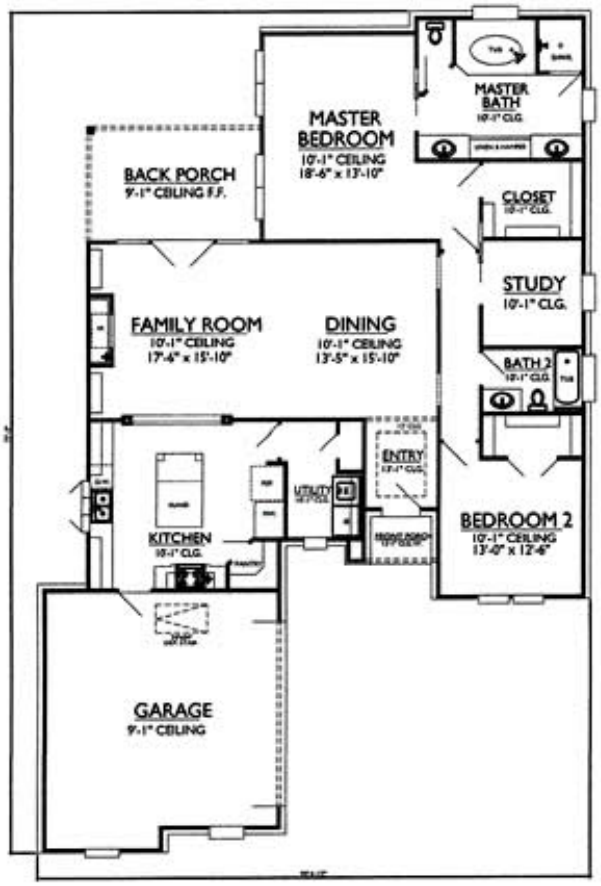
FOOTPRINT (48'-5" X 73'-7")

1806 SQ. FT. LIVING AREA 1st FLOOR

1806 TOTAL SQ. FT. LIVING AREA

489 SQ. FT. GARAGE
22 SQ. FT. FRONT PORCH
154 SQ. FT. BACK PORCH

2471 TOTAL SQ. FT. FRAME AREA



Solution.

Step 1. Calculate the Available Water Pressure

Municipal Water Service Pressure	= 80 psi
Minus pressure loss from equipment	
Main Meter	- 8 psi
Backflow Preventer	- 5 psi
Water Softener	- 15 psi
Minus pressure loss from elevation (10 ft x 0.433 psi/ft)	- 4.33
Adjusted Pressure	47.67 psi

Note: Deduct any pressure drop of more than 8 psi for the installation of special plumbing fixtures. Some of these are temperature-controlled showers or flushometer tank toilets. In this example none installed.

Step 2. Find the Effective Maximum Developed Length (DL) of Pipe

Length of pipe to the farthest fixture x 1.5 (to allow for pressure loss through the fittings) = 130 x 1.5 = 195 feet

Step 3. Calculate the Total WSFU

Fixture Type	WSFU
1 – BT/SHW	4.0
1 – BT	4.0
1 – SHW	2.0
3 – LAV	3.0
2 – WC FT	5.0
1 – KS	1.5
1 – DW	1.5
1 – CW	4.0
4 – HB	5.5
Total WSFU	30.5

Step 4. Look at Table 610.4. The tables give you a choice of three pressure ranges: 30 to 45 psi, 46 to 60 psi, or over 60 psi. Using the table Pressure Range – 46 to 60 psi:

1. Select the correct column for Maximum Developed Length (feet). There are 15 choices, 40 feet up to 1000 feet. Always use the column higher than the number calculated. In our example this number is 195 feet, so use the 200 feet column.
2. Find the number in the column that is the same as or the next higher number than the one we calculated for the WSFU value in our example. Our WSFU was 30.5. The next higher number in the 200 feet column is 32.
3. Now, look at the far left-hand column, Meter and Street Service (inches) and the Building Supply and Branches (inches) column directly to its right. Moving left from our number 32 in the example, these numbers are:
   3/4 inch for the Meter and Street Service
   1-1/4 inch for the Building Supply

METER AND STREET SERVICE (inches)	BUILDING SUPPLY AND BRANCHES (inches)	MAXIMUM ALLOWABLE LENGTH (feet)														
		40	60	80	100	150	200	250	300	400	500	600	700	800	900	1000
PRESSURE RANGE – 46 to 60 psi[1]																
¾	½[2]	7	7	6	5	4	3	2	2	1	1	1	0	0	0	0
¾	¾	20	20	19	17	14	11	9	8	6	5	4	4	3	3	3
¾	1	39	39	36	33	28	23	21	19	17	14	12	10	9	8	8
1	1	39	39	39	36	30	25	23	20	18	15	12	10	9	8	8
¾	1¼	39	39	39	39	39	39	34	32	27	25	22	19	19	17	16
1	1¼	78	78	76	67	52	44	39	36	30	27	24	20	19	17	16
1½	1¼	78	78	78	78	66	52	44	39	33	29	24	20	19	17	16
1	1½	85	85	85	85	85	85	80	67	55	49	41	37	34	32	30
1½	1½	151	151	151	151	128	105	90	78	62	52	42	38	35	32	30
2	1½	151	151	151	151	150	117	98	84	67	55	42	38	35	32	30
1	2	85	85	85	85	85	85	85	85	85	85	85	85	85	83	80
1½	2	370	370	340	318	272	240	220	198	170	150	135	123	110	102	94
2	2	370	370	370	370	368	318	280	250	205	165	142	123	110	102	94
2	2½	654	640	610	580	535	500	470	440	400	365	335	315	285	267	250

Sizing Branch Piping
How do you determine the size of pipe work you need for each branch?

Procedure

1. Calculate the WSFU value for all the fixtures you plan to install on each branch.

   Note: Most plumbing fixtures are connected to both cold water and hot water branches. Water is typically drawn from both the cold water and hot water supply lines.

   The fixture unit value for fixtures having both cold and hot water connections are taken as three-quarters (3/4) of the listed total value of the fixture. If both hot and cold branches supply a fixture (which, except for urinals, water closets, dishwashers and hose bibbs, is nearly always the case), then the WSFU for the fixture is reduced by a factor of 0.75.

   From Table 610.3 (Private)

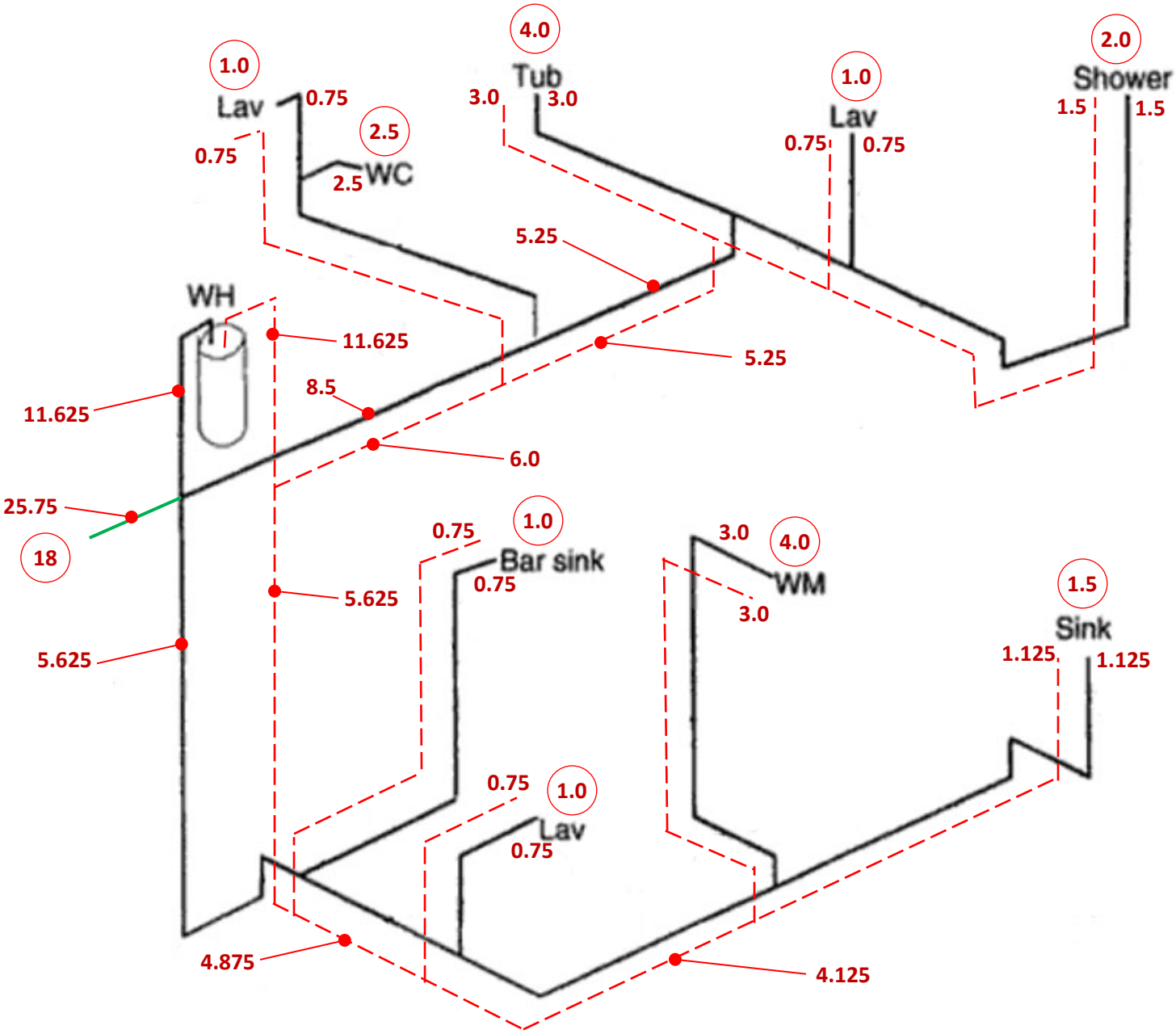
	Water Supply Fixture Unit Load (WSFU)		
Fixture Type	Hot Water	Cold Water	Combined Total
Bathtub or combination Bath/Shower (fill)	3.0	3.0	4.0
Lavatory	0.75	0.75	1.0
Shower	1.5	1.5	2.0
Kitchen Sink	1.125	1.125	1.5

   If the water in a branch will be:
   Only hot, use the Hot value (0.75 x Combined value)
   Only cold, use the Cold value (0.75 x Combined value)
   Both hot and cold, use the Combined column

2. Calculate the length of pipe you need and multiply by 1.5 to allow for pressure loss through the fittings.

3. Use Table 610.4 for the pressure range determined for the project and select the column that's the same as or greater than the DL. Find the WSFU that is the same as or greater than the WSFU. Look to the left to the second column and locate the pipe size you need for that branch line.

   Repeat these calculations for each branch line from the distribution pipe to each one of the water branches you plan to install in the residence.



Water Supply Fixture Units							
Fixture	# of Fix.	HOT WSFU		COLD WSFU		TOTAL WSFU	
		EACH	THIS JOB	EACH	THIS JOB	EACH	THIS JOB
SHW	1	1.5	1.5	1.5	1.5	2.0	2.0
LAV	3	0.75	2.25	0.75	2.25	1.0	3.0
BT	1	3.0	3.0	3.0	3.0	4.0	4.0
WC FT	1	------	------	2.5	2.5	2.5	2.5
BS	1	0.75	0.75	0.75	0.75	1.0	1.0
CW	1	3.0	3.0	3.0	3.0	4.0	4.0
KS	1	1.125	1.125	1.125	1.125	1.5	1.5
TOTALS			11.625		14.125		18.0

TOTAL GPM **13 GPM**

Design Assumptions:

Step 1: The design water supply pressure is between 40 and 49 psi.

Step 2: The developed length (DL) of the water pipe from the water meter to the furthest plumbing fixture is 84 feet.

METER AND STREET SERVICE (inches)	BUILDING SUPPLY AND BRANCHES (inches)	MAXIMUM ALLOWABLE LENGTH (feet)														
		40	60	80	100	150	200	250	300	400	500	600	700	800	900	1000
PRESSURE RANGE – 46 to 60 psi[1]																
¾	½[2]	7	7	6	5	4	3	2	2	1	1	1	0	0	0	0
¾	¾	20	20	19	17	14	11	9	8	6	5	4	4	3	3	3
¾	1	39	39	36	33	28	23	21	19	17	14	12	10	9	8	8
1	1	39	39	39	36	30	25	23	20	18	15	12	10	9	8	8
¾	1¼	39	39	39	39	39	39	34	32	27	25	22	19	19	17	16
1	1¼	78	78	76	67	52	44	39	36	30	27	24	20	19	17	16
1½	1¼	78	78	78	78	66	52	44	39	33	29	24	20	19	17	16
1	1½	85	85	85	85	85	85	80	67	55	49	41	37	34	32	30
1½	1½	151	151	151	151	128	105	90	78	62	52	42	38	35	32	30
2	1½	151	151	151	151	150	117	98	84	67	55	42	38	35	32	30
1	2	85	85	85	85	85	85	85	85	85	85	85	85	85	83	80
1½	2	370	370	340	318	272	240	220	198	170	150	135	123	110	102	94
2	2	370	370	370	370	368	318	280	250	205	165	142	123	110	102	94
2	2½	654	640	610	580	535	500	470	440	400	365	335	315	285	267	250