J∆S Engineering Suite

Module Guide: Plumbing Calculations

Version 1.2 — April 2026
JS Engineering Solutions

Software Version: J∆S Engineering Suite v1.2 **Guide Number:** 07 **Last Updated:** February 2026 **Applicable Codes:** IPC 2021, UPC 2022, CPC 2022, IFGC 2021, NFPA 54, ASHRAE 90.1-2022

Table of Contents

1. Overview

The J∆S Engineering Suite provides a complete plumbing engineering design toolkit spanning eleven dedicated modules. Together these modules cover every calculation a plumbing engineer performs on a commercial or institutional project: fixture counts, water supply sizing, sanitary drainage, vent design, hot water systems, gas piping, storm drainage, backflow prevention, grease interceptors, waste pipe inversions, and water pressure analysis.

All calculations are performed in IP (Imperial) units -- GPM, feet, inches, PSI, MBH -- and comply with the International Plumbing Code (IPC) 2021, Uniform Plumbing Code (UPC) 2022, California Plumbing Code (CPC) 2022, and the

International Fuel Gas Code (IFGC) 2021.

1.1 Scope

This guide walks through a complete plumbing design for a **100,000 SF, 4-story office building** (25,000 SF per floor) located in San Diego, California. The same project is referenced in the companion HVAC guides so that mechanical engineers can see how plumbing and HVAC systems interact within a single project file.

1.2 Applicable Codes and Standards

Code / Standard	Edition	Application
International Plumbing Code (IPC)	2021	Fixture counts, pipe sizing, drainage, venting
Uniform Plumbing Code (UPC)	2022	Fixture counts, pipe sizing, drainage, venting
California Plumbing Code (CPC)	2022	State amendments to UPC (California projects)
California Building Code (CBC)	2022	Occupancy classification, occupant load
International Fuel Gas Code (IFGC)	2021	Natural gas piping (non-California)
NFPA 54	2021	National Fuel Gas Code
ASME A112 series	Current	Plumbing fixture standards
ASSE 1000 series	Current	Backflow prevention, safety devices
ASHRAE 90.1	2022	Pipe insulation requirements
ASHRAE HVAC Applications	Ch. 51	Service water heating design
SMACNA	Current	Seismic bracing for piping
PDI G101	Current	Grease interceptor sizing
ASCE 7-22	Current	Rainfall intensity maps

1.3 Design Philosophy

The J∆S Engineering Suite follows the standard professional workflow:

1. Determine occupant load from building area and occupancy type.
2. Calculate minimum fixture counts per code.
3. Assign Water Supply Fixture Units (WSFU) and Drainage Fixture Units (DFU).
4. Convert WSFU to flow rate (GPM) using Hunter's Curve.
5. Size supply piping based on velocity limits and available pressure.
6. Size drainage piping based on DFU capacity tables.
7. Size vents per code tables and developed length.
8. Design hot water system with storage, recovery, and recirculation.
9. Design storm drainage from rainfall intensity and roof area.

10. Size natural gas piping from total appliance demand.
11. Verify backflow prevention, grease interception, and waste pipe inversions.

All calculations are performed in IP (Imperial) units: GPM, feet, inches, PSI, MBH.

2. Plumbing Module Map

The J∆S Engineering Suite contains the following plumbing-related modules, accessible from the left sidebar under the **PLUMBING TOOLS** category and related sections.

2.1 Primary Plumbing Modules

Module Name	Source File	Sidebar Location	Description
Fixture Calculator	`plumbing_calcs_app.py`	Plumbing Tools	WSFU/DFU per IPC/UPC, Hunter's curve, drain sizing, gas piping, storm drainage, water pressure -- all in 8 tabs
Water Pressure Calc	`water_pressure_app.py`	Plumbing Tools	IPC Chapter 6 / UPC domestic water pressure analysis and pipe sizing
Gas Pipe Sizer	`gas_pipe_app.py`	Plumbing Tools	IFGC/NFPA 54 gas pipe sizing with Spitzglass/Weymouth formulas
Hot Water Sizing	`hot_water_app.py`	Plumbing Tools	ASHRAE storage + recovery method with manufacturer equipment data
Domestic Hot Water	`domestic_hot_water_app.py`	Plumbing Tools	ASHRAE Ch.51, UPC/IPC fixture unit method, recirculation design, ASSE 1017
Storm Drainage	`storm_drainage_app.py`	Plumbing	IPC/UPC Chapter 11 storm drainage design with Manning's equation
Waste Pipe Invert	`waste_invert_app.py`	Plumbing Tools	Invert elevation calculations for gravity drainage

2.2 Supporting Modules

Module Name	Source File	Sidebar Location	Description
Pipe Sizer	`pipe_sizer_app.py`	Core Calculations	Hazen-Williams and Darcy-Weisbach pipe sizing for all fluid systems
Pipe Network	`pipe_network_app.py`	Specialty Engineering	Hydronic pipe network analysis with Darcy-Weisbach, ASHRAE Ch. 22

Module Name	Source File	Sidebar Location	Description
Grease Interceptor	`grease_interceptor_app.py`	Plant / System Tools	PDI G101, UPC, IPC sizing methods with manufacturer data
IPC/CPC Plumbing	Code Reference module	References & Standards	Plumbing code lookup and cross-reference tool

2.3 Launching Any Plumbing Module

1. Open the J∆S Engineering Suite: run `python launcher.py`.
2. Log in and navigate to the Dashboard.
3. In the left sidebar, expand the appropriate category (usually **Plumbing Tools** or **Plumbing**).
4. Click the module name.
5. The module opens in a new window with tabbed sub-panels.
6. Load an existing project (`.mep` file) or create a new one. Building geometry and occupancy data carry over from the HVAC model automatically when using a shared project file.

3. Fixture Unit Method

3.1 Theory and Background

The fixture unit method is the universal approach for sizing plumbing systems in commercial buildings. It was originally developed by Dr. Roy B. Hunter at the National Bureau of Standards in the 1940s and is codified in IPC Chapter 6, UPC Chapter 6, and CPC Chapter 6.

The method assigns numerical values -- Water Supply Fixture Units (WSFU) for supply sizing and Drainage Fixture Units (DFU) for drain sizing -- to each plumbing fixture. These values represent the probable hydraulic demand considering the intermittent nature of fixture use. The fixture unit totals are then converted to flow rates using probability-based curves (Hunter's Curve).

3.2 Occupant Load Calculation

The minimum number of plumbing fixtures is driven by the building occupant load. For an office (Business occupancy, Group B per IBC/CBC), the occupant load factor is **100 SF per occupant** (gross area).

Floor	Area (SF)	Occupant Load Factor	Occupants
1	25,000	100 SF/person	250
2	25,000	100 SF/person	250
3	25,000	100 SF/person	250
4	25,000	100 SF/person	250
Total	**100,000**		**1,000**

3.3 Minimum Fixture Counts per Code

For Business (Group B) occupancy, IPC Table 403.1 / CBC Table 422.1 requires the following minimum fixtures. Assuming a 50/50 male-to-female ratio (500 males, 500 females building-wide; 125 of each per floor):

Per-Floor Fixture Requirements (25,000 SF, 250 occupants):

Fixture Type	Male	Female	Total/Floor	Basis
Water Closets (WC)	2	4	6	1 per 25 male, 1 per 15 female
Urinals	4	--	4	May substitute for up to 67% of male WC; provided as supplemental
Lavatories	3	3	6	1 per 40 occupants
Kitchen/Break Room Sinks	1	1	2	1 per 100 occupants (service)
Drinking Fountains	1	--	1	1 per 100 occupants (hi-lo pair counts as 1)
Service Sinks	1	--	1	1 per floor minimum (janitor)
Floor Total			**20**	

Building Total (4 Floors):

Fixture Type	Per Floor	x 4 Floors	Building Total
Water Closets	6	x 4	24
Urinals	4	x 4	16
Lavatories	6	x 4	24
Sinks	2	x 4	8
Drinking Fountains	1	x 4	4
Service Sinks	1	x 4	4
Grand Total	**20**		**80**

3.4 WSFU Table -- IPC Table 604.3

Water Supply Fixture Units quantify the probable simultaneous demand from each fixture type. The J∆S Engineering Suite contains the complete IPC Table 604.3 data set, reproduced here for reference:

Fixture	WSFU (Cold)	WSFU (Hot)	WSFU (Total)
Water Closet (Tank)	2.5	0.0	2.5
Water Closet (Flushometer)	5.0	0.0	5.0
Urinal (Flushometer)	5.0	0.0	5.0

Fixture	WSFU (Cold)	WSFU (Hot)	WSFU (Total)
Urinal (Tank)	3.0	0.0	3.0
Lavatory (Public)	1.5	1.5	2.0
Lavatory (Private)	0.5	0.5	1.0
Bathtub (w/ Shower)	1.0	1.0	1.5
Shower (Public)	3.0	3.0	4.0
Shower (Private)	1.0	1.0	1.5
Kitchen Sink (Residential)	1.0	1.0	1.5
Kitchen Sink (Commercial)	3.0	3.0	4.0
Service Sink	1.5	1.5	3.0
Mop Sink	1.5	1.5	3.0
Drinking Fountain	0.5	0.0	0.5
Hose Bibb	2.5	0.0	2.5
Dishwasher (Residential)	0.0	1.4	1.4
Dishwasher (Commercial)	0.0	5.0	5.0
Clothes Washer (Residential)	1.0	1.0	1.5
Clothes Washer (Commercial)	3.0	3.0	4.0
Floor Drain	0.0	0.0	0.0
Emergency Shower	5.0	0.0	5.0
Emergency Eyewash	2.5	0.0	2.5
Water Cooler	0.5	0.0	0.5
Lab Sink	1.0	1.0	2.0

UPC Table 610.3 (Alternate Values):

The UPC assigns slightly different values for some fixtures, notably higher values for flush-valve water closets (10 WSFU) and flush-valve urinals (5 WSFU). The J∆S Engineering Suite allows the user to select IPC or UPC as the governing code, and the WSFU table updates accordingly.

Fixture	UPC WSFU (Total)	IPC WSFU (Total)	Difference
Water Closet (Flush Valve)	10	5	UPC is more conservative
Urinal (Flush Valve)	5	5	Same
Lavatory (Public)	2	2	Same
Kitchen Sink (Commercial)	4	4	Same

3.5 DFU Table -- IPC Table 709.1

Drainage Fixture Units quantify the probable discharge from each fixture and determine drain pipe sizing. The complete table as implemented in the software:

Fixture	DFU	Trap Size (in)
Water Closet (Tank)	3.0	3.0
Water Closet (Flushometer)	4.0	3.0
Urinal (Flushometer)	4.0	2.0
Urinal (Tank)	2.0	2.0
Lavatory (Public)	1.0	1.25
Lavatory (Private)	1.0	1.25
Bathtub (w/ Shower)	2.0	1.5
Shower (Public)	2.0	2.0
Shower (Private)	2.0	2.0
Kitchen Sink (Residential)	2.0	1.5
Kitchen Sink (Commercial)	3.0	2.0
Service Sink	3.0	2.0
Mop Sink	3.0	3.0
Drinking Fountain	0.5	1.25
Dishwasher (Residential)	2.0	1.5
Dishwasher (Commercial)	4.0	2.0
Clothes Washer (Residential)	2.0	2.0
Clothes Washer (Commercial)	3.0	2.0
Floor Drain	2.0	2.0
Emergency Shower	2.0	2.0
Emergency Eyewash	1.0	1.25
Water Cooler	0.5	1.25
Lab Sink	2.0	1.5

3.6 Entering Fixtures in the Fixture Calculator

In the **Fixtures** tab of the Fixture Calculator module, the software pre-populates fixture counts when you select an occupancy type and enter the floor area. You can override any value to match the architect's fixture schedule. Each fixture row includes:

- **Fixture Type** -- Drop-down menu containing all fixture types listed in the WSFU and DFU tables above
- **Quantity** -- Integer spinner for the number of fixtures
- **Flush/Flow Type** -- Selection between flush valve and flush tank (for water closets and urinals)

- **WSFU Cold** -- Auto-filled per the selected code table
- **WSFU Hot** -- Auto-filled per the selected code table
- **WSFU Total** -- Auto-filled per the selected code table
- **DFU** -- Auto-filled per the selected code table
- **Trap Size (in)** -- Auto-filled per the selected code table
- **Hot Water Demand (GPM)** -- For DHW calculations

The software flags any floor where the fixture count falls below code minimums with a red warning banner.

3.7 Floor-by-Floor WSFU Calculation -- Worked Example

Floor 1 (typical of all floors, using IPC values with flushometer WC/urinals):

Fixture	Qty	WSFU Each	Floor WSFU
Water Closets (flushometer)	6	5.0	30.0
Urinals (flushometer)	4	5.0	20.0
Lavatories (public)	6	2.0	12.0
Kitchen/Break Sinks (commercial)	2	4.0	8.0
Drinking Fountain	1	0.5	0.5
Service Sink	1	3.0	3.0
Floor 1 Total	**20**		**73.5**

Since all four floors are identical:

Level	WSFU
Floor 1	73.5
Floor 2	73.5
Floor 3	73.5
Floor 4	73.5
Building Total	**294.0**

3.8 Floor-by-Floor DFU Calculation -- Worked Example

Floor 1 (typical):

Fixture	Qty	DFU Each	Floor DFU
Water Closets (flushometer)	6	4.0	24.0
Urinals (flushometer)	4	4.0	16.0

Fixture	Qty	DFU Each	Floor DFU
Lavatories	6	1.0	6.0
Sinks (commercial)	2	3.0	6.0
Drinking Fountain	1	0.5	0.5
Service Sink	1	3.0	3.0
Floor 1 Total	**20**		**55.5**

Building Summary:

Level	DFU
Floor 1	55.5
Floor 2	55.5
Floor 3	55.5
Floor 4	55.5
Building Total	**222.0**

4. Water Supply Pipe Sizing

4.1 Hunter's Curve Conversion: WSFU to GPM

Hunter's Curve (IPC Table E103.3(2) / UPC Appendix A) converts the total WSFU to a peak probable demand in GPM. The curve accounts for the statistical improbability that all fixtures operate simultaneously.

The J∆S Engineering Suite contains the following Hunter's Curve data points (embedded in `plumbing_calcs_app.py`):

WSFU	GPM	WSFU	GPM
0	0.0	300	52.0
1	1.0	400	60.0
2	3.0	500	67.0
5	5.0	600	73.0
8	6.5	700	79.0
10	8.0	800	84.0
15	10.0	900	89.0
20	12.0	1,000	94.0
25	14.0	1,200	103.0
30	15.5	1,500	115.0

WSFU	GPM	WSFU	GPM
40	18.0	2,000	133.0
50	20.5	2,500	149.0
60	22.5	3,000	163.0
80	27.0	4,000	189.0
100	30.0	5,000	212.0
120	33.0	6,000	233.0
140	35.5	8,000	270.0
160	38.0	10,000	304.0
180	40.0		
200	42.0		
250	47.5		

Worked Example:

- Floor 1: 73.5 WSFU -- interpolating between 60 (22.5 GPM) and 80 (27.0 GPM):
- 22.5 + (73.5 - 60)/(80 - 60) x (27.0 - 22.5) = 22.5 + 3.04 = **~25.5 GPM per floor**
- Building Total: 294 WSFU -- interpolating between 250 (47.5 GPM) and 300 (52.0 GPM):
- 47.5 + (294 - 250)/(300 - 250) x (52.0 - 47.5) = 47.5 + 3.96 = **~51.5 GPM**
- Apply diversity factor for 4-story riser: use **~55 GPM** design flow

The J∆S Engineering Suite performs this interpolation automatically and displays the result in the **Water Supply** tab under "Peak Demand (GPM)."

4.2 Hazen-Williams Equation

For water supply pipe sizing, the software uses the Hazen-Williams equation for friction loss, which is the standard method in the plumbing industry:

```
h_f = (4.52 x Q^1.85) / (C^1.85 x d^4.87)

Where:
h_f = friction head loss (ft per ft of pipe)
Q = flow rate (GPM)
C = Hazen-Williams C-factor (pipe material roughness)
d = internal pipe diameter (inches)
```

Hazen-Williams C-Factors (from pipe_sizer_app.py):

Pipe Material	C-Factor
Copper (new)	140-150
Type L Copper	150
Type K Copper	150

Pipe Material	C-Factor
CPVC (SDR 11)	150
PEX	150
Galvanized Steel (new)	120
Steel (new)	130
Steel (10-year)	110
Steel (20-year)	90
Stainless Steel	140-150
Ductile Iron	130-140
Cast Iron	100
PVC	150
HDPE	150

4.3 Velocity Limits

Pipe sizing is governed by two constraints:

1. **Maximum velocity:** 8 fps for copper and plastic supply piping (ASME B31.9 / UPC/IPC recommendation to limit water hammer and erosion). For steel pipe, 10 fps is sometimes acceptable.
2. **Pressure drop:** Total friction loss + static head + fixture residual pressure must not exceed available street pressure.

Velocity-based sizing formula:

```
Q = A x V
GPM = (pi/4 x D^2 / 144) x V x 7.48 x 60

Where:
Q = flow rate (GPM)
D = internal pipe diameter (inches)
V = velocity (fps)
```

Pipe capacity at 8 fps (Type L Copper):

Nominal Size	ID (in)	Capacity at 8 fps (GPM)	Max WSFU (Flush Valve)	Max WSFU (Flush Tank)
3/8"	0.430	3.6	1	1
1/2"	0.545	5.8	3	5
3/4"	0.785	12.1	8	15
1"	1.025	20.7	20	40
1-1/4"	1.265	31.5	40	85
1-1/2"	1.505	44.6	70	150
2"	1.985	77.6	150	350

Nominal Size	ID (in)	Capacity at 8 fps (GPM)	Max WSFU (Flush Valve)	Max WSFU (Flush Tank)
2-1/2"	2.465	119.6	280	600
3"	2.945	170.8	500	1,000
4"	3.905	300.2	1,000	2,000
5"	4.875	468.0	1,800	3,600
6"	5.845	672.6	2,800	5,600

4.4 Minimum Pressure at Fixtures

IPC Table 604.3 and the Water Pressure Calculator module enforce minimum residual pressures:

Fixture Type	Minimum Pressure (psi)
Flush valve (WC or urinal)	15
Flush tank (WC or urinal)	8
All other fixtures (lavatory, sink, shower, etc.)	8
Drinking fountain	8
Bathtub	8
Emergency shower	8
Ice maker	8
Lab sink	8
Dental chair	8

4.5 Sizing Results for the Example Project

- **Building main (55 GPM, 294 WSFU):** 2" copper provides capacity for 150 WSFU (flush valve) -- sufficient. Select **2" Type L copper** for the building main.
- **Floor risers (~25.5 GPM per floor, 73.5 WSFU):** 1-1/2" copper provides capacity for 70 WSFU -- adequate. Select **1-1/2" Type L copper** for risers.
- **Branch lines to restroom groups (~15 GPM):** 1-1/4" copper (31.5 GPM capacity).
- **Individual fixture connections:** 1/2" to 3/4" per fixture manufacturer requirements.

4.6 Pipe Materials Supported

The Water Pressure Calculator and Pipe Sizer modules support the following pipe materials:

Material	C-Factor	Available Sizes
Type L Copper	150	1/2" through 6"
Type K Copper	150	1/2" through 6"

Material	C-Factor	Available Sizes
CPVC (SDR 11)	150	1/2" through 4"
PEX	150	3/8" through 2"
Galvanized Steel	120	1/2" through 6"
Ductile Iron	140	2" through 12"
Stainless Steel	150	1/2" through 4"

5. Drainage Pipe Sizing

5.1 Drainage Capacity Tables

The Fixture Calculator module sizes drainage piping based on DFU capacity tables per IPC Table 710.1 / UPC Table 702.1. Horizontal drain sizing considers both the total DFU load and the pipe slope:

Pipe Size (in)	Max DFU at 1/8"/ft Slope	Max DFU at 1/4"/ft Slope
1-1/4"	0	1
1-1/2"	1	1
2"	8	10
3"	35	42
4"	216	250
5"	428	500
6"	720	840
8"	1,920	2,240
10"	3,500	4,200
12"	5,600	6,700

Drain pipe inside diameters (for Manning's calculations):

Nominal Size	ID (in)
1-1/4"	1.38
1-1/2"	1.61
2"	2.07
3"	3.07
4"	4.03
5"	5.05

Nominal Size	ID (in)
6"	6.07
8"	7.98
10"	10.02
12"	11.94

5.2 Horizontal vs. Vertical Drain Sizing

Horizontal drains (building drains, branch drains) are sized from the tables above, using the DFU count and the desired slope. Steeper slopes carry more DFU because water velocity is higher.

Vertical stacks (soil and waste stacks) have different capacities than horizontal drains. Per IPC Table 710.1(1):

Stack Size	Max DFU Total (3+ stories)	Max DFU per Branch Interval
2"	16	6
3"	48	20
4"	240	90
5"	540	200
6"	960	350
8"	2,200	600
10"	3,800	1,000
12"	5,600	1,500

5.3 Building Drain Sizing -- Worked Example

For this project (222 DFU):

- At 1/8"/ft slope: 4" pipe handles 216 DFU (insufficient by 6 DFU). Select **5" building drain** (428 DFU capacity).
- At 1/4"/ft slope: 4" pipe handles 250 DFU (adequate with 28 DFU margin). A **4" building drain at 1/4"/ft slope** is acceptable.

The J∆S Engineering Suite defaults to 1/8"/ft slope (conservative) and selects the next size up when the DFU count is within 10% of the pipe capacity limit. For this project, the software recommends: **4" building drain at 1/4"/ft slope** or **5" building drain at 1/8"/ft slope**.

5.4 Sanitary Stack Sizing -- Worked Example

Each restroom group connects to a vertical soil/waste stack:

- Per-floor branch: 55.5 DFU -- 3" is insufficient (max 20 per branch interval). Select **4" stacks** (90 DFU per branch, 240 total).
- Total on one stack (if all 4 floors connect): 222 DFU. A single 4" stack handles 240 DFU -- adequate.

• Typical design: provide **two 4" stacks** (one for each restroom core) for redundancy and to keep branch distances manageable.

5.5 Building Sewer Sizing

The building sewer (pipe from the building to the municipal sewer main) is typically one size larger than the building drain to account for roots, settlement, and future growth:

Building Drain Size	Recommended Building Sewer Size
4"	5" or 6"
5"	6"
6"	6" or 8"
8"	8" or 10"

For this project with a 4" or 5" building drain, the building sewer should be **6" minimum**.

5.6 Manning's Equation for Drainage Flow

The software also uses Manning's equation to verify gravity drainage capacity:

```
Q = (1.486 / n) x A x R^(2/3) x S^(1/2)

Where:
Q = flow rate (CFS)
n = Manning's roughness coefficient
A = cross-sectional flow area (ft^2)
R = hydraulic radius = A/P (ft)
S = slope (ft/ft)
```

Manning's n values:

Pipe Material	Manning's n
PVC / ABS	0.009
Cast Iron (coated)	0.012
Cast Iron (uncoated)	0.013
Concrete	0.013
Clay (vitrified)	0.013
Ductile Iron	0.012
Copper DWV	0.011
Steel	0.015

6. Vent Sizing

6.1 Purpose of Venting

Every trap in a plumbing system must be vented to:

- Prevent siphonage (loss of trap seal when water flows past)
- Prevent back-pressure (positive pressure pushing sewer gas through the trap)
- Allow air to enter the drainage system so water flows freely by gravity

6.2 Types of Vents

Vent Type	Description	Typical Application
Individual vent	Single vent serving one fixture trap	Isolated fixtures
Common vent	Single vent serving two fixture traps at same level	Back-to-back fixtures
Branch vent	Vent connecting two or more individual vents	Groups of fixtures on same floor
Vent stack	Vertical vent extending through one or more stories	Multi-story buildings
Stack vent	Upper portion of a soil/waste stack above highest branch	Extension of stack through roof
Circuit vent	Single vent serving a group of fixtures on a horizontal branch	Battery of fixtures (restrooms)
Island vent (loop vent)	Special venting arrangement for island sinks	Kitchen islands
Air admittance valve (AAV)	Mechanical one-way valve allowing air in but not out	Where conventional venting is impractical
Combination waste and vent	Single pipe serving as both drain and vent	Limited applications per code

6.3 Vent Sizing Tables -- IPC Table 916.1 / UPC Table 703.2

Vent sizing depends on the connected DFU and the developed length (total length of the vent pipe from the trap to the vent termination):

Vent Size (in)	Max DFU (developed length < 40 ft)	Max DFU (developed length < 60 ft)	Max DFU (developed length < 100 ft)
1-1/4"	8	6	4
1-1/2"	24	18	12
2"	48	36	24
2-1/2"	96	72	48
3"	240	180	120
4"	500	390	256
5"	1,100	850	540
6"	1,900	1,500	960

6.4 Vent Sizing -- Worked Example

For the example project:

- **Individual fixture vents:** 1-1/2" for lavatories and sinks (1-3 DFU each); 2" for WC and urinal groups (4 DFU each)
- **Branch vents (per restroom group):** 55.5 DFU per floor on a branch vent with developed length < 60 ft -- 2-1/2" vent (72 DFU capacity)
- **Vent stack (combined all floors):** 222 DFU total on a 4-story vent stack with developed length ~60 ft -- 3" vent stack (180 DFU max at 60 ft) is marginal. Select **4" vent stack** (390 DFU capacity at 60 ft)
- **Vent termination:** Through the roof per IPC Section 903.1 / UPC Section 906, minimum 6" above roof surface and 10 feet from any air intake, operable window, or door

6.5 Circuit Venting

For battery installations (multiple fixtures in a row, such as a bank of water closets), circuit venting is an efficient alternative to individual venting:

- Per IPC Section 911: A circuit vent may serve up to 8 fixtures on a horizontal branch.
- The circuit vent connects downstream of the last fixture and upstream of the first fixture on the branch.
- The circuit vent pipe must be at least half the diameter of the horizontal branch, but not less than 1-1/2".
- A relief vent is required at the upstream end of the horizontal branch if it serves more than 4 water closets.

6.6 Vent Pipe Sizing Rules of Thumb

1. A vent pipe must be at least half the diameter of the drain it serves, but never less than 1-1/4".

2. A vent stack must be at least as large as the required individual vent for the highest connected branch.

3. The total developed length of vent piping affects the required diameter -- longer runs need larger vents.

4. Wet vents (pipes serving as both drain and vent) have specific sizing requirements per IPC Section 912.

7. Hot Water System Design

7.1 Overview

The J∆S Engineering Suite includes two dedicated hot water modules plus a DHW tab within the Plumbing Calculator:

Module	Focus	Key Methods
Hot Water Sizing (`hot_water_app.py`)	ASHRAE storage + recovery, manufacturer equipment selection, energy comparison	7 building type profiles, 5+ manufacturer databases
Domestic Hot Water (`domestic_hot_water_app.py`)	System design, pipe sizing, recirculation, ASSE 1017 mixing valves, Legionella compliance	ASHRAE 188, equipment selection, compliance export

Module	Focus	Key Methods
Plumbing Calculator DHW tab	Quick DHW demand within the main plumbing module	Fixture-based demand only

7.2 Hot Water Demand by Fixture Type

The software contains fixture hot water demands per ASHRAE HVAC Applications Chapter 51:

Fixture	Flow (GPM)	Peak (GPH)	Daily (gal)	Temp (deg F)	UPC FU
Lavatory (Public)	0.5	2.0	2.0	105	1.5
Lavatory (Private)	0.5	2.0	4.0	105	0.5
Shower (Public)	2.0	30.0	20.0	110	3.0
Shower (Private)	2.0	20.0	20.0	110	1.0
Kitchen Sink (Residential)	1.5	10.0	10.0	120	1.0
Kitchen Sink (Commercial)	1.5	20.0	15.0	140	3.0
Bathtub	4.0	20.0	20.0	105	1.0
Dishwasher (Residential)	1.0	15.0	10.0	140	1.4
Dishwasher (Commercial)	2.5	50.0	150.0	180	5.0
Clothes Washer	2.0	20.0	25.0	120	1.5
Service Sink	1.5	15.0	10.0	140	3.0
Mop Sink	1.5	20.0	15.0	140	3.0
Prep Sink	1.5	15.0	12.0	120	2.0
Bar Sink	1.0	10.0	8.0	120	1.0
Whirlpool Tub	4.0	40.0	40.0	105	4.0

7.3 Building Type Demand Profiles (ASHRAE Ch. 51)

The Hot Water Sizing module provides pre-configured demand profiles for seven building types:

Building Type	Unit	GPD/Unit	Peak Hour Fraction	Storage Factor	Recovery Fraction
Office	persons	1.0	0.30	0.20	0.70
Hotel/Motel	rooms	30.0	0.35	0.60	0.70
Restaurant	meals	2.5	0.40	0.40	0.60
Hospital	beds	60.0	0.25	0.60	0.80
School	students	1.5	0.40	0.30	0.70

Building Type	Unit	GPD/Unit	Peak Hour Fraction	Storage Factor	Recovery Fraction
Gym/Fitness	persons	10.0	0.50	0.50	0.70
Residential	units	40.0	0.30	0.40	0.70

Each profile includes a 24-hour demand curve (hourly fractions) for detailed analysis.

7.4 ASHRAE Storage + Recovery Method

The ASHRAE method sizes the hot water system based on two components:

1. **Storage volume** -- Hot water stored in a tank to meet peak demand bursts.
2. **Recovery rate** -- The rate at which the water heater can reheat incoming cold water.

```
Storage Volume = Peak Hour Demand x Storage Factor
Recovery Rate = Peak Hour Demand x Recovery Fraction
Heater Output = Recovery Rate x 500 x Delta_T

Where:
500 = 8.33 lb/gal x 60 min/hr x 1 BTU/(lb-deg F)
Delta_T = Storage temp - Inlet temp (deg F)
```

7.5 Hot Water Demand Analysis -- Worked Example

For the 100,000 SF office (1,000 occupants):

Parameter	Value
Daily demand (1.0 GPD/person x 1,000)	1,000 gal/day
Peak hour demand (1,000 x 0.30)	300 gal/hr
Storage volume (300 x 0.20)	60 gallons (min)
Recovery rate (300 x 0.70)	210 gal/hr
Temperature rise (140 - 60 deg F for San Diego winter)	80 deg F
Heater output (210/60 x 500 x 80)	140,000 BTU/hr = 140 MBH

Select a **100-gallon storage tank** (provides safety margin) with a **150 MBH** water heater. Manufacturer options include:

- A.O. Smith BTH-150 (150 MBH, 95% efficiency)
- Bradford White eF120T-150 (150 MBH, 96% efficiency)
- Rheem GHE150-150N (150 MBH, 95% efficiency)
- Lochinvar AWN151 (155 MBH, 96% efficiency)

7.6 Recirculation System Design

A domestic hot water recirculation loop is required per IPC Section 607.2.1 / CPC Section 609.11 for buildings where the hot water source is more than 50 feet developed length from the farthest fixture.

Recirculation system sizing procedure:

1. Calculate total loop length (supply + return).
2. Estimate heat loss from piping at 15-30 BTU/hr per linear foot (insulated pipe).
3. Calculate required recirculation flow to offset heat losses:

```
Q_recirc = Total Heat Loss / (500 x Delta_T_loop)

Where:
Delta_T_loop = Temperature drop allowed in loop (typically 5-10 deg F)
```

For this project:

- Loop length: approximately 400 feet (supply + return through 4 floors)
- Design temperature drop in loop: 10 deg F (140 deg F supply, 130 deg F return)
- Heat loss from piping: estimated 15 BTU/hr per linear foot (insulated)
- Total heat loss: 400 ft x 15 BTU/hr/ft = 6,000 BTU/hr
- Required recirculation flow: 6,000 / (500 x 10) = 1.2 GPM
- Design flow with safety margin: **5 GPM**
- Estimated head loss: **15 ft** (friction through 400 ft of 3/4" copper + fittings)

Selected: Bronze-fitted inline circulator, 5 GPM at 15 ft head, 1/12 HP, with timer and aquastat for night/weekend setback.

7.7 Mixing Valves -- ASSE 1017

Central mixing valves (thermostatic mixing valves) temper stored hot water (typically 140 deg F for Legionella control) down to a safe delivery temperature (typically 120 deg F or less):

Application	Maximum Delivery Temperature	Standard
Public lavatories	110 deg F	ASSE 1070
Showers	120 deg F	ASSE 1016
Kitchen sinks	120 deg F	ASSE 1017
Service sinks	140 deg F	Direct from heater
Commercial dishwasher	180 deg F	Direct from booster heater

The Domestic Hot Water module sizes mixing valves based on the mixed flow rate and the hot/cold supply temperatures using the mixing valve equation:

```
T_mixed = (Q_hot x T_hot + Q_cold x T_cold) / (Q_hot + Q_cold)
```

7.8 Pipe Insulation Requirements

Per ASHRAE 90.1-2022 Table 6.8.3-1 and IPC/CPC requirements, all DHW piping must be insulated:

Pipe Size	Insulation Thickness (Fiberglass)	R-value
3/4" and smaller	1/2"	R-2.6
1" to 1-1/2"	1"	R-4.2

Pipe Size	Insulation Thickness (Fiberglass)	R-value
2" to 4"	1-1/2"	R-5.5
Over 4"	2"	R-7.4

Recirculation return piping requires the same insulation as supply piping. The J∆S Engineering Suite automatically specifies insulation thickness in the piping schedule output.

7.9 Legionella Prevention (ASHRAE 188)

The Domestic Hot Water module includes Legionella risk assessment per ASHRAE Guideline 12 and Standard 188:

- **Storage temperature:** Maintain at 140 deg F minimum.
- **Distribution temperature:** Maintain above 124 deg F at all points in the recirculation loop.
- **Dead legs:** Limit stagnant pipe sections to less than 3 times the pipe diameter in length.
- **Recirculation:** Maintain continuous flow during occupied hours.
- **Flush protocol:** Periodic thermal disinfection at 160 deg F for 30 minutes.

8. Gas Piping

8.1 Overview

The Gas Pipe Sizer module (`gas_pipe_app.py`) provides professional gas pipe sizing per the International Fuel Gas Code (IFGC), NFPA 54, and CPC Chapter 12.

Supported gas types:

- Natural Gas (specific gravity 0.60, heating value ~1,000 BTU/CF)
- Propane / LP Gas (specific gravity 1.52, heating value ~2,500 BTU/CF)

Supported pipe materials:

- Schedule 40 Black Steel (most common for commercial)
- CSST (Corrugated Stainless Steel Tubing)
- Copper (Type L or ACR)
- PE (Polyethylene, for underground exterior only)

8.2 Gas Load Inventory

All gas-fired appliances are listed with their input ratings in MBH (thousands of BTU per hour) and CFH (cubic feet per hour). For natural gas, the conversion is approximately: **1 MBH approximately equals 1 CFH** (since 1,000 BTU/CF).

Example gas load schedule:

Appliance	Location	Input Rating (MBH)	Input Rating (CFH)
Hot Water Boiler (heating)	Mechanical Room, Floor 1	384	384
DHW Water Heater	Mechanical Room, Floor 1	150	150
Break Room Range/Oven	Break Room, Floor 1	75	75
Total Connected Load		**609 MBH**	**609 CFH**

8.3 Longest Run Method

The IFGC/CPC provides pipe sizing tables based on the longest run from the gas meter to the farthest appliance. The "longest run" method sizes all pipe segments based on this single longest distance, which simplifies the calculation and provides built-in conservatism.

System parameters:

Parameter	Value
Service pressure (from utility)	2 psi (available at meter)
Appliance manifold pressure	14 in. WC (0.5 psi)
Allowable pressure drop	1.5 psi (2.0 - 0.5)
Longest run (meter to break room range, Floor 1)	150 ft
Specific gravity of natural gas	0.60
Pipe material	Schedule 40 black steel

IFGC / CPC Table 1216.2 (2 psi systems, 150 ft longest run):

Pipe Size (in)	Max CFH Capacity
1/2"	56
3/4"	121
1"	254
1-1/4"	510
1-1/2"	786
2"	1,590
2-1/2"	2,630
3"	4,370

8.4 Spitzglass Formula

For low-pressure gas systems (less than 1.5 psi), the software uses the Spitzglass formula:

```
Q = 3550 x K x sqrt((h x D^5) / (L x S_g x (1 + 3.6/D + 0.03 x D)))
```

```
Where:
Q = gas flow (CFH)
K = constant based on pipe schedule
h = pressure drop (in. WC)
D = internal pipe diameter (inches)
L = pipe length (feet)
S_g = gas specific gravity (0.60 for natural gas)
```

8.5 Weymouth Formula

For high-pressure gas systems (above 1.5 psi), the software uses the Weymouth formula:

```
Q = 18.062 x D^(8/3) x sqrt((P1^2 - P2^2) / (S_g x L))

Where:
Q = gas flow (CFH)
D = internal pipe diameter (inches)
P1 = upstream pressure (psia)
P2 = downstream pressure (psia)
S_g = specific gravity
L = pipe length (feet)
```

8.6 Pipe Sizing Results -- Worked Example

Segment	Load (CFH)	Longest Run (ft)	Pipe Size
Meter to mechanical room main	609	150	1-1/2" (786 CFH capacity)
Branch to boiler	384	50	1-1/4" (510 CFH)
Branch to DHW heater	150	40	1" (254 CFH)
Branch to break room range	75	150	3/4" (121 CFH)

8.7 Gas Meter Sizing

The gas utility sizes and provides the meter, but the engineer must specify the required capacity on the utility application. For 609 CFH at 2 psi service pressure, a standard **AL-425 diaphragm meter** (capacity 425 CFH) may be insufficient. Specify a **rotary meter rated for 800+ CFH** or request the utility to verify meter sizing.

8.8 BTU Demand Calculations for Common Equipment

Equipment	Typical Input Range (MBH)	Notes
Residential furnace	40-120	80% to 98% AFUE
Commercial rooftop unit	50-400	Gas heat section
Boiler (condensing)	100-2,000	95-98% thermal efficiency
Boiler (non-condensing)	100-6,000	80-85% thermal efficiency
Water heater (storage)	30-750	Tank type

Equipment	Typical Input Range (MBH)	Notes
Water heater (tankless)	100-400	On-demand
Commercial range	30-90	Per burner section
Commercial oven	25-75	Convection or deck
Deep fryer	80-150	Per vat
Steam kettle	50-200	Tilting or stationary
Clothes dryer (commercial)	30-75	Per unit
Unit heater	30-350	Gas-fired
Infrared heater	30-200	High or low intensity
Pool heater	100-500	Depending on pool volume
Generator	50-2,000+	Varies by kW rating

8.9 Gas Piping Notes

- All gas piping to be Schedule 40 black steel with threaded or welded joints per IFGC/CPC.
- A manual gas shutoff valve is required at each appliance and at the building entrance (CPC Section 1212.4 / IFGC Section 409.5).
- Gas piping in concealed spaces must be protected from physical damage and tested at 1.5 times working pressure before concealment.
- An earthquake shutoff valve is required at the meter for California projects (CPC Section 1210.1.1).
- Provide a gas pressure regulator at each appliance if the service pressure exceeds the appliance inlet pressure rating.
- CSST must be bonded to the building grounding electrode system per IFGC Section 310.1.1 and manufacturer instructions.

9. Storm Drainage

9.1 Overview

The Storm Drainage module (`storm_drainage_app.py`) provides complete storm water drainage design per IPC Chapter 11 / UPC Chapter 11. The module includes four tabs:

1. **Rainfall & Location** -- IPC/UPC rainfall rates, return periods, city lookup
2. **Roof Drains & Vertical** -- Roof drain sizing, leaders, overflow
3. **Horizontal Piping** -- Manning's equation, pipe materials, slope options
4. **Results & Export** -- Pipe schedule, capacities, export to TXT/CSV

9.2 Design Rainfall Intensity

Storm drainage sizing begins with the local design rainfall intensity. The IPC uses a 60-minute duration, 100-year return period storm as the default design event.

Sample rainfall rates by US city:

City	Rainfall (in/hr)	City	Rainfall (in/hr)
Atlanta, GA	3.7	Miami, FL	4.0
Boston, MA	2.5	Minneapolis, MN	3.4
Chicago, IL	3.2	New York, NY	3.0
Dallas, TX	4.0	Phoenix, AZ	2.5
Denver, CO	2.8	Portland, OR	2.0
Houston, TX	4.5	Sacramento, CA	2.0
Los Angeles, CA	1.5	San Diego, CA	1.5
San Francisco, CA	2.5	Seattle, WA	2.0

The software includes NOAA Atlas 14 data for precise rainfall intensity at any US location.

9.3 Roof Drain Flow Calculation -- Rational Method

The total rainfall runoff from the roof is calculated using the rational method:

```
Q = C x I x A / 96.23

Where:
Q = flow rate (GPM)
C = runoff coefficient (1.0 for roofs)
I = rainfall intensity (in/hr)
A = roof area (SF)
96.23 = conversion constant (1 ft^2 x 1 in/hr = 1/96.23 GPM)
```

Worked Example (San Diego):

```
Q = 1.0 x 1.5 x 25,000 / 96.23
Q = 37,500 / 96.23
Q = 389.7 GPM
```

Design roof drainage flow: approximately 390 GPM

9.4 Roof Drain and Leader Sizing (IPC Table 1106.2 / UPC Table 1103.1)

Vertical leaders (roof drain downspouts) are sized from code tables based on GPM flow:

Leader Size (in)	Max GPM at 1 in/hr	Max GPM at 1.5 in/hr	Max GPM at 2 in/hr
2"	23	34	46
3"	58	87	116

Leader Size (in)	Max GPM at 1 in/hr	Max GPM at 1.5 in/hr	Max GPM at 2 in/hr
4"	120	180	240
5"	208	311	415
6"	359	538	717
8"	768	1,152	1,536

Sizing for this project (390 GPM at 1.5 in/hr):

- Using 4" leaders (180 GPM each): 390 / 180 = 2.17 -- minimum **3 roof drains with 4" leaders**
- Using 5" leaders (311 GPM each): 390 / 311 = 1.25 -- minimum **2 roof drains with 5" leaders**

Typical design: provide **4 roof drains with 4" leaders** (one per quadrant) for balanced drainage. Each drain handles approximately 98 GPM, well within the 180 GPM capacity.

9.5 Horizontal Storm Drain Sizing

The horizontal storm drain collecting all leaders is sized per code tables for horizontal pipe:

Pipe Size (in)	Max GPM at 1/8"/ft Slope	Max GPM at 1/4"/ft Slope	Max GPM at 1/2"/ft Slope
3"	50	72	102
4"	145	204	289
5"	260	368	520
6"	425	600	849
8"	930	1,315	1,860
10"	1,650	2,330	3,300
12"	2,700	3,810	5,400

For 390 GPM at 1/8"/ft slope: 6" pipe handles 425 GPM. Select **6" horizontal storm drain at 1/8"/ft slope**.

9.6 Overflow (Secondary) Drain Sizing

Per IPC Section 1107 / UPC Section 1101.11.1, a secondary (overflow) drainage system is required for roofs where ponding could cause structural failure. The overflow system must be sized for the full primary design rainfall rate, and the overflow drains are set 2 inches above the primary roof drain:

```
Q_overflow = C x I x A / 96.23
Q_overflow = 1.0 x 1.5 x 25,000 / 96.23 = 390 GPM
```

Provide **4 overflow drains with 4" leaders** (matching or exceeding primary drain capacity). Overflow drains discharge to grade via a visible location (exterior wall scupper or independent piping to daylight) to alert building occupants of primary system failure.

9.7 Controlled Flow (Detention) Systems

Where local jurisdictions require storm water detention to limit discharge rate, the Storm Drainage module can calculate detention volumes using the Modified Rational Method:

```
V_detention = (Q_inflow - Q_allowable) x t x 60 / 7.48

Where:
V_detention = detention volume (gallons)
Q_inflow = peak inflow (GPM)
Q_allowable = maximum permitted discharge rate (GPM)
t = storm duration (minutes)
```

10. Backflow Prevention

10.1 Overview

Backflow prevention protects the potable water supply from contamination due to backpressure or back-siphonage. The plumbing code requires specific types of backflow prevention based on the degree of hazard and the cross-connection type.

10.2 Types of Backflow Prevention Devices

Device	Abbreviation	Hazard Level	Testable	Typical Application
Reduced Pressure Backflow Assembly	RPBA (RP)	High	Yes	Fire sprinkler connections, boiler makeup, chemical feed, irrigation with fertilizer
Double Check Valve Assembly	DCVA (DC)	Moderate	Yes	HVAC cooling tower makeup, swimming pool fill, standard irrigation
Atmospheric Vacuum Breaker	AVB	Low	No	Hose bibbs, individual fixtures above flood rim
Pressure Vacuum Breaker	PVB	Low-Moderate	Yes	Irrigation systems, continuous pressure applications
Air Gap	AG	Any (highest protection)	N/A	Receptacle/vessel (e.g., roof tank fill, commercial dishwasher)
Spill-Resistant Vacuum Breaker	SVB	Low	No	Laboratory fixtures, dental units
Dual Check Valve	DuC	Low	No	Residential service connections in some jurisdictions

10.3 When Each Type is Required

High-hazard cross-connections (RPBA or Air Gap required):

- Fire sprinkler systems with chemical additives
- Boiler connections (chemical treatment in loop)
- Medical aspirator systems
- Chemical dispensing or industrial processes
- Irrigation with chemical injection (fertilizer, herbicide)
- Laboratory equipment with hazardous fluids
- Mortuary equipment

Moderate-hazard cross-connections (DCVA acceptable):

- Fire sprinkler systems (no chemical additives)
- HVAC cooling tower makeup water
- Swimming pool fill lines
- Standard landscape irrigation (no chemicals)
- Commercial laundry connections

Low-hazard cross-connections (AVB, PVB, or SVB acceptable):

- Hose bibbs (individual)
- Residential irrigation (no chemicals)
- Individual fixtures with below-rim supply (e.g., bathtub hand shower)

10.4 Sizing Backflow Preventers

Backflow preventers are sized based on the design flow rate (GPM) and the acceptable pressure loss. Typical pressure losses through backflow prevention devices:

Device	Pressure Loss at Design Flow
RPBA	10-15 psi
DCVA	3-8 psi
PVB	5-10 psi
AVB	1-3 psi
Air Gap	0 psi (but requires break tank and re-pump)

For the example project, the building main supply requires a DCVA (fire sprinkler system with no chemical additives) or RPBA (if local AHJ requires higher protection):

- Flow: 55 GPM
- Pressure loss through 2" DCVA: approximately 5 psi
- Pressure loss through 2" RPBA: approximately 12 psi

10.5 Installation Requirements

- All testable backflow prevention assemblies (RPBA, DCVA, PVB) must be accessible for annual testing.
- RPBAs must be installed with adequate drainage provisions because the relief valve can discharge water.
- Minimum clearance: 12" from floor to bottom of assembly, 12" between assemblies.
- RPBAs cannot be installed in pits or below grade in most jurisdictions.
- Thermal expansion protection is required downstream of backflow preventers per IPC Section 607.3.

11. Water Heater Sizing

11.1 Storage vs. Tankless Selection

The Hot Water Sizing module compares storage and tankless water heater options:

Parameter	Storage	Tankless	Heat Pump
Recovery rate	Moderate (30-90 gal/hr typical)	Unlimited (on-demand)	Low (60-80 gal/hr typical)
First hour rating	High (storage + recovery)	Equal to flow rate	Moderate
Standby loss	2-5% of stored energy	None	2-4%
Space requirement	Large (tank footprint)	Small (wall-mounted)	Medium
Energy efficiency	80-96% (gas), 90-95% (electric)	82-99% (gas), 99% (electric)	200-400% (COP 2-4)
Capital cost	Moderate	Moderate-High	High
Best application	High peak demand	Low-moderate steady demand	Moderate demand, low energy cost priority

11.2 Recovery Rate and First Hour Rating

Recovery rate is the amount of hot water a heater can produce in one hour when starting with a full tank at setpoint temperature:

```
Recovery Rate (GPH) = Heater Output (BTU/hr) / (500 x Delta_T / 60)
= Heater Output / (8.33 x Delta_T)
```

First Hour Rating (FHR) is the total hot water the system can deliver in the first hour, which equals storage volume plus one hour of recovery:

```
FHR = Storage Volume (gal) x 0.70 (usable fraction) + Recovery Rate (GPH)
```

For the example project:

- Storage: 100 gal x 0.70 = 70 gal usable
- Recovery: 150 MBH / (8.33 x 80) = 225 GPH
- **FHR = 70 + 225 = 295 GPH**

11.3 Manufacturer Equipment Data

The software includes manufacturer data for equipment selection:

Manufacturer	Product Lines	Types
A.O. Smith	Cyclone, BTH, BTC series	Gas storage, condensing
Bradford White	eF Series, Brute	Gas storage, condensing, electric
Rheem	GHE, Marathon, Triton	Gas, electric, tankless
Navien	NPE, NCB series	Tankless, combi boiler
Rinnai	RU, RL, RSC series	Tankless
Lochinvar	ARMOR, KNIGHT, Shield	Condensing storage, fire-tube

11.4 Energy Comparison

The Hot Water Sizing module provides annual energy cost comparison between gas, electric, and heat pump water heaters:

```
Annual Cost (Gas) = (Daily Demand x 365 x 8.33 x Delta_T) / (Efficiency x 100,000) x $/therm
Annual Cost (Electric) = (Daily Demand x 365 x 8.33 x Delta_T) / (Efficiency x 3,412) x $/kWh
Annual Cost (Heat Pump) = (Daily Demand x 365 x 8.33 x Delta_T) / (COP x 3,412) x $/kWh
```

11.5 Diversity Factors by Building Type

Building Type	Diversity Factor	Application
Residential	0.30	Peak overlaps are moderate
Office	0.30	Morning arrival + lunch peaks
Hotel	0.35	Morning shower peak
Restaurant	0.40	Meal service peaks
Hospital	0.25	Continuous demand, lower peaks
School	0.40	Morning + lunch peaks
Gym/Fitness	0.50	Post-workout shower peaks

12. Grease Interceptor Sizing

12.1 Overview

The Grease Interceptor module (`grease_interceptor_app.py`) sizes grease interceptors for commercial food service establishments using four code-approved methods:

1. **PDI G101** -- Plumbing & Drainage Institute method (most widely used)
2. **UPC method** -- Fixture unit based

3. **IPC method** -- Flow rate based
4. **Direct flow rate** -- Engineering judgment when fixture count is unknown

12.2 PDI G101 Method

The PDI G101 method calculates the required grease interceptor flow rate based on fixture drainage capacity and loading factors:

```
Required Flow Rate (GPM) = (Total Fixture Drainage Capacity) x Loading Factor x Occupant Factor

Where:
Fixture Drainage Capacity = sum of all fixture drains x 75% fill factor
Loading Factor = 1.0 (low), 1.5 (medium), 2.0 (high)
```

Fixture drainage capacities per PDI G101:

Fixture Type	Drainage Capacity (GPM)	Fixture Units
3-Compartment Sink	75.0	3
2-Compartment Sink	50.0	2
Single Compartment Sink	25.0	1
Pre-Rinse Spray	5.0	1
Pot Sink	50.0	2
Mop Sink	20.0	1
Floor Drain (kitchen)	20.0	1
Dishwasher (under counter)	15.0	1
Dishwasher (rack type)	25.0	1
Wok Range	30.0	1
Steam Table	10.0	1
Ice Cream Cabinet	10.0	1

Loading factors:

Loading	Factor	Description
Low	1.0	Cafeteria, no fryer
Medium	1.5	Short-order cooking
High	2.0	Full menu, fryers, wok

12.3 Interceptor Types

Type	Abbreviation	Flow Rate Range	Application
Under-Sink / Point-of-Use	POU	10-50 GPM	Individual fixtures

Type	Abbreviation	Flow Rate Range	Application
Hydromechanical (HGI)	HGI	10-200 GPM	Small to medium kitchens
Gravity Grease Interceptor (GGI)	GGI	20-500+ GPM	Large kitchens, multiple fixtures
In-Ground	IG	50-3,000+ GPM	High-volume facilities, central systems
Above-Ground Recovery Unit	AGRU	10-100 GPM	Space-constrained installations

12.4 Manufacturer Data

The module includes equipment data from five major manufacturers:

- **Schier** -- Great Basin series
- **Watts** -- Grease interceptors and separators
- **Zurn** -- GT series
- **Highland Tank** -- Steel grease interceptors
- **Thermaco** -- Big Dipper, Trapzilla series

13. Waste Pipe Invert Calculations

13.1 Overview

The Waste Pipe Invert module (`waste_invert_app.py`) calculates invert elevations for gravity drainage systems. Proper invert calculations ensure that drainage pipes maintain the required slope and connect correctly at manholes, cleanouts, and building transitions.

13.2 Invert Elevation Formula

```
Invert_downstream = Invert_upstream - (Length x Slope)

Where:
Invert = elevation of the inside bottom of the pipe (feet)
Length = horizontal run of the pipe (feet)
Slope = pipe slope (ft/ft), e.g., 1/8"/ft = 0.0104 ft/ft
```

13.3 Slope Conversions

Slope (in/ft)	Slope (ft/ft)	Slope (%)
1/16" per ft	0.0052	0.52%
1/8" per ft	0.0104	1.04%
1/4" per ft	0.0208	2.08%
1/2" per ft	0.0417	4.17%

Slope (in/ft)	Slope (ft/ft)	Slope (%)
1" per ft	0.0833	8.33%

13.4 Crown vs. Invert

- **Invert** = inside bottom of the pipe
- **Crown** = inside top of the pipe
- **Obvert** = outside top of the pipe (invert + pipe OD)

When pipes of different sizes connect at a manhole or junction, the crowns should be aligned (crown-matching) rather than inverting matching, to prevent surcharging of the smaller pipe.

13.5 Minimum Cover

Building sewers must maintain minimum cover (depth from finished grade to top of pipe) to prevent damage from surface loads:

Location	Minimum Cover
Under building slab	Per structural engineer
Under paved areas (light traffic)	12"
Under paved areas (heavy traffic)	18"
Under unpaved areas	12"
Under roadways	36" (varies by jurisdiction)
Subject to frost	Below frost depth

14. Water Pressure Analysis

14.1 Overview

The Water Pressure Calculator (`water_pressure_app.py`) performs a complete IPC Chapter 6 / UPC domestic water pressure analysis to determine whether the available street pressure is adequate to serve all fixtures, or whether a booster pump is needed.

14.2 Pressure Budget Method

The available pressure at the highest, most remote fixture is calculated by subtracting all losses from the available street pressure:

```
P_available = P_street - P_meter - P_backflow - P_static - P_friction - P_fittings

Where:
P_street = static pressure at the water main (psi)
```

```
P_meter = pressure loss through water meter (psi)
P_backflow = pressure loss through backflow preventer (psi)
P_static = static head loss due to elevation (psi) = H / 2.31
P_friction = friction loss in piping (psi)
P_fittings = additional loss for fittings (typically 50% of pipe friction)
```

14.3 Pressure Budget -- Worked Example

Item	Value	Units
Street pressure (given by utility)	60	psi
Minus: Water meter loss	-8	psi
Minus: Backflow preventer (DCVA) loss	-5	psi
Minus: Static head (4 stories x 14 ft = 56 ft / 2.31)	-24.2	psi
Minus: Friction loss in piping (est. 3 psi/100 ft x 200 ft EL)	-6	psi
Minus: Fitting losses (50% of friction)	-3	psi
Available at top-floor fixture	**13.8**	**psi**

The minimum residual pressure required for a flushometer valve is **15 psi** (IPC Table 604.3). Since 13.8 psi is below 15 psi, a **domestic water booster pump** is required.

14.4 Booster Pump Sizing

When available pressure is insufficient:

- **Flow:** Building peak demand (55 GPM)
- **Required discharge pressure:** Calculate to provide minimum residual at top fixture
- **Boost required:** (Required pressure at fixture + losses) - Available inlet pressure

For this project:

- Required at fixture: 15 psi
- Total losses above inlet: 24.2 + 6 + 3 = 33.2 psi
- Required pump discharge: 15 + 33.2 = 48.2 psi
- Available inlet (after meter + BFP): 60 - 8 - 5 = 47 psi
- Boost required: 48.2 - 47 = 1.2 psi minimum -- a marginal case. For safety margin, specify a booster pump with **20 psi minimum boost at 55 GPM**.

Select duplex variable-speed booster package rated **55 GPM at 50 ft TDH** (21.6 psi) with VFD for energy efficiency and constant pressure control.

14.5 Equivalent Length of Fittings

The Water Pressure Calculator includes a fittings library for equivalent length calculations:

Fitting	Equivalent Length (ft of pipe)
90-degree elbow (standard)	2.5 x pipe diameter
90-degree elbow (long radius)	1.5 x pipe diameter
45-degree elbow	1.2 x pipe diameter
Tee (straight through)	1.5 x pipe diameter
Tee (branch)	5.0 x pipe diameter
Gate valve (full open)	0.5 x pipe diameter
Globe valve (full open)	17 x pipe diameter
Ball valve (full open)	0.5 x pipe diameter
Check valve (swing)	6.0 x pipe diameter
Butterfly valve	2.0 x pipe diameter

15. Pipe Network Analysis

15.1 Overview

The Pipe Network module (`pipe_network_app.py`) provides detailed pipe network analysis for hydronic systems using the Darcy-Weisbach equation and Colebrook-White equation for friction factor determination. While primarily designed for HVAC hydronic systems, it is also applicable to domestic water distribution networks.

15.2 Darcy-Weisbach Equation

```
h_f = f x (L/D) x (V^2 / (2g))

Where:
h_f = friction head loss (ft)
f = Darcy friction factor (dimensionless)
L = pipe length (ft)
D = pipe internal diameter (ft)
V = flow velocity (fps)
g = acceleration due to gravity (32.174 ft/s^2)
```

15.3 Colebrook-White Equation

The Darcy friction factor is determined iteratively from the Colebrook-White equation:

```
1/sqrt(f) = -2.0 x log10((e/D)/3.7 + 2.51/(Re x sqrt(f)))

Where:
e = pipe absolute roughness (ft)
D = pipe internal diameter (ft)
Re = Reynolds number = V x D / kinematic_viscosity
```

15.4 Pipe Roughness Values

Material	Absolute Roughness (ft)
Copper	0.000005
Steel (new)	0.00015
Steel (10-year)	0.0004
Steel (20-year)	0.001
Stainless Steel	0.000015
PVC	0.000005
CPVC	0.000005
HDPE	0.000005
Ductile Iron	0.00085
Cast Iron	0.00085

15.5 Applications

- Multi-branch domestic water supply verification
- Hot water recirculation loop balancing
- Large building riser analysis
- Hydronic heating/cooling pipe sizing

16. Code Compliance -- IPC, CPC, UPC Differences

16.1 Overview of Plumbing Codes

Three primary plumbing codes are used in the United States:

Code	Full Name	Publisher	Adoption
IPC	International Plumbing Code	ICC	~35 states, federal buildings
UPC	Uniform Plumbing Code	IAPMO	~13 states (including CA, AZ, NV)
CPC	California Plumbing Code	CBSC	California (based on UPC with state amendments)

The J∆S Engineering Suite's IPC/CPC Plumbing reference module (accessible from **References & Standards > IPC/CPC Plumbing**) provides a searchable cross-reference between these codes.

16.2 Key Differences Between IPC and UPC

Topic	IPC 2021	UPC 2022
Fixture units (WC flush valve)	5 WSFU	10 WSFU
Hunter's curve source	IPC Appendix E	UPC Appendix A
Drainage sizing table	IPC Table 710.1	UPC Table 702.1
Vent sizing table	IPC Table 916.1	UPC Table 703.2
Circuit venting	Permitted (Section 911)	Permitted (Section 908)
Air admittance valves (AAV)	Permitted (Section 917)	Not permitted in most UPC jurisdictions
Combination waste and vent	Permitted (Section 910)	Permitted with restrictions
Wet venting	Extensive provisions (Section 912)	More limited
Gas piping reference	IFGC (separate code)	CPC Chapter 12 (integrated)
Maximum building drain slope	No upper limit specified	1/2"/ft maximum for 3" and larger

16.3 When Each Code Applies

Jurisdiction	Code
California	CPC 2022 (based on UPC + state amendments)
Arizona, Nevada, Oregon, Washington	UPC 2022
Most other states	IPC 2021
Federal buildings (GSA, DOD)	IPC 2021 (typically)
International (some countries)	IPC-based

16.4 Code Selection in the Software

When creating a new project, the Fixture Calculator module asks you to select the governing plumbing code. This selection affects:

- WSFU and DFU values used in calculations
- Hunter's Curve data source
- Drainage capacity tables
- Vent sizing tables
- Minimum fixture count requirements (IPC Table 403.1 vs. CPC/CBC Table 422.1)
- Gas piping reference (IFGC vs. CPC Chapter 12)

The default code is **IPC 2024**. Change to UPC or CPC in the module settings or in the Project Settings dialog.

17. Step-by-Step Walkthroughs for Each Module

17.1 Fixture Calculator (plumbing_calcs_app.py)

Tab 1: Fixture Units

1. In the **Code** dropdown, select "IPC 2021", "UPC 2022", or "CPC 2022".
2. In the **Flush Type** dropdown, select "Flush Valve" or "Flush Tank".
3. Enter the **Number of Floors**.
4. In the fixture table, set the **Quantity** for each fixture type present in the building.
5. The software auto-fills WSFU (Cold, Hot, Total) and DFU columns based on the selected code.
6. Review the **Summary** panel showing total WSFU (cold, hot, combined) and total DFU.
7. Red warning banners appear if fixture counts are below code minimums.

Tab 2: Water Supply

1. The total WSFU from Tab 1 is carried forward automatically.
2. The software performs Hunter's Curve interpolation to calculate **Peak GPM**.
3. Select the **Pipe Material** (Type L Copper, CPVC, PEX, etc.).
4. Set the **Maximum Velocity** (default 8 fps).
5. The software sizes the building main, risers, and branch lines.
6. Review the pipe schedule table with segment ID, WSFU, GPM, pipe size, velocity, and material.

Tab 3: Drainage

1. Total DFU from Tab 1 is carried forward.
2. Select the desired **Pipe Slope** (1/8"/ft or 1/4"/ft).
3. Select the **Drain Pipe Material** (cast iron, PVC, ABS, etc.).
4. The software sizes the building drain, branch drains, and soil/waste stacks.
5. Manning's equation verification is shown alongside the table method.
6. A separate section calculates vent pipe sizes based on connected DFU and developed length.

Tab 4: DHW (Domestic Hot Water)

1. Enter the building type and occupancy count.
2. Enter the **Inlet Water Temperature** and **Storage Temperature**.
3. The software calculates peak demand, storage volume, and recovery rate.
4. Basic water heater sizing is provided; for detailed DHW design, use the dedicated modules.

Tab 5: Gas Pipe

1. Add gas appliances with their input ratings in MBH or CFH.
2. Enter the **Longest Run** distance from meter to farthest appliance.
3. Select the **Gas Type** (natural gas or propane) and **Pipe Material** (Sch 40 steel, CSST, etc.).
4. Enter the **Service Pressure** and **Allowable Pressure Drop**.
5. The software sizes each segment and produces a gas piping schedule.

Tab 6: Storm Drainage

1. Enter the **Rainfall Intensity** (in/hr) or select a city for automatic lookup.

2. Enter the **Roof Area** (SF) and **Runoff Coefficient** (default 1.0 for roof).

3. The software calculates total runoff flow (GPM).

4. Enter the number and size of roof drains desired.

5. The software verifies capacity and sizes horizontal storm drains.

Tab 7: Water Pressure

1. Enter the **Street Pressure** (psi).

2. Enter the **Elevation Change** from meter to highest fixture (ft).

3. Enter the **Total Pipe Length** (ft) and select pipe material.

4. Enter losses for meter, backflow preventer, and PRV (if applicable).

5. The software calculates available pressure at the remote fixture.

6. If pressure is insufficient, a booster pump recommendation is generated.

Tab 8: Reports

1. Click **Generate Report** to compile all calculations.

2. Select export format: **PDF**, **Excel**, or **TXT**.

3. The report includes all pipe schedules, fixture schedules, and compliance summaries.

17.2 Water Pressure Calculator (water_pressure_app.py)

1. Launch from **Plumbing Tools > Water Pressure Calc**.

2. Fixture Schedule Tab: Add fixtures from the dropdown (bathtub, WC, lavatory, urinal, etc.) and enter quantities. Each fixture shows its WSFU and minimum required pressure.

3. Pipe Sizing Tab: Select pipe material from the dropdown (Type L Copper, CPVC, PEX, Galvanized Steel, Ductile Iron, Stainless Steel). The software calculates pipe size based on the total WSFU and velocity limit.

4. Pressure Analysis Tab: Enter street pressure, meter size, backflow preventer type, elevation change, and pipe routing details. The software computes the complete pressure budget from street to fixture.

5. Export: Save the analysis as PDF or Excel for inclusion in the plumbing submittal package.

17.3 Gas Pipe Sizer (gas_pipe_app.py)

1. Launch from **Plumbing Tools > Gas Pipe Sizer**.

2. Appliance Tab: Add appliances from the built-in library or enter custom equipment with BTU/hr input ratings.

3. System Parameters Tab: Set gas type (natural gas or propane), service pressure, allowable pressure drop, specific gravity, and pipe material.

4. Pipe Sizing Tab: Enter the layout as a series of segments with from/to labels, pipe length, and connected load. The software selects pipe sizes per the longest-run method and verifies with Spitzglass or Weymouth formulas.

5. Results Tab: Review the pipe sizing schedule. Export to PDF, TXT, or CSV.

17.4 Storm Drainage (storm_drainage_app.py)

1. Launch from **Plumbing > Storm Drainage**.

2. Rainfall & Location Tab: Select a US city from the dropdown for automatic rainfall intensity lookup, or enter custom values. Set the return period (10, 25, 50, or 100 year).

3. Roof Drains & Vertical Tab: Enter roof area, number of roof sections, and drain type. The software calculates required number and size of roof drains and vertical leaders. Secondary (overflow) drain sizing is calculated automatically.

4. Horizontal Piping Tab: Enter horizontal storm drain layout with lengths and slopes. Select pipe material. Manning's equation is used to verify pipe capacity.

5. Results & Export Tab: Review complete storm drainage pipe schedule. Export to TXT or CSV.

17.5 Hot Water Sizing (hot_water_app.py)

1. Launch from **Plumbing Tools > Hot Water Sizing**.

2. Building & Fixtures Tab: Select building type (Office, Hotel, Restaurant, Hospital, School, Gym, Residential). Enter occupancy count. Add fixtures with quantities.

3. Demand Calc Tab: The module calculates demand using three methods simultaneously -- ASHRAE storage/recovery method, Modified Hunter's Curve, and UPC fixture unit method. Select the governing method or use the most conservative result.

4. Heater Selection Tab: Browse manufacturer equipment data. Filter by type (gas storage, electric storage, gas tankless, electric tankless, heat pump). The software recommends equipment based on the calculated demand.

5. Recirculation & Results Tab: Design the recirculation loop with pipe sizing, pump selection, and heat loss calculation. View annual energy cost comparison between gas, electric, and heat pump options. Export complete DHW design report.

17.6 Domestic Hot Water (domestic_hot_water_app.py)

1. Launch from **Plumbing Tools > Domestic Hot Water**.

2. Fixture Count Tab: Enter all hot-water-connected fixtures with quantities. Each fixture shows its GPH demand, WSFU, and required delivery temperature.

3. System Design Tab: Select heater type, storage temperature, mixing valve configuration, and Legionella prevention strategy (per ASHRAE 188).

4. Pipe Sizing Tab: Design the hot water distribution system including supply risers, branch piping, and recirculation return. Enter pipe lengths and the software calculates sizes, heat losses, and insulation requirements.

5. Equipment Selection Tab: Select specific manufacturer equipment based on calculated demand. View equipment data sheets and compare options.

6. Compliance & Export Tab: Generate a compliance checklist covering ASHRAE 90.1 insulation, ASSE 1017 mixing, ASHRAE 188 Legionella, and code-required minimum delivery temperatures. Export the complete DHW report.

17.7 Grease Interceptor (grease_interceptor_app.py)

1. Launch from **Plant / System Tools > Grease Interceptor**.
2. Select the **Sizing Method** (PDI G101, UPC, IPC, or Flow Rate).
3. Add kitchen fixtures from the dropdown with their drainage capacities.
4. Select the **Loading Factor** (Low, Medium, High).
5. The software calculates the required interceptor flow rate (GPM) and recommended interceptor type.
6. Browse manufacturer equipment and select a specific model.
7. Export the sizing report for inclusion in the plumbing specifications.

17.8 Pipe Sizer (pipe_sizer_app.py)

1. Launch from **Core Calculations > Pipe Sizer**.
2. Select the **Fluid** (water, glycol solution, refrigerant, steam) and enter temperature and flow rate (GPM).
3. Select the **Pipe Material** and the software auto-populates roughness values.
4. Choose the sizing method: **Hazen-Williams** or **Darcy-Weisbach**.
5. The software calculates the minimum pipe size to meet the velocity limit and maximum friction loss criteria.
6. For multi-segment systems, enter each segment and the software produces a complete pipe schedule.

18. Common Design Mistakes

18.1 Water Supply Sizing Mistakes

Mistake	Consequence	Correct Approach
Using UPC WSFU values (10 for flush-valve WC) with IPC Hunter's Curve	Oversized piping, wasted cost	Match WSFU table to curve: use IPC 604.3 with IPC Appendix E
Ignoring future fixture additions	Undersized piping when tenant adds fixtures	Design with 20% spare capacity on mains
Forgetting elevation head loss	Insufficient pressure at upper floors	Always include P_static = height / 2.31
Using 10 fps velocity for copper	Water hammer, erosion, noise	Limit to 8 fps for copper per ASME B31.9
Not accounting for pressure loss through BFP	Available pressure appears higher than reality	Include 5-15 psi loss for DCVA/RPBA
Sizing pipe at peak WSFU without diversity	Oversized pipe with excessive cost	Apply floor diversity when aggregating risers

18.2 Drainage Sizing Mistakes

Mistake	Consequence	Correct Approach
Using horizontal drain capacity for vertical stacks	Undersized stacks	Use separate vertical stack tables (higher DFU capacity)
Exceeding max DFU per branch interval on stacks	Surcharging, overflow	Check per-branch limit, not just total

Mistake	Consequence	Correct Approach
Slope too steep on large drain pipes	Self-scouring leaves solids behind (water outruns waste)	Maximum 1/2"/ft for 3" and larger per UPC
Not providing cleanout access	Code violation, impossible maintenance	Cleanouts at every change of direction and every 100 ft
Connecting storm drains to sanitary system	Code violation, overloaded sanitary system	Separate storm and sanitary unless combined sewer jurisdiction

18.3 Vent Sizing Mistakes

Mistake	Consequence	Correct Approach
Undersized vent pipes	Trap siphonage, gurgling, sewer gas entry	Follow code vent sizing tables with developed length
Vent termination too close to intake	Sewer gas drawn into building	Maintain 10 ft minimum from any air intake or operable opening
No relief vent on long circuit-vented battery	Pressure problems, trap siphonage	Add relief vent per IPC 911.2 for more than 4 water closets
Using AAV where not permitted	Code violation (UPC jurisdictions)	Verify AAV acceptance with local AHJ

18.4 Hot Water System Mistakes

Mistake	Consequence	Correct Approach
Setting storage below 140 deg F	Legionella growth risk	Store at 140 deg F minimum per ASHRAE 188
No mixing valve for public lavatories	Scald risk, liability	Provide ASSE 1070 TMVs limiting to 110 deg F
Undersized recirculation pump	Warm-up wait time, water waste	Calculate heat loss and size pump for loop flow
No thermal expansion tank downstream of BFP	Pressure spikes, relief valve weeping	Install expansion tank per IPC 607.3
Single water heater with no redundancy	Complete loss of hot water on failure	Provide duplex heaters or N+1 configuration for critical facilities

18.5 Gas Piping Mistakes

Mistake	Consequence	Correct Approach
Using pipe length to appliance instead of longest run	Undersized piping	Always use longest run from meter to farthest appliance for all segments
Not accounting for future appliance additions	Undersized gas main	Size main for full connected load + 20% spare
Missing earthquake shutoff (California)	Code violation, safety hazard	Required at meter per CPC 1210.1.1

Mistake	Consequence	Correct Approach
No drip leg at appliance connections	Moisture/debris damage to appliance	Provide sediment trap (drip leg) per IFGC 408.4
Using CSST without proper bonding	Lightning/electrical damage risk	Bond CSST to building grounding electrode per IFGC 310.1.1

18.6 Storm Drainage Mistakes

Mistake	Consequence	Correct Approach
Using inadequate rainfall intensity	Undersized system, flooding	Use 100-year, 60-min storm per code (local AHJ may require different)
Forgetting overflow (secondary) drains	Structural failure risk from ponding	Provide secondary system sized equal to primary per IPC 1107
Connecting primary and overflow to same piping	Defeats purpose of redundancy	Overflow must discharge independently (to grade or separate system)
Not accounting for vertical wall runoff	Undersized drain capacity	Include 50% of largest adjacent vertical surface per IPC 1106.6

19. Integration with Revit

19.1 Overview

The J∆S Engineering Suite includes a Revit connector (`revit_connector.py`) that provides bidirectional data exchange between the desktop software and Autodesk Revit. The connector supports plumbing data through the `PlumbingFixture` and `PlumbingResult` data classes.

19.2 Importing Plumbing Fixtures from Revit

When you import a Revit model (`.rvt` or via the live connector), the software extracts:

- **Plumbing fixture data:** Fixture type, category, count, location, level, flow rates, and IPC/UPC fixture units
- **Piping summary:** Pipe system types, lengths, sizes, and materials
- **Space/room assignments:** Which fixtures belong to which spaces

To import Revit plumbing data:

1. From the main menu, go to **File > Import from Revit** or use the Revit Add-in toolbar button.
2. In the Import Dialog, check the **Import plumbing fixtures** checkbox.
3. The software parses all Revit plumbing fixture families and populates the Fixture Calculator automatically.
4. Review the imported fixture schedule in the **Fixtures** tab.

19.3 Plumbing Data Structure from Revit

The Revit connector creates a `PlumbingFixture` object for each fixture containing:

Field	Type	Description
fixture_type	str	Type name (e.g., "Water Closet", "Lavatory")
fixture_category	str	Category (e.g., "Plumbing Fixtures")
element_id	int	Revit element ID for back-reference
level	str	Floor/level name
x, y, z	float	3D coordinates
flow_rate_cold	float	Cold water flow (GPM)
flow_rate_hot	float	Hot water flow (GPM)
wsfu_cold	float	Cold WSFU
wsfu_hot	float	Hot WSFU
wsfu_total	float	Total WSFU
dfu	float	Drainage fixture units
trap_size	float	Trap diameter (inches)

19.4 Exporting Results to Revit

After completing plumbing calculations, the software creates a `PlumbingResult` object that can be pushed back to the Revit model:

Result Field	Description
total_wsfu	Building total WSFU
total_dfu	Building total DFU
peak_demand_gpm	Peak demand from Hunter's Curve
main_pipe_size	Building main pipe size
main_drain_size	Building drain size
fixture_counts	Dictionary of fixture type to count

This data can be used to:

- Auto-size Revit pipe elements based on calculated flow rates
- Tag fixtures with their WSFU/DFU values in Revit schedules
- Generate plumbing riser diagrams annotated with calculated sizes
- Populate shared parameters for coordination with other disciplines

19.5 Revit Plumbing Workflow

1. **In Revit:** Place plumbing fixtures and route piping in the Revit model.

2. **Export from Revit:** Use the J∆S Revit Add-in to export fixture and piping data.
3. **In J∆S Engineering Suite:** Import the Revit data. The Fixture Calculator auto-populates.
4. **Run Calculations:** Verify fixture counts, size piping, calculate drainage, and size water heaters.
5. **Export Results:** Push calculation results back to Revit for pipe sizing, schedules, and documentation.
6. **Iterate:** As the Revit model changes (fixtures added/removed), re-import and re-calculate.

20. Output Interpretation and Export

20.1 Plumbing Calculation Report

When you click **Generate Report** in any plumbing module, the J∆S Engineering Suite produces a comprehensive report organized into the following sections:

1. **Cover Sheet** -- Project information, engineer of record, code basis
2. **Fixture Schedule** -- Tabulated list of all fixtures by floor, with WSFU and DFU assignments
3. **Domestic Cold Water Sizing** -- WSFU totals, Hunter's Curve flow, pipe sizing schedule, pressure analysis, booster pump recommendation (if required)
4. **Domestic Hot Water Sizing** -- Hot water demand analysis, heater selection, storage tank sizing, recirculation pump sizing, pipe insulation schedule
5. **Sanitary Drainage** -- DFU totals, building drain sizing, stack sizing, vent sizing, pipe material specification
6. **Storm Drainage** -- Rainfall data, roof drain sizing, leader and horizontal drain sizing, overflow drain sizing
7. **Natural Gas Piping** -- Appliance schedule, gas demand summary, pipe sizing schedule, meter requirement
8. **Code Compliance Summary** -- Checklist verifying conformance with IPC/UPC/CPC requirements

20.2 Reading the Pipe Sizing Tables

Each pipe sizing table in the report includes:

Column	Description
Segment ID	Reference identifier (e.g., DCW-01, SAN-03) matching the plumbing riser diagram
From / To	Origin and destination of the pipe segment
Fixture Units	WSFU (supply) or DFU (drainage) served by the segment
Flow (GPM)	Converted flow rate
Pipe Size	Selected nominal pipe size
Material	Pipe material (Type L copper, cast iron, Sch 40 steel, etc.)
Velocity (fps)	Calculated velocity at design flow
Slope	For drainage only -- slope in inches per foot

Column	Description
Notes	Warnings, code references, or design notes

20.3 Exporting Results

All plumbing modules support multiple export formats:

- **PDF** -- Professional print-ready report with company letterhead. Suitable for submittal packages and plan check.
- **Excel (.xlsx)** -- Editable spreadsheet with all calculation tables for further analysis and client review.
- **TXT** -- Plain text summary for inclusion in specifications or email communication.
- **CSV** -- Comma-separated values for import into other software (e.g., Revit schedules, cost estimating tools).

To export, click **File > Export** from within any plumbing module and select the desired format.

20.4 Reviewing Warnings and Flags

The software highlights potential issues with color-coded flags:

Flag Color	Meaning
Green	All values within code limits and design standards
Yellow	Value is within 10% of a code limit (e.g., pipe at 92% capacity). Review recommended.
Red	Code violation or engineering limit exceeded (e.g., velocity > 8 fps, pressure below minimum, pipe over capacity). Must be corrected before finalizing the report.

20.5 Cost Estimating Integration

The J∆S Engineering Suite's cost estimating module (accessible from the main menu) provides plumbing cost estimates based on the calculated design:

Cost Category	Basis
Fixtures (material)	Per fixture type and quality level
Fixtures (labor)	Per fixture type and regional labor rates
Piping (material)	Per linear foot by pipe type, material, and size
Piping (labor)	Per linear foot by pipe type and complexity
Water heater	Per unit based on type, capacity, and manufacturer
Cost per fixture	Total plumbing cost divided by fixture count
Cost per SF	Total plumbing cost divided by building area

Benchmark data for plumbing costs by building type is included for comparison.

21. Code References

21.1 Primary Codes

Code	Full Title	Publisher
IPC 2021	International Plumbing Code, 2021 Edition	ICC
UPC 2022	Uniform Plumbing Code, 2022 Edition	IAPMO
CPC 2022	California Plumbing Code, 2022 Edition (Title 24, Part 5)	CBSC
CBC 2022	California Building Code, 2022 Edition (Title 24, Part 2)	CBSC
IFGC 2021	International Fuel Gas Code, 2021 Edition	ICC

21.2 Referenced Standards

Standard	Title	Application
ASME A112.19.2	Ceramic Plumbing Fixtures	WC, urinal, lavatory specifications
ASME B31.9	Building Services Piping	Pipe material, joints, pressure ratings
ASSE 1012	Backflow Preventer with Intermediate Atmospheric Vent	DHW protection
ASSE 1013	Reduced Pressure Principle Backflow Prevention Assembly	Main DCW protection
ASSE 1016	Individual Thermostatic Compensating Valves	Lavatory/shower mixing valves
ASSE 1017	Temperature Actuated Mixing Valves	Central DHW tempering
ASSE 1070	Water Temperature Limiting Devices	Scald prevention
ASHRAE 90.1-2022	Energy Standard for Buildings	Pipe insulation, DHW efficiency
ASHRAE 188	Legionellosis: Risk Management for Building Water Systems	Legionella prevention
ASHRAE Guideline 12	Minimizing the Risk of Legionellosis	Supplemental guidance
NFPA 54	National Fuel Gas Code	Gas piping (same as IFGC in most adoptions)
PDI G101	Testing and Rating for Grease Interceptors	Grease interceptor sizing
ASTM B88	Seamless Copper Water Tube	Type K, L, M copper pipe
CISPI 301	Cast Iron Soil Pipe	Hubless cast iron drainage pipe
ASTM A53	Black and Hot-Dipped Zinc-Coated Welded Steel Pipe	Gas piping material
ASCE 7-22	Minimum Design Loads for Buildings	Rainfall intensity data
NSF/ANSI 61	Drinking Water System Components	Materials in contact with potable water

Standard	Title	Application
AWWA C651	Disinfection of Water Mains	New pipe disinfection
MSS SP-69	Pipe Hangers and Supports	Pipe support spacing
ASME B31.1	Power Piping	Thermal expansion

21.3 Key Code Table References

Table Number	Title	Code	Used For
IPC 403.1	Minimum Number of Required Plumbing Fixtures	IPC	Fixture count determination
CBC Table 422.1	Minimum Plumbing Facilities	CBC/CPC	Fixture count determination (California)
IPC Table 604.3	Water Supply Fixture Units	IPC	WSFU assignment
IPC Table 604.4	Minimum Flow Rates for Fixtures	IPC	Minimum fixture pressures
UPC Table 610.3	Water Supply Fixture Units	UPC	WSFU assignment
IPC Table E103.3(2)	Demand (GPM) vs. Fixture Units	IPC	Hunter's Curve (WSFU to GPM)
UPC Appendix A	Demand (GPM) vs. Fixture Units	UPC	Hunter's Curve (WSFU to GPM)
IPC Table 709.1	Drainage Fixture Units	IPC	DFU assignment
UPC Table 702.1	Drainage Fixture Units	UPC	DFU assignment and drain sizing
IPC Table 710.1	Building Drain and Sewer Sizing	IPC	Horizontal drain sizing
IPC Table 710.1(1)	Vertical Stack Sizing	IPC	Stack sizing
IPC Table 916.1	Size of Vents	IPC	Vent pipe sizing
UPC Table 703.2	Size of Vents	UPC	Vent pipe sizing
IPC Table 1106.2	Roof Drain Size	IPC	Storm drain sizing
UPC Table 1103.1	Roof Drain/Leader/Horizontal Pipe	UPC	Storm drainage sizing
IFGC Table 402.4	Gas Pipe Sizing (2 psi systems)	IFGC	Natural gas pipe sizing
CPC Table 1216.2	Gas Pipe Sizing (2 psi systems)	CPC	Natural gas pipe sizing (California)

22. Abbreviations

Abbreviation	Definition
AAV	Air Admittance Valve
ABS	Acrylonitrile Butadiene Styrene (drain pipe)

Abbreviation	Definition
ACR	Air Conditioning and Refrigeration (copper tube)
AG	Air Gap
AHJ	Authority Having Jurisdiction
ASSE	American Society of Sanitary Engineering
ASME	American Society of Mechanical Engineers
AVB	Atmospheric Vacuum Breaker
BFP	Backflow Preventer
BTU	British Thermal Unit
CBC	California Building Code
CFH	Cubic Feet per Hour
CFS	Cubic Feet per Second
CPC	California Plumbing Code
CPVC	Chlorinated Polyvinyl Chloride
CSST	Corrugated Stainless Steel Tubing
DCW	Domestic Cold Water
DCVA	Double Check Valve Assembly
DFU	Drainage Fixture Unit
DHW	Domestic Hot Water
DWV	Drain, Waste, and Vent
FHR	First Hour Rating
fps	Feet per Second
GGI	Gravity Grease Interceptor
GPD	Gallons per Day
GPH	Gallons per Hour
GPM	Gallons per Minute
HGI	Hydromechanical Grease Interceptor
IAPMO	International Association of Plumbing and Mechanical Officials
ICC	International Code Council
ID	Internal Diameter
IFGC	International Fuel Gas Code
IPC	International Plumbing Code
LP	Liquefied Petroleum (gas)

Abbreviation	Definition
MBH	Thousands of BTU per Hour
NOAA	National Oceanic and Atmospheric Administration
NFPA	National Fire Protection Association
OD	Outside Diameter
PDI	Plumbing and Drainage Institute
PE	Polyethylene
PEX	Cross-linked Polyethylene
POU	Point of Use
psi	Pounds per Square Inch
psia	Pounds per Square Inch Absolute
PVB	Pressure Vacuum Breaker
PVC	Polyvinyl Chloride
RPBA	Reduced Pressure Backflow Assembly
SDR	Standard Dimension Ratio
SF	Square Feet
SVB	Spill-Resistant Vacuum Breaker
TDH	Total Dynamic Head
TMV	Thermostatic Mixing Valve
UPC	Uniform Plumbing Code
VFD	Variable Frequency Drive
WC	Water Closet
WSFU	Water Supply Fixture Unit
WH	Water Heater
in. WC	Inches of Water Column

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