J∆S Engineering Suite

Module Guide: Equipment Sizing & Schedules

Version 1.2 — April 2026
JS Engineering Solutions

Version: 1.1 **Applicable Standards:** ASHRAE 90.1-2022, ASHRAE 62.1-2022, AHRI 550/590, AHRI 1500, AMCA 201/210, CTI, IGSHPA, SMACNA **Last Updated:** February 2026 **Publisher:** JS Engineering Solutions

Table of Contents

1. Overview

The Equipment Sizing & Schedules modules in the J∆S Engineering Suite convert zone-level heating and cooling loads into fully specified mechanical equipment. Rather than manually transcribing peak load values into spreadsheets, engineers use these modules to flow calculated loads directly into equipment selections with appropriate safety factors, diversity adjustments, and code-mandated minimums.

Why Equipment Sizing Matters

Under-sized equipment cannot meet design conditions. Over-sized equipment wastes capital cost, increases energy consumption through short-cycling, and degrades humidity control. The J∆S Engineering Suite applies industry-standard sizing methodology to strike the right balance:

• **Safety factors** account for unknowns in construction quality, occupancy growth, and load calculation uncertainty.

• **Diversity factors** recognize that not all zones peak simultaneously, reducing central plant capacity below the simple sum of zone peaks.

• **Code compliance** ensures that equipment efficiency meets or exceeds ASHRAE 90.1-2022 mandatory minimums for each equipment category and size range.

Sizing Workflow

The equipment sizing workflow proceeds as follows:

1. Zone loads are computed in the Room Load Calculation module (see Guide 01).

2. System-level aggregation sums zone loads to air handling unit and plant level, applying diversity where applicable.

3. Equipment selection rounds to commercially available sizes and verifies compliance.

4. Schedule generation produces formatted tables suitable for inclusion in construction documents.

5. Export outputs schedules to Excel, CSV, or PDF for coordination with other disciplines.

Accessing Equipment Modules

All equipment sizing modules are accessible from the J∆S Engineering Suite sidebar under the following categories:

• **Sizing Tools**: Pump Calculator, Fan Laws, Exhaust Fan Sizing

• **Plant Equipment**: Chiller Plant, Boiler Plant, Equipment Schedule, Equipment Wizard

• **Advanced Tools**: Pump Curves, Heat Exchanger, Cooling Tower, VRF Design

To open any module, click the corresponding entry in the sidebar. Each module opens as a tabbed interface within the main application window.

All calculations use IP units (BTU/hr, CFM, degrees Fahrenheit, GPM) consistent with North American HVAC practice and EnergyPro methodology.

2. Air Handling Units (AHUs)

Air handling units are the central air distribution equipment in most commercial HVAC systems. The J∆S Engineering Suite sizes AHUs based on the aggregate loads of all zones served, with adjustments for diversity, outdoor air requirements, and system pressure losses.

2.1 Opening the Module

Navigate to **Plant Equipment > Equipment Schedule** or use the **Equipment Wizard** (Plant Equipment > Equipment Wizard) and select "Air Handling Unit" as the equipment type. The Equipment Schedule module provides the AHU schedule tab for entering and managing AHU data directly.

2.2 Total Supply CFM

The total supply airflow is the sum of individual zone supply airflows, reduced by a diversity factor:

```
Supply_CFM = SUM(Zone_CFM) x Diversity_Factor
```

The default diversity factor is **0.90** (90%), reflecting the reality that not all zones reach peak cooling load at the same hour. This factor is appropriate for typical office buildings. For mission-critical spaces (hospitals, data centers), diversity should be set to 1.0.

2.3 Return CFM

Return airflow is set to 90% of the supply airflow to maintain **positive building pressurization**:

```
Return_CFM = Supply_CFM x 0.90
```

The 10% difference between supply and return is made up by outdoor air introduced at the AHU, which slightly pressurizes the building and prevents uncontrolled infiltration of unconditioned air.

2.4 Outdoor Air

Outdoor air (OA) is determined by ASHRAE 62.1-2022 ventilation rate procedure and is **never reduced by diversity**. Each zone's OA requirement (based on people count and floor area) is summed at the system level:

```
OA_CFM = SUM(Zone_OA_CFM) (no diversity applied)
```

The reason diversity does not apply to outdoor air is that ventilation is a health and safety requirement -- every occupied zone must receive its full code-required outdoor air quantity regardless of whether the zone is at peak thermal load.

2.5 Total Static Pressure (TSP)

The AHU fan must overcome all pressure drops in the air distribution system. The J∆S Engineering Suite uses the following default component pressure drops:

Component	Pressure Drop
Supply ductwork	4.0 in. WG

Component	Pressure Drop
Cooling coil	1.0 in. WG
Filters (clean)	0.5 in. WG
Total Static Pressure	**5.5 in. WG**

For more complex systems, users can add components such as energy recovery wheels (1.0 in. WG), sound attenuators (0.5 in. WG), or mixing boxes (0.3 in. WG). The supply ductwork allowance of 4.0 in. WG is typical for a medium-rise building and can be adjusted based on actual duct sizing calculations.

2.6 Fan Horsepower

Fan brake horsepower (BHP) is calculated from airflow and total static pressure:

```
Fan_BHP = (CFM x TSP) / (6,356 x Fan_Eff x Motor_Eff)
```

Where:

- **CFM** = supply air volume flow rate
- **TSP** = total static pressure (in. WG)
- **6,356** = unit conversion constant (CFM x in. WG to HP)
- **Fan_Eff** = fan mechanical efficiency (default 0.65 for forward-curved, 0.75 for airfoil)
- **Motor_Eff** = motor efficiency (default 0.93 for premium efficiency motors)

The selected motor HP should be the next standard size above the calculated BHP: 1, 1.5, 2, 3, 5, 7.5, 10, 15, 20, 25, 30, 40, 50, 60, 75, 100 HP.

2.7 Cooling Coil Sizing

The AHU cooling coil handles the sum of all zone sensible and latent cooling loads (after diversity). Chilled water flow through the coil is:

```
CHW_GPM = q_total / (500 x DeltaT_chw)
```

Where:

- **q_total** = total cooling load (BTU/hr)
- **500** = constant (lb/hr per GPM x specific heat of water = 8.33 lb/gal x 60 min/hr x 1.0 BTU/lb-F)
- **DeltaT_chw** = chilled water temperature differential, typically **10 degrees F** (44 degrees F entering, 54 degrees F leaving)

2.8 Heating Coil Sizing

The AHU preheat or heating coil handles morning warm-up and cold outdoor air tempering. Hot water flow is:

```
HW_GPM = q_heating / (500 x DeltaT_hw)
```

Where:

- **DeltaT_hw** = hot water temperature differential, typically **40 degrees F** (180 degrees F supply, 140 degrees F return)

The larger temperature differential for heating (40 degrees F vs. 10 degrees F for cooling) results in significantly lower GPM per unit of capacity, which is why heating piping is smaller than cooling piping for the same load.

2.9 Worked Example: AHU-1 Serving Floors 1-2

Given:

- Zone loads sum to 28,900 CFM across Floors 1 and 2
- Total cooling load (sum of zones): 780,000 BTU/hr
- Total heating load: 320,000 BTU/hr
- Outdoor air requirement: 5,200 CFM

Supply CFM:

```
Supply_CFM = 28,900 x 0.90 = 26,010 CFM --> round to 26,000 CFM
```

Return CFM:

```
Return_CFM = 26,000 x 0.90 = 23,400 CFM
```

Outdoor Air: 5,200 CFM (no diversity)

Fan BHP (airfoil fan, premium motor):

```
Fan_BHP = (26,000 x 5.5) / (6,356 x 0.75 x 0.93)
= 143,000 / 4,433
= 32.3 BHP --> select 40 HP motor
```

CHW GPM (cooling coil):

```
CHW_GPM = 780,000 / (500 x 10) = 156 GPM
```

HW GPM (heating coil):

```
HW_GPM = 320,000 / (500 x 40) = 16 GPM
```

AHU-1 Summary:

Parameter	Value
Supply CFM	26,000
Return CFM	23,400
Outdoor Air CFM	5,200
Total Static Pressure	5.5 in. WG
Supply Fan Motor	40 HP
Cooling Coil Capacity	780 MBH (65 tons)
CHW Flow	156 GPM
Heating Coil Capacity	320 MBH
HW Flow	16 GPM

3. Rooftop Units (RTUs)

Rooftop units are factory-packaged systems that combine supply fan, cooling section (typically DX), heating section, filters, and controls in a single casing installed on the building roof. The J∆S Engineering Suite supports RTU selection through the **Equipment Wizard** (select "Rooftop Unit") and the **Equipment Schedule** module.

3.1 When to Use RTUs

RTUs are appropriate for:

- Single-story retail, restaurants, and small offices under 20,000 SF
- Warehouse and industrial spaces
- Strip malls and stand-alone buildings
- Situations where mechanical rooms are not available
- Value-engineered projects where first cost is critical

3.2 Key Input Fields

Field	Description	Typical Range
Cooling Capacity (Tons)	Peak block cooling load for area served	3 - 150 tons
Heating Capacity (MBH)	Peak heating load	50 - 3,000 MBH
Supply CFM	Total supply airflow	1,000 - 50,000 CFM
External Static Pressure	Ductwork pressure drop	0.5 - 3.0 in. WG
Economizer	ASHRAE 90.1 required in most climates	Yes/No
Energy Recovery	For units with high OA percentage	Wheel, Plate, Runaround
Heating Source	Gas, Electric, Heat Pump	Select from dropdown

3.3 Efficiency Ratings

RTU efficiency is rated in SEER2 (cooling) and AFUE or HSPF2 (heating). ASHRAE 90.1-2022 minimums for RTUs depend on capacity:

Cooling Capacity	Minimum EER2	Minimum IEER
< 65,000 BTU/hr	11.2	12.9
65,000 - 135,000 BTU/hr	11.0	12.4
135,000 - 240,000 BTU/hr	10.8	12.2
240,000 - 760,000 BTU/hr	10.0	11.6

Cooling Capacity	Minimum EER2	Minimum IEER
> 760,000 BTU/hr	9.8	11.0

3.4 RTU Selection Procedure

1. Calculate block cooling and heating loads for the served area

2. Apply a 10-15% safety factor to cooling, 15-20% to heating

3. Select unit capacity that meets or exceeds the factored load

4. Verify external static pressure is adequate for the duct system

5. Confirm economizer is included (ASHRAE 90.1 requires it for most units above 54,000 BTU/hr)

6. Check gas connection size if gas heating

7. Verify structural capacity of roof for equipment weight

4. VAV Terminal Units

Variable Air Volume (VAV) terminal units regulate airflow to individual zones. Each VAV box modulates from a maximum airflow at peak cooling to a minimum airflow during low-load conditions. Boxes serving interior zones are cooling-only; boxes serving perimeter zones typically include reheat coils.

4.1 Opening the Module

Navigate to **Advanced Tools > VAV Box** in the sidebar. The VAV Box sizing module allows individual or batch entry of zone data for automated sizing.

4.2 Maximum CFM

The maximum airflow is derived from the zone sensible cooling load:

```
Max_CFM = q_sensible / (1.08 x (T_room - T_supply))
```

Where:

- **q_sensible** = zone peak sensible cooling load (BTU/hr)
- **1.08** = sea-level constant (0.075 lb/ft3 x 60 min/hr x 0.24 BTU/lb-F)
- **T_room** = room design temperature (typically 75 degrees F)
- **T_supply** = supply air temperature (typically 55 degrees F)

Note: The 1.08 constant applies at sea level. At altitude, the J∆S Engineering Suite automatically adjusts this value based on the project location's barometric pressure. At 5,000 ft elevation, for example, the constant drops to approximately 0.92, meaning more CFM is needed to deliver the same cooling capacity.

4.3 Minimum CFM

The minimum airflow is the largest of three constraints:

```
Min_CFM = MAX(0.30 x Max_CFM, OA_CFM, 50 CFM)
```

Where:

- **0.30 x Max_CFM** = 30% of maximum to maintain adequate air distribution
- **OA_CFM** = zone outdoor air requirement per ASHRAE 62.1
- **50 CFM** = absolute minimum for any active VAV box

The 30% minimum ensures that the air distribution pattern from the diffuser remains effective. Below this threshold, the supply jet "dumps" and causes drafts and temperature stratification.

4.4 Inlet Sizing

The VAV box inlet duct connection is sized for a maximum velocity of **2,000 FPM** to limit noise and pressure drop. Standard round inlet sizes and their approximate maximum CFM capacities:

Inlet Diameter	Max CFM at 2,000 FPM
6 in.	350 CFM
8 in.	700 CFM
10 in.	1,200 CFM
12 in.	1,800 CFM
14 in.	2,500 CFM
16 in.	3,500 CFM

Select the smallest inlet size whose capacity exceeds the box maximum CFM. For example, a box with 1,500 CFM maximum should use a 12-inch inlet.

4.5 Reheat Coil Sizing

Perimeter VAV boxes with reheat coils must offset the zone heating load at winter design conditions. The reheat coil capacity equals the zone peak heating load. Hot water flow through the reheat coil is:

```
HW_GPM = q_heating / (500 x DeltaT_reheat)
```

Where **DeltaT_reheat** is typically **20 degrees F** (160 degrees F entering, 140 degrees F leaving for reheat applications, a smaller differential than the central heating coil to keep coil size manageable).

4.6 Worked Examples

Open Office VAV (VAV-1-01)

Given:

- Sensible cooling load: 24,300 BTU/hr
- Heating load: 8,000 BTU/hr

- Outdoor air: 180 CFM (15 people x 5 CFM/person + 0.06 CFM/sf x 1,500 sf)
- Supply air: 55 degrees F, room: 75 degrees F

Max CFM:

```
Max_CFM = 24,300 / (1.08 x 20) = 24,300 / 21.6 = 1,125 CFM
```

Min CFM:

```
Min_CFM = MAX(0.30 x 1,125, 180, 50) = MAX(338, 180, 50) = 338 CFM
```

Inlet Size: 1,125 CFM --> 10-inch inlet (capacity 1,200 CFM)

Reheat Coil:

```
HW_GPM = 8,000 / (500 x 20) = 0.8 GPM
```

Conference Room VAV (VAV-1-05)

Given:

- Sensible cooling load: 14,040 BTU/hr
- Heating load: 3,500 BTU/hr
- Outdoor air: 135 CFM (20 people x 5 CFM/person + 0.06 CFM/sf x 580 sf)
- Supply air: 55 degrees F, room: 75 degrees F

Max CFM:

```
Max_CFM = 14,040 / (1.08 x 20) = 14,040 / 21.6 = 650 CFM
```

Min CFM:

```
Min_CFM = MAX(0.30 x 650, 135, 50) = MAX(195, 135, 50) = 195 CFM
```

Inlet Size: 650 CFM --> 8-inch inlet (capacity 700 CFM)

Reheat Coil:

```
HW_GPM = 3,500 / (500 x 20) = 0.35 GPM
```

5. Fan Coil Units

Fan coil units (FCUs) are terminal HVAC devices containing a fan, cooling coil, and optionally a heating coil. They are commonly used in hotels, condominiums, offices, and hospitals.

5.1 Accessing the Module

Fan coil unit sizing is available through **Plant Equipment > Equipment Schedule**. Select the "Fan Coil Unit" category to access the FCU schedule tab. The Equipment Wizard also supports FCU selection.

5.2 Input Fields

Field	Description	Typical Values
Cooling Capacity (MBH)	Zone sensible + latent cooling	6 - 60 MBH
Heating Capacity (MBH)	Zone heating load	4 - 40 MBH
Airflow (CFM)	Typically 200-400 CFM/ton	200 - 2,000 CFM
Fan Speed	Low/Medium/High or variable	3-speed or ECM
Coil Type	2-pipe, 4-pipe, or DX	Select from dropdown
Mounting	Horizontal, vertical, ceiling	Select from dropdown

5.3 Selection Criteria

• **2-pipe systems** use a single coil that alternates between chilled water and hot water seasonally. Lower first cost but no simultaneous heating/cooling.

• **4-pipe systems** have separate heating and cooling coils with independent water connections. Higher first cost but full year-round comfort control.

• **DX fan coils** use direct expansion refrigerant and are common in split system configurations.

• **ECM motors** should be specified for energy code compliance (ASHRAE 90.1-2022 requires ECM motors for fan coil units in most applications).

5.4 Noise Considerations

FCUs are located in occupied spaces, so sound levels are critical. Specify maximum NC (Noise Criteria) levels:

Space Type	Maximum NC Level
Hotel guest room	NC 30
Open office	NC 40
Conference room	NC 30-35
Hospital patient room	NC 30
Corridor	NC 45

Select units that achieve the required NC at medium fan speed (not low), since the unit will often operate at medium speed.

6. Chiller Sizing

Chillers are the central cooling plant equipment that produce chilled water for AHU cooling coils and other cooling loads. The J∆S Engineering Suite provides comprehensive chiller selection through the `chiller_selection.py` module and the Chiller Plant tool.

6.1 Opening the Module

Navigate to **Plant Equipment > Chiller Plant** in the sidebar. The module opens the Chiller Plant Design interface where you can enter building cooling loads and select chiller configurations.

6.2 Chiller Types Supported

The J∆S Engineering Suite supports the following chiller types:

Chiller Type	Typical Range	Full Load kW/ton	IPLV kW/ton
Air-Cooled Scroll	15 - 200 tons	1.10	0.85
Air-Cooled Screw	80 - 500 tons	1.05	0.80
Water-Cooled Scroll	15 - 200 tons	0.68	0.52
Water-Cooled Screw	100 - 800 tons	0.62	0.48
Water-Cooled Centrifugal	300 - 3,000 tons	0.55	0.42
Centrifugal Magnetic Bearing	200 - 2,000 tons	0.48	0.35
Single-Effect Absorption	100 - 1,500 tons	See Section 7	See Section 7
Double-Effect Absorption	100 - 1,500 tons	See Section 7	See Section 7

6.3 Input Fields

Field	Description	Default
Capacity (Tons)	Required cooling capacity	Calculated from loads
Chiller Type	Compressor/condenser type	Water-Cooled Screw
Application	Comfort, process, data center, etc.	Comfort Cooling
Leaving CHW Temp (F)	Chilled water supply temperature	44 F
Entering CHW Temp (F)	Chilled water return temperature	54 F
Entering CW Temp (F)	Condenser water from tower (water-cooled)	85 F
Ambient Temp (F)	Design outdoor temp (air-cooled)	95 F
Operating Hours	Annual chiller operating hours	3,000 hrs
Electricity Rate	Cost per kWh	$0.12/kWh
Redundancy	N, N+1, or 2N configuration	N

6.4 Total Cooling Load with Safety Factor

The chiller plant capacity starts with the sum of all AHU cooling coil loads (after diversity), plus any process cooling loads, then adds a 10% safety factor:

```
Chiller_Capacity = Total_Cooling_Load x 1.10
```

The 10% safety factor covers:

- Load calculation uncertainty
- Future tenant fit-out unknowns
- Degradation of equipment performance over time
- Pump heat gain in the chilled water loop

6.5 Rounding to Standard Sizes

Chillers are manufactured in nominal tonnage increments. After applying the safety factor, round up to the nearest 10 tons:

```
Selected_Tons = CEILING(Chiller_Capacity / 12,000, 10)
```

For example, if the total cooling load after safety factor is 843,000 BTU/hr:

```
843,000 / 12,000 = 70.3 tons --> round up to 80 tons
```

6.6 Performance Metrics

Key chiller performance parameters:

Metric	Definition	Typical Value (Water-Cooled Screw)
kW/ton	Power input per ton of cooling	0.55 - 0.70 kW/ton at full load
COP	Coefficient of Performance	5.0 - 6.5
IPLV	Integrated Part Load Value	0.40 - 0.55 kW/ton
NPLV	Non-Standard Part Load Value	Site-specific IPLV

The relationship between these metrics:

```
COP = 12.0 / kW_per_ton
IPLV = 0.01A + 0.42B + 0.45C + 0.12D
```

Where A = 100% load, B = 75% load, C = 50% load, D = 25% load performance.

IPLV is almost always better (lower) than full-load kW/ton because chillers operate at part load the majority of the year, and modern compressors are more efficient at part load.

6.7 Refrigerant Selection

The J∆S Engineering Suite automatically selects the appropriate refrigerant based on chiller type and capacity:

Chiller Type	Typical Refrigerant	GWP	Notes
Air-Cooled Scroll/Screw	R-410A	2,088	Being phased down
Water-Cooled Scroll/Screw	R-134a	1,430	Standard HFC
Centrifugal	R-1233zd(E)	1	Low GWP, large machines
Magnetic Bearing Centrifugal	R-1234ze(E)	7	Ultra-low GWP

Chiller Type	Typical Refrigerant	GWP	Notes
Centrifugal (> 500 tons)	R-1233zd(E)	1	Replacing R-123
Absorption	Water/LiBr	0	No synthetic refrigerant

6.8 Chilled Water Flow

Chilled water flow through the chiller evaporator:

```
CHW_GPM = Tons x 12,000 / (500 x DeltaT_chw)
= Tons x 2.4 (at 10 degrees F DeltaT)
```

The **2.4 GPM per ton** rule of thumb (at standard 10 degrees F differential) is one of the most commonly used values in HVAC engineering.

6.9 Condenser Water Flow

For water-cooled chillers, the condenser water flow is typically:

```
CW_GPM = Tons x 3.0 (at standard 10 degrees F DeltaT)
```

The condenser rejects both the cooling load and the compressor heat, so the condenser water flow (3.0 GPM/ton) is higher than the evaporator flow (2.4 GPM/ton).

6.10 Output Fields

The chiller selection output includes:

- Equipment ID and tag
- Manufacturer recommendation (Trane, Carrier, Daikin, York)
- Model suggestion
- Full load and IPLV efficiency
- COP at full load and IPLV conditions
- CHW and CW flow rates
- Evaporator and condenser pressure drops
- Electrical data (voltage, FLA, MCA, MOP)
- Physical dimensions and weight
- Sound power level
- Equipment cost estimate
- Installation cost estimate
- Annual energy cost
- 20-year life cycle cost
- ASHRAE 90.1 compliance status
- Part load performance at 25%, 50%, and 75%

6.11 ASHRAE 90.1-2022 Minimum Efficiency

ASHRAE 90.1-2022 Table 6.8.1-3 specifies minimum chiller efficiency by type and size. The J∆S Engineering Suite automatically checks selections against these requirements:

Chiller Type	Size Range	Max kW/ton (Full Load)	Max kW/ton (IPLV)
Air-Cooled Scroll	< 150 tons	1.188	0.920
Air-Cooled Scroll	>= 150 tons	1.188	0.890
Air-Cooled Screw	< 150 tons	1.188	0.920
Air-Cooled Screw	>= 150 tons	1.153	0.860
Water-Cooled Scroll	< 75 tons	0.750	0.600
Water-Cooled Scroll	75-150 tons	0.720	0.560
Water-Cooled Scroll	150-300 tons	0.660	0.540
Water-Cooled Screw	< 75 tons	0.750	0.600
Water-Cooled Screw	75-150 tons	0.720	0.560
Water-Cooled Screw	150-300 tons	0.660	0.540
Water-Cooled Screw	>= 300 tons	0.610	0.520
Water-Cooled Centrifugal	< 300 tons	0.610	0.550
Water-Cooled Centrifugal	300-600 tons	0.560	0.500
Water-Cooled Centrifugal	>= 600 tons	0.560	0.500

Equipment that does not meet these minimums is flagged with a warning in the selection output.

7. Absorption Chillers

Absorption chillers use a thermal energy source (steam, hot water, or direct-fired gas) instead of an electric compressor to provide cooling. The J∆S Engineering Suite includes the `absorption_chillers.py` module for sizing these systems.

7.1 Types Supported

Type	COP Range	Heat Source	Typical Application
Single-Effect	0.65 - 0.75	Low-pressure steam (5-20 psig) or hot water (200-270 F)	CHP integration, waste heat recovery
Double-Effect	1.0 - 1.2	Medium-pressure steam (40-150 psig) or direct-fired	Base-load plants, district cooling
Triple-Effect	1.4 - 1.7	High-pressure steam (>150 psig)	Industrial, very large plants

7.2 When to Use Absorption

Absorption chillers are appropriate when:

- Waste heat is available from CHP (combined heat and power) systems
- Natural gas is significantly cheaper than electricity
- Electric utility demand charges are very high
- Building has an existing steam system
- Peak electric demand reduction is a design priority
- The project is in a region with high electricity-to-gas cost ratios

7.3 Key Design Considerations

- Absorption chillers require significantly more condenser water than electric chillers (typically 4.5 GPM/ton vs. 3.0 GPM/ton)
- Cooling towers must be oversized for the higher heat rejection
- Physical footprint is 2-3 times larger than equivalent electric chillers
- Maintenance includes periodic crystallization testing and lithium bromide solution monitoring
- Low-pressure steam single-effect machines have the lowest COP but accept the widest range of heat sources

8. Chiller Plant Design

The Chiller Plant Design module (`chiller_plant_sizing.py`) goes beyond individual chiller selection to design the complete central chilled water plant.

8.1 Opening the Module

Navigate to **Plant Equipment > Chiller Plant** in the sidebar. The module opens with tabs for plant configuration, chiller selection, pump sizing, piping, and sequence of operation.

8.2 Plant Configurations

Configuration	Description	Use Case
Single Chiller	One chiller handles full load	Small buildings < 100 tons
N+1	Multiple chillers with one standby	Hospitals, data centers
Parallel Equal	Equal-sized chillers, staged on/off	Most commercial buildings
Series Counterflow	Chillers in series for low kW/ton	Campus plants > 1,000 tons
Primary-Secondary	Decoupled chiller and building flow	Standard practice for variable flow
Variable Primary	Single-loop with bypass	Newer plants, energy savings

8.3 Output

The module produces a complete chiller plant design including:

- Total plant capacity (tons)
- Number and size of chillers
- Chilled water supply/return temperatures and flow
- Condenser water supply/return temperatures and flow
- Primary and secondary pump HP
- Cooling tower capacity and flow
- Design kW/ton, IPLV, NPLV
- Annual energy consumption (kWh) and cost
- Plant configuration recommendation
- Equipment schedule data for all plant components

9. Boiler Sizing

Boilers provide hot water for heating coils, reheat coils, and domestic hot water preheat. The J∆S Engineering Suite provides comprehensive boiler selection through the `boiler_selection.py` module.

9.1 Opening the Module

Navigate to **Plant Equipment > Boiler Plant** in the sidebar. The Boiler Plant Design interface allows entering building heating loads and selecting boiler configurations.

9.2 Boiler Types Supported

Boiler Type	Efficiency Range	Turndown	Capacity Range (MBH)	Typical Life (Years)
Fire Tube	80-85%	4:1	500 - 10,000	30
Water Tube	80-85%	10:1	1,000 - 50,000	35
Cast Iron	80-84%	3:1	50 - 4,000	30
Condensing	90-98%	10:1	50 - 6,000	20
Copper Fin Tube	82-86%	5:1	100 - 2,000	15
Electric	98-100%	Infinite	10 - 3,000	20
Steam (Low Pressure)	78-82%	varies	100 - 5,000	30+
Steam (High Pressure)	80-85%	varies	500 - 20,000	30+

9.3 Fuel Types

The module supports multiple fuel types with integrated cost and emissions calculations:

Fuel Type	HHV	Typical Cost	CO_2 (lb/MMBTU)
Natural Gas	1,030 BTU/cf	$1.20/therm	117
Propane	91,500 BTU/gal	$2.50/gal	139
#2 Fuel Oil	140,000 BTU/gal	$3.50/gal	163
#6 Fuel Oil	150,000 BTU/gal	$3.00/gal	173
Electric	3,412 BTU/kWh	$0.12/kWh	~200 (grid avg)

9.4 Total Heating Load with Safety Factor

Boiler capacity uses a **20% safety factor**, larger than the 10% used for cooling, because:

- Heating loads often include morning warm-up (pulling the building from setback temperature)
- Snow-melt or other intermittent loads may not appear in the zone load calculation
- Boilers lose capacity at altitude due to combustion air density

```
Boiler_Output = Total_Heating_Load x 1.20
```

9.5 Altitude Derating

The J∆S Engineering Suite automatically derates boiler capacity for altitude. The derating applies above 2,000 ft elevation:

```
Derate_Factor = 1.0 - 0.04 x ((Altitude_ft - 2000) / 1000)
```

For example, at 5,000 ft: Derate = 1.0 - 0.04 x 3 = 0.88 (12% capacity reduction). The boiler must be oversized to compensate.

9.6 Input vs. Output Rating

Boilers are rated by both input and output capacity. The input rating accounts for combustion efficiency:

```
Boiler_Input_MBH = Boiler_Output_MBH / Efficiency
```

For modern **condensing boilers** (efficiency 95%):

```
Boiler_Input_MBH = Boiler_Output_MBH / 0.95
```

For conventional **non-condensing boilers** (efficiency 82%):

```
Boiler_Input_MBH = Boiler_Output_MBH / 0.82
```

Condensing boilers achieve higher efficiency by recovering latent heat from flue gas condensation, but require return water temperatures below approximately 130 degrees F to maintain condensing operation.

9.7 Hot Water Flow

Hot water flow at the standard 40 degrees F differential (180 degrees F supply, 140 degrees F return):

```
HW_GPM = Boiler_Output_BTUhr / (500 x 40)
= Boiler_Output_BTUhr / 20,000
```

9.8 Emissions Considerations

The J∆S Engineering Suite calculates NOx and CO emissions for each boiler type. Typical NOx levels:

Boiler Type	Standard NOx (ppm)	Ultra-Low NOx (ppm)
Fire Tube	30	< 9
Water Tube	25	< 9
Cast Iron	40	< 20
Condensing	20	< 9
Copper Fin Tube	25	< 12

Many jurisdictions (particularly California AQMD districts) require ultra-low NOx burners with emissions below 9 ppm or even 7 ppm. Always verify local air quality regulations.

9.9 Worked Example

Given:

- Total zone heating load (all AHUs and VAV reheat): 650,000 BTU/hr

Boiler output:

```
Boiler_Output = 650,000 x 1.20 = 780,000 BTU/hr = 780 MBH
```

Boiler input (95% condensing):

```
Boiler_Input = 780 / 0.95 = 821 MBH
```

HW flow:

```
HW_GPM = 780,000 / (500 x 40) = 39 GPM
```

Select two (2) 400 MBH output condensing boilers for N+1 redundancy, each sized to carry the full building load independently.

10. Boiler Plant Design

The Boiler Plant Design module (`boiler_plant_sizing.py`) designs the complete hot water plant, including multiple boiler configurations, primary/secondary pumping, and staging.

10.1 Plant Configurations

Configuration	Description	When to Use
Single Boiler	One boiler, no redundancy	Low-criticality spaces
Lead-Lag	Two equal boilers at ~60% each	Standard commercial practice
Modular	3+ smaller boilers	High turndown needed, variable loads

Configuration	Description	When to Use
N+1	N boilers carry full load, +1 standby	Hospitals, critical facilities
Primary-Secondary	Decoupled plant and building loops	Large plants > 2,000 MBH

10.2 Lead-Lag Sizing

In a lead-lag configuration, two equal boilers are each sized at 60% of the total load. The 120% combined capacity provides both redundancy and a safety margin:

```
Each_Boiler = Total_Load x 0.60
Combined = Total_Load x 1.20
```

The lead boiler operates first. When it reaches full capacity, the lag boiler stages on. This approach extends equipment life by rotating lead/lag duty.

10.3 Modular Boiler Sizing

For modular configurations, the J∆S Engineering Suite calculates the optimal number and size of boilers based on the load profile and the required redundancy:

```
Num_Boilers = MAX(3, CEILING(Total_Load / 500))
Each_Boiler = Total_Load / (Num_Boilers - 1) # N-1 sizing for redundancy
```

11. Cooling Tower Sizing

Cooling towers reject heat from water-cooled chillers to the atmosphere. The J∆S Engineering Suite provides cooling tower selection through the `cooling_tower.py` module.

11.1 Opening the Module

Navigate to **Advanced Tools > Cooling Tower** in the sidebar. The module allows specifying design conditions and selecting tower type, fill type, and manufacturer.

11.2 Tower Types

Tower Type	Airflow Pattern	Fan	Best For
Induced Draft Counterflow	Vertical, counter to water	Top-mounted	Most commercial HVAC
Induced Draft Crossflow	Horizontal across water	Top-mounted	Lower noise, maintenance access
Forced Draft Counterflow	Vertical, counter to water	Bottom-mounted	Indoor installations
Forced Draft Crossflow	Horizontal	Bottom-mounted	Freeze protection
Natural Draft	Convective	None	Very large industrial

Tower Type	Airflow Pattern	Fan	Best For
Hybrid Dry	Air + water combination	Varies	Plume abatement, water conservation

11.3 Key Design Terms

- **Range** = Entering water temp minus leaving water temp (typically 10 degrees F for HVAC)
- **Approach** = Leaving water temp minus outdoor wet bulb (typically 7-10 degrees F)
- **Design Wet Bulb** = ASHRAE 0.4% cooling design wet bulb for the project location
- **Heat Rejection** = Chiller cooling load + compressor heat (cooling tower tons = chiller tons x 1.25 approximately)

11.4 Input Fields

Field	Description	Typical HVAC Values
Heat Rejection (Tons)	Total heat to reject	Chiller tons x 1.25
Entering Water Temp (F)	Hot water from condenser	95 F
Leaving Water Temp (F)	Cold water to condenser	85 F
Water Flow (GPM)	Condenser water flow	3.0 GPM/chiller ton
Design Wet Bulb (F)	Outdoor design condition	Per ASHRAE weather data

11.5 Fill Types

Fill Type	Efficiency	Water Quality Tolerance	Cost
Film (PVC)	Highest	Low (needs clean water)	Standard
Splash	Moderate	High (tolerates sediment)	Higher
Hybrid	Good	Moderate	Moderate
Low-Clog	Good	Highest	Premium

11.6 Makeup Water

The J∆S Engineering Suite calculates cooling tower water consumption including:

- **Evaporation**: Approximately 1% of circulation rate per 10 degrees F range
- **Drift**: 0.001-0.005% of circulation rate (with modern drift eliminators)
- **Blowdown**: Depends on cycles of concentration (typically 3-6 cycles)

```
Makeup_GPM = Evaporation + Drift + Blowdown
Evaporation = CW_GPM x Range / 1000
Drift = CW_GPM x 0.002%
Blowdown = Evaporation / (Cycles - 1)
```

11.7 Output

The tower selection produces: nominal and design capacity, range and approach, water and air flow rates, fan motor HP, physical dimensions, weight, sound level at 50 feet, makeup water rate, and manufacturer recommendations.

12. Heat Pump Systems

The `heat_pump_design.py` module provides comprehensive heat pump sizing and analysis for building electrification projects.

12.1 Heat Pump Types

Type	Application	Refrigerant	SEER2 Range	HSPF2 Range
Air Source (ASHP)	Ducted residential/light commercial	R-410A, R-454B	14-22	7-12
Cold Climate (ccHP)	Northern climates, ducted	R-410A, R-32	15-20	9-13
Ductless Mini-Split	Single zone, wall mount	R-410A, R-32	16-33	9-15
Multi-Zone Mini-Split	2-8 zones from one outdoor unit	R-410A	16-24	9-12
Water Source (WSHP)	Geothermal or loop systems	R-410A	N/A	N/A
Ground Source (GSHP)	Geothermal ground loops	R-410A	N/A	N/A
Hybrid (Dual Fuel)	Heat pump + gas furnace	R-410A	14-20	7-10
Heat Pump Water Heater	Domestic hot water	R-134a, R-744	N/A	UEF 2.0-4.0

12.2 Key Input Fields

Field	Description	Example Value
Cooling Load (BTU/hr)	Peak block cooling	60,000
Heating Load (BTU/hr)	Peak block heating	45,000
Climate Zone	ASHRAE zone for location	5A (Cool Humid)
Design Outdoor Temp (F)	Winter design temperature	5 F
Compressor Type	Single, two-stage, or variable	Variable Speed
Backup Heat Type	None, electric strip, gas furnace	Electric Resistance

12.3 Balance Point Analysis

The balance point is the outdoor temperature at which the heat pump's heating capacity equals the building heating load. Below the balance point, supplemental (backup) heat is required.

```
Balance_Point = T_room - (q_hp_rated / UA_building)
```

The J∆S Engineering Suite plots the heat pump capacity curve against the building load line to determine:

- The thermal balance point temperature
- The economic balance point (where backup heat is cheaper)
- Annual heating energy by source (heat pump vs. backup)
- Defrost energy penalty (2-10% depending on outdoor temp)

12.4 Cold Climate Requirements (NEEP)

For cold climate heat pump projects, the J∆S Engineering Suite verifies compliance with NEEP ccASHP specifications:

Requirement	Minimum Value
COP at 47 F	>= 3.0
COP at 17 F	>= 2.0
COP at 5 F	>= 1.75
Capacity loss at 17 F	<= 30% of rated
Minimum operating temp	-15 F or lower

12.5 ENERGY STAR Requirements

System Type	Min SEER2	Min EER2	Min HSPF2
Ducted	15.2	11.7	7.8
Ductless	15.2	9.0	8.5

13. Ground Source Heat Pumps

The `ground_source_heat_pump.py` module designs geothermal heat pump systems with ground loop sizing.

13.1 Loop Types

Loop Type	Description	Land Requirement	Bore Depth
Vertical Closed	U-tube in boreholes	Minimal	150-500 ft each
Horizontal Closed	Trenched loops	1,500-3,000 ft per ton	4-6 ft deep
Slinky	Coiled horizontal loops	Less than straight horizontal	4-6 ft deep

Loop Type	Description	Land Requirement	Bore Depth
Pond/Lake	Submerged coils	Access to water body	N/A
Open Loop (Well)	Groundwater pump/return	Well drilling access	Varies
Standing Column	Single deep well	Minimal	500-1,500 ft

13.2 Soil Thermal Conductivity

The module includes a database of soil thermal conductivity values critical for ground loop sizing:

Soil/Rock Type	Conductivity (BTU/hr-ft-F)	Heat Transfer Rate (BTU/hr per ft bore)
Heavy Clay (Saturated)	1.0 - 1.4	30 - 40
Light Clay	0.5 - 0.8	20 - 28
Heavy Sand (Saturated)	1.2 - 1.6	32 - 42
Light Sand (Dry)	0.4 - 0.6	15 - 22
Limestone	1.4 - 2.0	35 - 50
Granite	1.5 - 2.5	40 - 55

13.3 Hybrid GSHP Systems

The module supports hybrid configurations that supplement the ground loop during peak conditions:

- GSHP + Cooling Tower (reduces bore field size for cooling-dominant buildings)
- GSHP + Boiler (reduces bore field size for heating-dominant buildings)
- GSHP + Solar Thermal (recharges ground for balanced annual loads)

14. CO2 (R-744) Heat Pumps

The `co2_heat_pump.py` module designs transcritical CO2 heat pump systems, which are gaining adoption for high-temperature hot water production and building electrification.

14.1 System Types

Type	Application	Hot Water Temp	COP Range
Water Heating (EcoCute)	Domestic hot water	140-185 F	3.0-5.0
Space Heating	Hydronic heating	120-150 F	2.5-4.0
Simultaneous	Heating + cooling	Varies	5.0-8.0 (combined)
Industrial	High-temp process	Up to 250 F	2.0-3.5

14.2 Advantages of CO_2 Heat Pumps

- GWP = 1 (lowest possible for non-natural refrigerants)
- Excellent for high-temperature lift applications (domestic hot water at 140+ degrees F)
- Transcritical cycle provides efficient heat rejection at variable gas cooler pressures
- No ozone depletion potential
- Particularly effective in cold climates where temperature lift is high

15. VRF/VRV Systems

The `vrf_design.py` module designs Variable Refrigerant Flow systems with indoor/outdoor unit selection, refrigerant piping sizing, and branch controller placement.

15.1 Opening the Module

Navigate to **Advanced Tools > VRF Design** in the sidebar. The module opens with tabs for system configuration, indoor units, outdoor units, piping, and branch controllers.

15.2 System Types

Type	Description	Simultaneous Heating/Cooling
Heat Pump (HP)	All indoor units in same mode	No
Heat Recovery (HR)	Independent mode per indoor unit	Yes

15.3 Indoor Unit Types

Type	CFM Range	ESP (in. WG)	Sound (dBA)	Best Application
Wall Mount	200-700	0	20-35	Hotels, residences
Ceiling Cassette (4-way)	300-1,400	0.08	28-40	Open offices, retail
Ceiling Cassette (1-way)	250-900	0.04	26-38	Corridors, narrow spaces
Concealed Duct	200-1,600	0.12-0.30	24-35	Spaces requiring ducted supply
High Static Duct	400-3,000	0.40-1.00	30-42	Long duct runs, large zones
Floor Console	200-600	0	22-34	Perimeter heating, under windows
Ceiling Suspended	300-1,200	0.04	28-38	Exposed ceiling applications

15.4 Piping Limits

The J∆S Engineering Suite enforces manufacturer piping limits per AHRI 1230:

Parameter	Maximum Limit
Total piping length (ODU to farthest IDU)	540 ft
Actual piping length (not equivalent)	330 ft
Elevation difference (ODU above IDU)	130 ft
Elevation difference (ODU below IDU)	164 ft
ODU to first branch controller	295 ft
Branch controller to indoor unit	130 ft
Maximum indoor units per system	64
Maximum connected capacity ratio	130%
Minimum connected capacity ratio	50%

15.5 Outdoor Unit Sizing

Standard outdoor unit sizes range from 6 to 48 nominal tons. The total connected indoor unit capacity should be between 50% and 130% of the outdoor unit's rated capacity. This range is called the **capacity ratio** or **connection ratio**.

15.6 Refrigerant Piping Sizing

The module automatically sizes liquid and suction refrigerant lines based on capacity:

Capacity (kBTU/hr)	Liquid Line OD (in.)	Suction Line OD (in.)
0 - 18	0.25	0.50
18 - 30	0.375	0.625
30 - 54	0.50	0.75
54 - 90	0.625	0.875
90 - 144	0.75	1.00
144 - 240	0.875	1.125
240 - 360	1.00	1.375

15.7 Efficiency Ratings for VRF

VRF systems are rated by EER (cooling) and COP (heating):

Manufacturer	Typical EER	Typical IEER	Typical COP (Heating)
Daikin VRV	10.5-13.5	18-24	3.5-4.5

Manufacturer	Typical EER	Typical IEER	Typical COP (Heating)
Mitsubishi CITY MULTI	10.0-13.0	17-23	3.4-4.3
LG Multi V	10.5-12.5	17-22	3.3-4.2
Samsung DVM	10.0-12.0	16-21	3.2-4.0
Carrier/Toshiba	10.0-12.5	17-22	3.3-4.2

16. Pump Sizing

Hydronic pumps circulate chilled water and hot water through the building. The J∆S Engineering Suite provides pump sizing through the `pump_selection.py` module, the `pump_curves.py` performance analysis module, and the `pump_calculator_app.py` GUI application.

16.1 Opening the Module

Navigate to **Sizing Tools > Pump Calculator** in the sidebar for the pump sizing tool, or **Advanced Tools > Pump Curves** for detailed pump curve analysis with system curve overlay.

16.2 Pump Applications

Application	Typical Flow	Typical Head	Pump Type
Chilled Water Primary	2.4 GPM/ton	60 ft	End Suction or Split Case
Chilled Water Secondary	2.4 GPM/ton	80 ft	End Suction (with VFD)
Condenser Water	3.0 GPM/ton	50 ft	Split Case
Hot Water Primary	Per boiler flow	50 ft	End Suction
Hot Water Secondary	Per building load	70 ft	End Suction (with VFD)
Hot Water Recirculation	0.5-10 GPM	5-25 ft	Circulator
Domestic Water Booster	Per fixture demand	40-150 ft	End Suction or Vertical Turbine
Fire Pump	Per NFPA 20	Per system	Listed Fire Pump
Sump	Per drainage calc	15-40 ft	Submersible

16.3 Pump Configuration Types

Type	Efficiency	Application	Cost
Circulator	55%	Small HW loops	Low
Inline	65%	Light commercial	Low-Medium
Close Coupled	70%	General HVAC	Medium

Type	Efficiency	Application	Cost
End Suction	75%	Standard HVAC	Medium
Split Case	82%	Large systems	High
Vertical Turbine	78%	Deep well, booster	High
Submersible	60-70%	Sump, sewage	Medium

16.4 Pump Horsepower

Pump brake horsepower is calculated as:

```
Pump_BHP = (GPM x Head_ft) / (3,960 x Pump_Eff)
```

Where:

- **GPM** = flow rate in gallons per minute
- **Head_ft** = total dynamic head in feet of water
- **3,960** = conversion constant (GPM x ft to HP)
- **Pump_Eff** = pump efficiency (varies by type, see table above)

Select the next standard motor size above the calculated BHP with a 15% service factor. Add VFD (Variable Frequency Drive) for all secondary pumps and any pump over 5 HP per ASHRAE 90.1-2022.

16.5 NPSH Analysis

The module calculates Net Positive Suction Head (NPSH) to prevent cavitation:

```
NPSHA = H_atm + H_static - H_friction - H_vapor
```

The NPSHA must exceed the pump's NPSHR by at least 5 ft for a safe margin. If the NPSH margin is less than 5 ft, the J∆S Engineering Suite issues a warning.

16.6 Specific Speed

Pump specific speed (Ns) determines the optimal impeller type:

```
Ns = RPM x sqrt(GPM) / Head^0.75
```

Specific Speed	Impeller Type	Efficiency
500 - 2,000	Radial	Lower
2,000 - 4,000	Francis	Peak
4,000 - 8,000	Mixed Flow	Good
> 8,000	Axial	Lower at high head

16.7 VFD Savings Analysis

The module calculates annual VFD energy savings based on the affinity laws (power varies as the cube of speed):

```
Power at reduced speed = Power_full x (Speed_ratio)^3
```

Assuming a typical load profile (20% at full speed, 30% at 80%, 30% at 60%, 20% at 40%), VFD savings are typically 40-60% of annual pump energy.

16.8 Domestic Water Booster Pump Sizing

The module includes a dedicated booster pump calculator that determines:

- Required boost pressure based on building height, street pressure, and fixture requirements
- Pump arrangement (simplex, duplex, or triplex)
- VFD vs. constant speed with pressure tank
- PRV requirements at lower floors if pressure exceeds 80 psi

16.9 Hot Water Recirculation Pump Sizing

The recirculation pump calculator sizes pumps to offset pipe heat losses:

- Calculates required flow from pipe heat loss and allowable temperature drop
- Sizes head from friction loss in the recirculation loop using Hazen-Williams
- Specifies bronze-fitted construction for potable water
- Recommends control strategy (continuous, aquastat, timer, or demand)

16.10 Worked Example: Chilled Water Pumps

Given (from chiller sizing):

- Chiller capacity: 80 tons
- CHW flow: 80 x 2.4 = 192 GPM

Primary CHW Pump:

```
Pump_BHP = (192 x 60) / (3,960 x 0.70) = 11,520 / 2,772 = 4.2 BHP --> select 5 HP motor
```

Secondary CHW Pump:

```
Pump_BHP = (192 x 80) / (3,960 x 0.70) = 15,360 / 2,772 = 5.5 BHP --> select 7.5 HP motor (with
VFD)
```

17. Fan Sizing

The `fan_selection.py` module provides comprehensive fan sizing per AMCA standards with ASHRAE 90.1 fan power compliance checking.

17.1 Opening the Module

Navigate to **Sizing Tools > Fan Laws** for fan law calculations, or use the Equipment Wizard to select fans as part of a complete system design. The Fan Laws module calculates performance changes from speed, diameter, and density variations.

17.2 Fan Types

Fan Type	Efficiency	Noise	Pressure Range	Best Application
Centrifugal Forward Curved	60%	High	Low-Medium	Small systems, FCUs
Centrifugal Backward Curved	75%	Medium	Medium-High	AHU supply/return
Centrifugal Airfoil	85%	Low	Medium-High	Large AHUs (preferred)
Centrifugal Backward Inclined	78%	Medium	Medium-High	General HVAC
Vaneaxial	78%	Medium-High	Medium	Inline ducted exhaust
Tubeaxial	65%	High	Low-Medium	Straight-through ducted
Propeller	50%	Very High	Very Low	Wall/roof exhaust
Mixed Flow	72%	Medium	Medium	Space-constrained inline
Plenum (Plug)	82%	Very Low	Medium-High	AHU plenum discharge
Inline Centrifugal	72%	Medium	Medium	General inline exhaust

17.3 Fan Applications

The module supports the following applications with specific ASHRAE 90.1 fan power limits:

Application	Fan Power Limit (BHP/1000 CFM)
Supply Air	1.10
Return Air	0.30
General Exhaust	0.30
Kitchen Exhaust	1.50
Laboratory Exhaust	1.20
Relief Air	0.30

17.4 AMCA Fan Classes

Class	Max Static Pressure	Application
Class I	3.75 in. WG	Low pressure systems
Class II	6.75 in. WG	Medium pressure (most HVAC)
Class III	12.0 in. WG	High pressure (industrial, lab)

Class	Max Static Pressure	Application
Class IV	Custom	Special applications

17.5 System Effect Factors (AMCA 201)

The J∆S Engineering Suite calculates system effect factors (SEF) based on inlet and outlet conditions:

Condition	SEF (in. WG)
Free/open inlet	0.00
Ducted inlet (standard)	0.10
Inlet with elbow	0.35
Inlet with obstruction	0.50
Non-uniform inlet	0.25
Ducted outlet (standard)	0.10
Short outlet/elbow	0.40
Free discharge (no duct)	0.50
Outlet with turning vanes	0.15

High system effects (> 0.25 in. WG combined) trigger a warning to review installation conditions.

17.6 Sound Power Calculation

Fan sound power is calculated per AMCA 300:

```
Lw = Kw + 10 x log10(CFM) + 20 x log10(SP)
```

Where Kw is a constant that depends on fan type (lower is quieter):

Fan Type	Kw
Centrifugal Airfoil	30
Plenum (Plug)	32
Centrifugal BC/BI	35
Mixed Flow	38
Vaneaxial	40
Forward Curved	42
Tubeaxial	45
Propeller	48

17.7 Air Density Correction

The module automatically corrects fan performance for altitude and temperature:

```
Density = 0.075 x exp(-Altitude / 27,000) x (530 / (460 + Temp_F))
```

At altitude, air is less dense, so more CFM is needed to deliver the same mass flow. The fan will require less BHP at altitude for the same CFM, but the system requires more CFM for the same cooling effect.

18. Exhaust Fan Sizing

The `exhaust_fan_sizing.py` module sizes exhaust fans for specific applications with code-required ventilation rates.

18.1 Exhaust Types

Type	Code Reference	Rate Basis
General	IMC/ASHRAE 62.1	CFM/sf or ACH
Toilet/Restroom	IMC Table 403.3.2	75 CFM/WC, 50 CFM/urinal
Kitchen Type I	ASHRAE 154, IMC 507	CFM per linear ft of hood
Kitchen Type II	IMC 507	CFM per sf of hood face
Laboratory	ASHRAE 62.1, NFPA 45	ACH, fume hood CFM
Paint Booth	OSHA, NFPA 33	100 FPM face velocity
Welding	ACGIH, OSHA	CFM per welding station
Parking Garage	IMC 403.3.2	0.75 CFM/sf
Locker Room	IMC 403.3.2	0.25 CFM/sf
Janitor Closet	IMC 403.3.2	100 CFM
Copy Room	IMC 403.3.2	0.5 CFM/sf or 6 ACH

18.2 Kitchen Hood Sizing

The module calculates kitchen exhaust based on hood type and cooking equipment duty level:

Hood Type	Light Duty (CFM/ft)	Medium Duty (CFM/ft)	Heavy Duty (CFM/ft)	Extra Heavy (CFM/ft)
Wall Canopy	200	300	400	550
Island Canopy	250	350	500	700
Single Island	300	400	600	800
Proximity	150	200	250	-
Back Shelf	200	275	350	-

18.3 Fan Selection

For small exhaust fans (under 500 CFM), inline or ceiling-mounted fans are typical. For larger systems, roof-mounted upblast fans (Greenheck CUBE or equivalent) provide weather protection and easy maintenance access.

19. Coil Selection

The `coil_selection.py` module provides comprehensive coil sizing with a full PyQt6 GUI interface for cooling and heating coil selection per AHRI 410 standards.

19.1 Opening the Module

The coil selection tool is integrated into the AHU and FCU design workflows. It can also be accessed as a standalone calculation by importing the module in the equipment wizard.

19.2 Coil Types

Coil Type	Application	Fluid	Rows	FPI
Chilled Water	AHU/FCU cooling	44/54 F water	4-8	8-14
DX (Direct Expansion)	DX cooling systems	Refrigerant	3-6	10-14
Hot Water	AHU/FCU heating	180/160 F water	1-4	8-12
Steam	Preheat, humidif.	5-15 PSIG steam	1-2	6-10
Electric	Duct heating	N/A	1-3	N/A

19.3 Key Design Limits (AHRI 410)

Parameter	Cooling Coil	Heating Coil
Min face velocity	200 FPM	200 FPM
Max face velocity	550 FPM	800 FPM
Min water velocity	1.0 fps	1.0 fps
Max water velocity	8.0 fps	8.0 fps
Typical FPI range	8-14	6-12

19.4 Input Fields

Design Conditions Tab:

- Application (Cooling or Heating)
- Coil Type (Chilled Water, DX, Hot Water, Steam, Electric)
- Airflow (CFM), entering DB/WB, altitude

- Target leaving DB/WB
- Water temperatures and fluid type (water or glycol solutions)
- Steam pressure (for steam coils)

Coil Configuration Tab:

- Maximum face height and width (inches)
- Maximum rows
- Preferred FPI (fins per inch)
- Fin type (Plate, Wavy, Corrugated, Louvered, Spine)
- Tube pattern (Staggered or Inline)
- Manufacturer selection (Trane, Carrier, Daikin, York, Heatcraft)

19.5 Performance Output

The coil selection report includes:

- Total, sensible, and latent capacity (BTU/hr, tons, MBH)
- Sensible heat ratio (SHR)
- Leaving air DB, WB, and relative humidity
- Apparatus dew point (ADP) and bypass factor (BF)
- Face velocity and face area
- Air-side pressure drop
- Water flow rate, velocity, and pressure drop
- Coil geometry (height x width, rows, FPI)
- Total surface area

19.6 Bypass Factor

The coil bypass factor (BF) indicates what fraction of air passes through the coil without being fully conditioned. Lower BF means better dehumidification:

```
BF = 0.45 x 0.7^(rows-1) x (8/FPI)^0.3 x (V_face/400)^0.25
```

Rows	8 FPI	10 FPI	12 FPI	14 FPI
2	0.32	0.29	0.27	0.25
4	0.16	0.14	0.13	0.12
6	0.08	0.07	0.06	0.06
8	0.04	0.03	0.03	0.03

For dehumidification-critical applications (museums, hospitals), specify 6-8 rows with 12-14 FPI.

19.7 Glycol Correction

When glycol is used (freeze protection), the coil capacity and water flow must be corrected:

Glycol Concentration	Specific Heat Factor	Density Factor	Capacity Penalty
0% (water)	1.00	1.00	0%
20% Propylene Glycol	0.96	1.02	5-8%
30% PG	0.92	1.03	10-15%
40% PG	0.88	1.04	15-22%
50% PG	0.84	1.06	22-30%

20. Heat Exchanger Selection

The `heat_exchanger_selection.py` module designs heat exchangers for HVAC hydronic applications using LMTD and Effectiveness-NTU methods.

20.1 Opening the Module

Navigate to **Advanced Tools > Heat Exchanger** in the sidebar.

20.2 Heat Exchanger Types

Type	U-Value (BTU/hr-ft2-F)	Pressure Rating	Best For
Brazed Plate	200-400	435 psi	Standard HVAC
Gasketed Plate	150-350	150 psi	Easy maintenance
Shell and Tube	100-200	600+ psi	High pressure/temp
Coaxial/Tube-in-Tube	50-150	300 psi	Small applications
Double-Wall Plate	150-300	435 psi	Potable water isolation

20.3 Applications

Application	Hot Side	Cold Side	Approach
Waterside Economizer	Condenser water	Chilled water	2-5 F
Heat Recovery	Condenser water	Heating water	5-10 F
DHW Preheat	Condenser water	City water	5 F
Pool Heating	Boiler water	Pool water	10 F
Snow Melt	Boiler water	Glycol loop	10 F

Application	Hot Side	Cold Side	Approach
Geothermal Loop	Ground loop	Building loop	3-5 F
District Energy	District supply	Building loop	3-5 F

20.4 Key Calculations

Log Mean Temperature Difference (LMTD):

```
LMTD = (dT1 - dT2) / ln(dT1 / dT2)
```

Required Surface Area:

```
A = Q / (U x LMTD x F)
```

Where F is the correction factor for the flow arrangement (1.0 for counterflow, 0.8-0.95 for other arrangements).

Fouling Factors:

Fluid	Fouling Factor (hr-ft2-F/BTU)
Clean treated water	0.0001
City water	0.0005
Cooling tower water	0.001
Clean glycol	0.0002
River water	0.002

21. Humidifier Sizing

The `humidifier_sizing.py` module sizes commercial and industrial humidification systems.

21.1 Humidifier Types

Type	Energy Source	Efficiency	Water Quality	Maintenance
Electrode Steam	Electric	95%	Potable or softened	Cylinder replacement
Element Steam	Electric	98%	RO or DI preferred	Low
Gas-Fired Steam	Natural gas	80%	Potable	Moderate
Evaporative Wetted Media	Adiabatic	85%	Potable	Media replacement
Evaporative Spray	Adiabatic	70%	RO or DI	Nozzle cleaning
Ultrasonic	Electric	90%	RO or DI	Transducer replacement
High-Pressure Fog	Adiabatic	92%	RO required	Nozzle cleaning

21.2 Load Calculation

The humidification load is calculated from the difference in moisture content between entering and required leaving air:

```
Load_lb_hr = 4.5 x CFM x (W_leaving - W_entering)
```

Where W is the humidity ratio in grains per pound of dry air, and 4.5 is the constant derived from: (0.075 lb/ft3 x 60 min/hr) / 7000 grains/lb.

21.3 Application Requirements

Application	Target RH	Tolerance	Humidifier Type
General Comfort	30-50%	+/- 5%	Electrode Steam
Healthcare	30-60%	+/- 5%	Element Steam
Data Center	40-60%	+/- 5%	Electrode Steam
Museum/Archive	45-55%	+/- 3%	Element Steam or Ultrasonic
Printing	45-55%	+/- 3%	Evaporative or Steam
Textile	50-65%	+/- 5%	Evaporative Wetted Media
Cleanroom	35-55%	+/- 2%	Element Steam (RO water)

21.4 Dispersion and Absorption Distance

Steam humidifiers require adequate duct length downstream for the steam to be absorbed into the airstream without causing condensation on duct walls. The module calculates the required absorption distance based on duct velocity, capacity, and duct dimensions.

22. Equipment Schedule Tables

The J∆S Engineering Suite generates equipment schedules in standardized tabular formats through the `equipment_schedules.py` and `equipment_schedule_app.py` modules. Schedules are suitable for inclusion in construction document Mechanical Specification sections and on drawing sheets.

22.1 Opening the Module

Navigate to **Plant Equipment > Equipment Schedule** in the sidebar. The Equipment Schedule application supports all major equipment categories.

22.2 Supported Equipment Categories

The schedule module generates formatted tables for:

- Air Handling Units (AHUs)

- Rooftop Units (RTUs)
- Chillers
- Boilers
- Cooling Towers
- Pumps (HVAC and plumbing)
- Fans (supply, return, exhaust)
- VAV Terminal Units
- Fan Coil Units
- Heat Pumps
- VRF Outdoor and Indoor Units
- Unit Heaters
- Water Heaters
- Expansion Tanks
- Air Separators
- VFDs and Motor Starters

22.3 AHU Schedule Columns

Column	Description
Tag	Equipment identifier (e.g., AHU-1, AHU-2)
Location	Mechanical room or floor served
Supply CFM	Design supply airflow
Return CFM	Design return airflow
OA CFM	Minimum outdoor air
TSP (in. WG)	Total static pressure at design airflow
Fan Motor HP	Nameplate motor horsepower
Cooling MBH	Total cooling coil capacity in thousands of BTU/hr
CHW GPM	Chilled water flow through cooling coil
Heating MBH	Heating coil capacity in thousands of BTU/hr
HW GPM	Hot water flow through heating coil
Filter Type	Filter rating (e.g., MERV 13 + MERV 8 prefilter)
Controls	DDC, VFD, economizer, demand-controlled ventilation

22.4 Chiller Schedule Columns

Column	Description
Tag	Equipment identifier (e.g., CH-1)
Type	Air-cooled screw, water-cooled centrifugal, etc.
Capacity (Tons)	Nominal cooling capacity
kW/ton	Full-load efficiency
IPLV	Integrated part load value
EWT / LWT	Entering/leaving chilled water temperatures
CHW GPM	Evaporator water flow
CW GPM	Condenser water flow (water-cooled only)
Refrigerant	Type (R-134a, R-1234ze, etc.)
Voltage	Electrical supply (e.g., 460V/3ph/60Hz)
FLA	Full load amps
MCA / MOP	Minimum circuit amps / Maximum overcurrent protection

22.5 Pump Schedule Columns

Column	Description
Tag	Equipment identifier (e.g., CHWP-1)
Service	Primary CHW, Secondary CHW, Primary HW, etc.
GPM	Design flow rate
Head (ft)	Total dynamic head
Motor HP	Nameplate motor horsepower
RPM	Motor speed
Voltage	Electrical supply
FLA	Full load amps
VFD	Yes/No for variable frequency drive
Impeller Trim	Percentage of full impeller diameter
NPSH Required	Net Positive Suction Head Required

22.6 Motor Data

The equipment schedule module automatically estimates motor data based on horsepower. Motor full load amps (FLA) are estimated for standard 460V/3Ph motors:

HP	FLA (460V)	NEMA Premium Eff.
1	1.8	85.5%
5	7.6	89.5%
10	14.0	91.7%
25	34.0	93.0%
50	65.0	94.1%
100	124.0	95.0%
200	240.0	95.8%

22.7 Export Formats

Equipment schedules can be exported in:

- **CSV** for spreadsheet editing
- **Excel** for formatted schedules with column widths
- **PDF** for construction document inclusion
- **TXT** for plain text reports

22.8 How to Read Equipment Schedules

- **MBH** means thousands of BTU/hr (M = Roman numeral for 1,000).
- **MCA** (Minimum Circuit Ampacity) determines wire size; **MOP** (Maximum Overcurrent Protection) determines breaker size.
- **EWT/LWT** are entering/leaving water temperatures at the equipment, not at the coil.
- All flows and capacities are at **design conditions** unless otherwise noted.
- "N+1" in the remarks column means a standby unit is provided for redundancy.

23. Equipment Selection Wizard

The `equipment_wizard.py` module provides a step-by-step wizard interface that guides engineers through equipment selection for any supported equipment type.

23.1 Opening the Wizard

Navigate to **Plant Equipment > Equipment Wizard** in the sidebar. The wizard opens with an equipment type selector on the first page.

23.2 Supported Equipment Types

The wizard supports: Chiller, Boiler, Air Handling Unit, Cooling Tower, VRF System, Heat Pump, Pump, Fan, and Rooftop Unit.

23.3 Wizard Steps

1. **Equipment Type Selection** -- Choose the category of equipment
2. **Load Input** -- Enter or import loads from the Room Load Calculation module
3. **System Configuration** -- Select plant configuration, redundancy, and staging
4. **Equipment Parameters** -- Enter design conditions (temperatures, pressures, flow rates)
5. **Manufacturer Preference** -- Select preferred manufacturer or "any"
6. **Selection Results** -- Review selected equipment with performance data
7. **Schedule Generation** -- Generate equipment schedule entry

23.4 Redundancy Configurations

Config	Description	Application
None	Single piece of equipment	Budget projects, non-critical
N+1	One standby unit	Standard for critical spaces
2N	Full redundancy (two complete systems)	Data centers, hospitals
2N+1	Full redundancy plus one spare	Mission-critical facilities

23.5 Features

- **Load-based matching**: Automatically matches equipment to calculated loads
- **AHRI certified data**: Integrates with manufacturer performance databases
- **Part-load curves**: Input or select from standard part-load performance curves
- **Multi-manufacturer comparison**: Compare selections from Trane, Carrier, Daikin, and York side-by-side
- **Energy simulation integration**: Feed selections into the 8,760-hour energy simulation module

24. Safety Factors and Diversity

24.1 Recommended Safety Factors

Equipment Type	Cooling Safety Factor	Heating Safety Factor	Justification
Chillers	10%	N/A	Load uncertainty, degradation
Boilers	N/A	15-25%	Morning warm-up, altitude
AHU Cooling Coils	5-10%	10-15%	Coil fouling

Equipment Type	Cooling Safety Factor	Heating Safety Factor	Justification
AHU Fans	10-15%	N/A	System effect, duct leakage
Pumps	10% head, 0% flow	Same	Piping aging, valve losses
Cooling Towers	10%	N/A	Fill degradation
Heat Pumps	0-10%	10-15%	Depends on backup heat strategy

24.2 Diversity Factors

Diversity factors reduce central plant capacity below the sum of individual zone peaks because not all zones peak at the same time:

Building Type	Cooling Diversity	Heating Diversity
Office building	0.85-0.90	0.80-0.85
Hotel	0.65-0.75	0.70-0.80
Hospital	0.90-1.00	0.90-1.00
Data center	1.00	N/A
Retail	0.85-0.95	0.80-0.90
School	0.85-0.90	0.85-0.90
Apartment/Condo	0.60-0.70	0.65-0.75

24.3 When NOT to Apply Safety Factors

- Energy modeling (use actual calculated loads)
- Utility rebate applications (over-sizing disqualifies some rebates)
- Title 24 compliance calculations (use actual loads per ACM)
- When equipment already has built-in capacity margin

25. ASHRAE 90.1-2022 Minimum Efficiency Requirements

25.1 Unitary Air Conditioners and Heat Pumps

Equipment	Size	Min EER2	Min IEER
Split Systems	< 65 kBTU/hr	11.2	12.9
Single Package	< 65 kBTU/hr	11.0	12.1
Split Systems	65-135 kBTU/hr	11.0	12.4
Split Systems	135-240 kBTU/hr	10.8	12.2

Equipment	Size	Min EER2	Min IEER
Split Systems	240-760 kBTU/hr	10.0	11.6
Split Systems	> 760 kBTU/hr	9.8	11.0

25.2 Heat Pump Heating Efficiency

Equipment	Size	Min COP (47 F)	Min COP (17 F)
Split Systems	< 65 kBTU/hr	3.3	2.25
Single Package	< 65 kBTU/hr	3.3	2.25
Split Systems	65-135 kBTU/hr	3.3	2.05
Split Systems	135-240 kBTU/hr	3.2	2.05

25.3 Boiler Minimum Efficiency

Fuel	Type	Size (MBH)	Min Et (%)	Min Ec (%)
Gas	Hot Water	< 300	82	80
Gas	Hot Water	300-2,500	84	82
Gas	Hot Water	> 2,500	84	82
Gas	Steam	< 300	80	79
Gas	Steam	300-2,500	79	79
Oil	Hot Water	< 300	84	82
Oil	Hot Water	300-2,500	85	83
Oil	Steam	< 300	82	80
Oil	Steam	300-2,500	83	81

25.4 Fan Power Limitations (ASHRAE 90.1-2022 Section 6.5.3)

Fan systems with total fan motor nameplate HP exceeding specific thresholds must demonstrate compliance with fan power limits. The allowable fan system BHP is calculated based on design supply airflow plus system pressure drop adjustments.

25.5 Pump Power Limitations

ASHRAE 90.1-2022 requires:

- Variable speed drives on pumps exceeding specific thresholds
- Hydronic system balance using automatic balancing valves or calibrated balance valves
- Isolation valves on equipment to allow shutdown without draining the system

26. Part Load Performance

26.1 Why Part Load Matters

HVAC equipment operates at full load only a few hours per year. The majority of operating hours are at 25-75% of design capacity. Equipment selection should prioritize part-load efficiency (IPLV, IEER, NPLV) over full-load efficiency.

26.2 IPLV/NPLV Weighting

The AHRI standard weighting factors for IPLV calculation are:

```
IPLV = 0.01 x A + 0.42 x B + 0.45 x C + 0.12 x D
```

Where:

- A = Performance at 100% load
- B = Performance at 75% load
- C = Performance at 50% load
- D = Performance at 25% load

The 0.45 weighting at 50% load reflects the reality that most buildings spend the majority of operating hours near half capacity. The 0.01 weighting at full load shows that peak conditions are rarely sustained.

26.3 Chiller Part Load Behavior

Load %	Typical kW/ton (WC Screw)	Typical kW/ton (WC Centrifugal)	Typical kW/ton (Magnetic Bearing)
100%	0.62	0.55	0.48
75%	0.57	0.49	0.40
50%	0.48	0.43	0.32
25%	0.42	0.40	0.28
IPLV	0.48	0.42	0.35

Magnetic bearing centrifugal chillers show the most dramatic part-load improvement because the oil-free compressor eliminates bearing friction losses at low speeds.

26.4 Boiler Part Load Behavior

Condensing boilers maintain high efficiency across a wide load range because:

- High turndown ratios (10:1 or better) eliminate short-cycling
- Lower return water temperatures at part load improve condensing operation
- Modulating burners track load precisely

Non-condensing boilers lose efficiency at part load due to increased standby losses and cycling.

26.5 VFD Impact on Pumps and Fans

Variable frequency drives (VFDs) dramatically reduce energy consumption at part load because power varies as the cube of speed:

Speed	Flow	Head	Power
100%	100%	100%	100%
80%	80%	64%	51%
60%	60%	36%	22%
40%	40%	16%	6%

A pump or fan operating at 60% speed uses only 22% of full-load power.

27. Manufacturer Selection Guidance

The J∆S Engineering Suite includes manufacturer catalogs and performance data for major HVAC equipment manufacturers. While the software does not endorse specific brands, the following manufacturers are commonly specified in commercial HVAC projects and are included in the equipment selection databases.

27.1 Chillers

Manufacturer	Strengths	Common Product Lines
Trane	Industry-leading centrifugal and helical-rotary compressors	RTAC (air-cooled), CenTraVac (centrifugal), CVHE/CVHF
Carrier	Wide range of capacities, strong controls integration	AquaEdge 19DV, 30XA (air-cooled), 30XV
Daikin	Excellent part-load efficiency, magnetic bearing	Magnitude (centrifugal), Pathfinder (air-cooled)
York (JCI)	Competitive pricing, strong VSD offerings	YVAA (air-cooled), YZ (magnetic bearing), YKEP
Thermax	Absorption chiller specialist	Absorption single/double effect

27.2 Boilers

Manufacturer	Strengths	Common Product Lines
Lochinvar	Industry leader in condensing technology	CREST, KNIGHT, Copper-Fin II
Cleaver-Brooks	Heavy commercial and industrial applications	ClearFire, Model CB, HAWK
Aerco	Modular condensing, excellent turndown	Benchmark, Innovation
Weil-McLain	Commercial cast iron and condensing	Evergreen, SVF

Manufacturer	Strengths	Common Product Lines
Fulton	Vertical design, pulse combustion	Endura, VMP
Burnham	Commercial cast iron, atmospheric	Alpine, Aspen, MPO-IQ
Patterson-Kelley	Compact high-efficiency	MACH boilers
Raypak	Pool heating and commercial	MVB, XTherm

27.3 Cooling Towers

Manufacturer	Strengths	Product Lines
Evapco	Market leader, wide range	AT, UT, eco-Air
BAC (Baltimore Aircoil)	Premium quality, low sound	Series 3000, VXI
SPX Cooling (Marley)	Large industrial and HVAC	NC, MD Everest
Tower Tech	Factory-assembled, modular	TTXR

27.4 Pumps

Manufacturer	Strengths	Product Lines
Bell & Gossett	Standard HVAC pumps, broadest selection	Series e-80, e-1510, Series 100
Armstrong	Energy-efficient, integrated VFDs	Design Envelope, 4300
Grundfos	Small to medium, premium quality	CR, TP, MAGNA, Alpha
Peerless	Fire pumps, large HVAC	Horizontal Split Case, Vertical Turbine
Wilo	European quality, smart pumps	Stratos, CronoLine

27.5 Fans

Manufacturer	Strengths	Common Product Lines
Greenheck	Market leader, broadest selection	CUBE (upblast), SQ/BSQ (inline), G/GB (centrifugal), Vektor
Cook	Competitive pricing, quick delivery	Gemini (upblast), ACE (inline)
Twin City Fan	Heavy-duty industrial and airfoil	BAF, BAMF, PCV
Hartzell	Vaneaxial and tubeaxial specialist	Series 31, Series 44
Loren Cook	Quality centrifugal fans	Model CDB, Model ACE

27.6 VRF/VRV Systems

Manufacturer	Product Line	Max IDU per ODU	Recovery Type
Daikin	VRV IV, VRV IV-S	64	Heat Recovery
Mitsubishi Electric	CITY MULTI Y/R2	50	Heat Recovery
LG	Multi V 5	64	Heat Recovery
Samsung	DVM S2	64	Heat Recovery
Carrier/Toshiba	VRF Systems	48	Heat Recovery

27.7 Air Handling Units

Manufacturer	Strengths	Common Product Lines
Trane	Custom and semi-custom, strong energy recovery	Climate Changer, M-Series
Carrier	Wide range, good controls	39M Aero, 39CC
Daikin	Energy recovery expertise	Rebel, Maverick
McQuay/Daikin	Premium custom AHUs	Skyline, Distinction

27.8 VAV Terminal Units

Manufacturer	Strengths	Common Product Lines
Trane	Integrated controls, low leakage	DERA (single duct), DPRA (parallel fan)
Carrier	Competitive pricing	Trumarc, EasyCool
Price	Premium quality, low noise	SD/DD series, fan-powered series
Nailor	Strong reheat coil options	N-Series, Model 7400

27.9 Coils

Manufacturer	Strengths	Product Lines
Trane	Factory-matched AHU coils	WCCM, WCCH, HWCM
Carrier	Integrated with AHU platform	39M, 39S, 39H
Daikin	CW and DX coils	CW-Series, DX-Series
York	Standard commercial coils	CWC, DXC, HWC
Heatcraft	Refrigeration and unit heater coils	LP, ML series

When specifying equipment, always list a basis of design manufacturer with "or approved equal" to maintain competitive bidding while establishing the expected quality level.

28. Common Mistakes and Pitfalls

28.1 Over-Sizing

The Problem: Selecting equipment significantly larger than the calculated load.

Consequences:

- Chillers short-cycle, reducing compressor life and degrading humidity control
- Boilers short-cycle, increasing standby losses and thermal shock on heat exchangers
- Fans and pumps operate at low efficiency, far from their best efficiency point (BEP)
- Higher first cost, larger electrical service, larger mechanical room

Prevention: Apply appropriate safety factors (not "comfortable" round-up numbers). A 10% safety factor on a 97-ton load means selecting 107 tons, not 120 tons.

28.2 Ignoring Altitude Effects

The Problem: Using sea-level constants and ratings at elevation.

Consequences:

- The 1.08 sensible heat factor drops at altitude (0.92 at 5,000 ft), meaning more CFM is needed
- Boiler capacity is derated 4% per 1,000 ft above 2,000 ft elevation
- Fan motor HP calculated from standard air density will be insufficient at altitude
- Chiller condenser fan motors need altitude derating for air-cooled machines

Prevention: Always set the project altitude in the J∆S Engineering Suite project settings. The software automatically adjusts all density-dependent calculations.

28.3 Wrong Entering/Leaving Conditions

The Problem: Confusing coil conditions with chiller/boiler conditions.

Consequences:

- Specifying 44 F CHW supply as the coil EWT when the coil actually sees 46-48 F after piping losses
- Using 85 F entering condenser water when the tower actually delivers 87-88 F at peak
- Specifying boiler supply temperature as the reheat coil EWT when the coil sees 165-170 F after distribution losses

Prevention: Account for piping temperature gains (CHW typically 2-3 F, HW typically 5-10 F) between plant and coil.

28.4 Forgetting Pump Heat

The Problem: Not accounting for pump energy added to the water.

Consequences: In a chilled water system, pump energy adds approximately 2-5 degrees F to the water temperature over a day of operation. This additional heat load must be rejected by the chiller.

Rule of Thumb: Add 3-5% to the chiller capacity for pump heat in the chilled water loop.

28.5 Incorrect Diversity Application

The Problem: Applying diversity to outdoor air, or not applying it when appropriate.

Consequences:

- Reduced outdoor air violates ASHRAE 62.1 and can cause IAQ problems
- Not applying diversity to zone loads results in over-sized central plant

Prevention: Never reduce outdoor air below code minimums. Apply diversity only to thermal loads, not to ventilation air.

28.6 Selecting Based on Full Load Efficiency Alone

The Problem: Choosing the chiller with the best full-load kW/ton while ignoring IPLV.

Consequences: A chiller with excellent full-load efficiency but poor part-load performance will cost more to operate annually than a chiller with slightly worse full-load but superior IPLV.

Prevention: Compare selections based on IPLV/NPLV for realistic annual energy cost.

28.7 Ignoring Water-Side Fouling

The Problem: Sizing coils and heat exchangers for clean conditions without fouling allowance.

Consequences: Performance degrades over time as scale and deposits accumulate on heat transfer surfaces.

Prevention: Include appropriate fouling factors (see Section 20.4) and size coils with 10% excess capacity for fouling.

28.8 Glycol Without Capacity Correction

The Problem: Sizing coils for water when the system uses glycol.

Consequences: 30% propylene glycol reduces coil capacity by 10-15% compared to plain water. A coil sized for water will under-perform with glycol.

Prevention: Always specify the glycol concentration in the J∆S Engineering Suite and verify capacity corrections are applied.

28.9 Condensing Boiler with High Return Water Temperature

The Problem: Specifying a condensing boiler on a system with 160 F+ return water.

Consequences: Condensing boilers require return water below approximately 130 F to achieve condensing operation. Above this temperature, efficiency drops to non-condensing levels (82-85%), wasting the premium paid for condensing technology.

Prevention: Design heating systems with low-temperature distribution (radiant floors, fan coils with larger coils) to take advantage of condensing boilers. Or use a non-condensing boiler and save the premium.

29. Integration with Load Calculations

29.1 Load-to-Equipment Flow

The J∆S Engineering Suite maintains a data flow from load calculations to equipment selection:

1. **Room Load Calculation (Guide 01)** produces zone-level cooling and heating loads in BTU/hr
2. Zones are assigned to **systems** (VAV, FCU, etc.) which aggregate zone loads with diversity
3. Systems are assigned to **plants** (chiller plant, boiler plant) which aggregate system loads
4. Equipment is selected from the aggregated plant loads

29.2 Automatic Data Import

When using the Equipment Wizard, loads can be imported directly from saved project files (.mep files). The wizard automatically:

- Sums zone loads by system assignment
- Applies appropriate diversity factors
- Calculates outdoor air requirements
- Determines peak block loads by system and plant

29.3 Equipment Schedule Integration

Selected equipment populates the Equipment Schedule module, which can then be exported as a complete equipment schedule for construction documents. The schedule includes all calculated performance data, electrical data, and physical data.

29.4 Energy Simulation Integration

Equipment selections feed into the 8,760-hour energy simulation module, which uses:

- Chiller part-load curves at each hour
- Boiler part-load efficiency at each hour
- Fan and pump affinity law calculations at each hour
- Weather data for all 8,760 hours of the year
- Building load profiles from the hourly load calculation

This integration allows accurate annual energy cost estimation and system comparison.

30. Abbreviations and Formulas Reference

30.1 Common Abbreviations

Abbreviation	Meaning
ACH	Air Changes per Hour
ADP	Apparatus Dew Point
AFUE	Annual Fuel Utilization Efficiency
AHU	Air Handling Unit
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AMCA	Air Movement and Control Association
BEP	Best Efficiency Point
BF	Bypass Factor
BHP	Brake Horsepower
BTU/hr	British Thermal Units per hour
CFM	Cubic Feet per Minute
CHW	Chilled Water
COP	Coefficient of Performance
CTI	Cooling Technology Institute
CW	Condenser Water
DDC	Direct Digital Control
DeltaT	Temperature Differential
DX	Direct Expansion
ECM	Electronically Commutated Motor
EER	Energy Efficiency Ratio
EER2	EER per DOE 2023 test procedure
EWT	Entering Water Temperature
FCU	Fan Coil Unit
FLA	Full Load Amps
FPI	Fins Per Inch
FPM	Feet Per Minute
GPM	Gallons Per Minute
GSHP	Ground Source Heat Pump
GWP	Global Warming Potential
HP	Horsepower
HSPF	Heating Seasonal Performance Factor

Abbreviation	Meaning
HSPF2	HSPF per DOE 2023 test procedure
HW	Hot Water
IEER	Integrated Energy Efficiency Ratio
IPLV	Integrated Part Load Value
LMTD	Log Mean Temperature Difference
LWT	Leaving Water Temperature
MBH	Thousands of BTU per hour
MCA	Minimum Circuit Ampacity
MOP	Maximum Overcurrent Protection
NC	Noise Criteria
NEEP	Northeast Energy Efficiency Partnerships
NPSH	Net Positive Suction Head
NPLV	Non-Standard Part Load Value
NTU	Number of Transfer Units
OA	Outdoor Air
RTU	Rooftop Unit
SEER	Seasonal Energy Efficiency Ratio
SEER2	SEER per DOE 2023 test procedure
SEF	System Effect Factor
SHR	Sensible Heat Ratio
TSP	Total Static Pressure
VAV	Variable Air Volume
VFD	Variable Frequency Drive
VRF	Variable Refrigerant Flow
VRV	Variable Refrigerant Volume (Daikin trade name)
WG	Water Gauge (inches)
WSHP	Water Source Heat Pump

30.2 Key Formulas Summary

Airflow from sensible load:

```
CFM = q_sensible / (1.08 x DeltaT)
```

Note: 1.08 applies at sea level. At altitude, multiply by (local_density / 0.075).

Total cooling capacity from enthalpy:

```
q_total = 4.5 x CFM x (h_entering - h_leaving)
```

Where h is enthalpy in BTU/lb.

Fan horsepower:

```
BHP = (CFM x TSP) / (6,356 x Fan_Eff x Motor_Eff)
```

Water flow from load:

```
GPM = q / (500 x DeltaT)
```

Note: 500 = 8.33 lb/gal x 60 min/hr x 1.0 BTU/lb-F. Adjust for glycol.

Pump horsepower:

```
BHP = (GPM x Head_ft) / (3,960 x Pump_Eff)
```

Chiller flow rule of thumb:

```
CHW_GPM = Tons x 2.4 (at 10 deg F DeltaT)
CW_GPM = Tons x 3.0 (at 10 deg F DeltaT)
```

Boiler input from output:

```
Input_MBH = Output_MBH / Efficiency
```

COP from kW/ton:

```
COP = 12.0 / kW_per_ton
```

Cooling tons from BTU/hr:

```
Tons = BTU_hr / 12,000
```

IPLV:

```
IPLV = 0.01 x A + 0.42 x B + 0.45 x C + 0.12 x D
```

VFD power at reduced speed:

```
Power = Power_full x (N/N_full)^3
```

LMTD:

```
LMTD = (dT1 - dT2) / ln(dT1 / dT2)
```

Pump specific speed:

```
Ns = RPM x sqrt(GPM) / Head^0.75
```

Cooling tower makeup water:

```
Evaporation_GPM = CW_GPM x Range / 1000
Blowdown_GPM = Evaporation / (Cycles - 1)
Makeup = Evaporation + Blowdown + Drift
```

Humidification load:

```
Load_lb_hr = 4.5 x CFM x (W_out - W_in) / 7000
```

Altitude correction for air density:

```
Density = 0.075 x exp(-Alt/27000) x (530/(460+T))
```

Boiler altitude derating:

```
Derate = 1.0 - 0.04 x ((Alt - 2000) / 1000) for Alt > 2000 ft
```

30.3 Standard Conditions

Parameter	Value
Air density (sea level, 70 F)	0.075 lb/ft3
Air specific heat	0.24 BTU/lb-F
Water density	8.33 lb/gal
Water specific heat	1.0 BTU/lb-F
Sensible heat constant (1.08)	60 min/hr x 0.075 lb/ft3 x 0.24 BTU/lb-F
Water flow constant (500)	60 min/hr x 8.33 lb/gal x 1.0 BTU/lb-F
Latent heat constant (4,840)	60 min/hr x 0.075 lb/ft3 x 1,076 BTU/lb
1 ton of cooling	12,000 BTU/hr
1 boiler HP	33,475 BTU/hr
1 HP (mechanical)	746 watts
1 ft of water head	0.433 psi
1 psi	2.31 ft of water

30.4 Standard Motor Sizes (HP)

```
0.25, 0.33, 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 5.0, 7.5, 10, 15, 20, 25,
30, 40, 50, 60, 75, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500
```

Always select the next standard size above the calculated BHP with service factor applied.

30.5 Voltage Configurations

Designation	Typical Application
120V/1Ph/60Hz	Small controls, unit heaters < 5 kW
208V/1Ph/60Hz	Small motors < 1 HP, residential equipment
208V/3Ph/60Hz	Small commercial motors, mini-splits
230V/1Ph/60Hz	Residential, small commercial
230V/3Ph/60Hz	Small to medium commercial
460V/3Ph/60Hz	Standard commercial/industrial (most common)
575V/3Ph/60Hz	Canadian standard voltage

This guide is part of the JΔS Engineering Suite documentation series, published by JS Engineering Solutions. For load calculation methodology, see Guide 01. For duct and pipe sizing, see Guide 03. For compliance checking, see Guide 04.