

SECTION 1.00 — ARCHITECTURAL FEATURES

Obtain a fairly complete set of architectural floor plans. They should be final or existing drawings. Schematic or preliminary drawings are not desirable due to the possibility of extensive changes. The drawings should indicate dimensions to be listed to calculate surface areas. Try not to scale a drawing unless absolutely necessary.

A. FLOOR PLANS

1. Obtain floor areas for all spaces to be conditioned. Areas can be separated into three types: air conditioned, heated only, and unconditioned.
2. Obtain roof areas of uppermost floors. Obtain areas of exposed floor section.
3. Using indicated floor to ceiling heights, obtain all partition areas of spaces adjacent to unconditioned spaces.
4. Obtain partition floor and ceiling areas of unconditioned spaces above and below conditioned space.

B. BUILDING ELEVATIONS

1. Obtain wall and glass areas by building exposure. Separate areas of various wall and glass types. Door areas can be calculated separately or included in a wall type.
2. Obtain linear footage of window and door crack lengths for calculation of infiltration described in Section 3.00.

C. WALL SECTIONS

1. Determine all construction materials and thicknesses for each exterior wall type, exposed floor or ceiling type, and interior partition type adjacent to unconditioned spaces. This information is used for calculation of U-Values.

D. U-VALUE CALCULATIONS

1. Heat Transfer Coefficient, or U-Value, describes the heat transfer performance of a wall, roof, floor, or ceiling section. Heat transfer through a section is determined using the following equation:

$$(EQ. 1-1) Q = U \times A \times \Delta T$$

Q = Heat Transfer (BTUH)

U = U-Value (BTUH/SF - Degrees F)

A = Area (Sq. Ft.)

DELTA T = Temperature Difference (°F)

2. Thermal Resistance, or R-Value describes the resistance to heat transfer of a particular construction material or section.
3. Calculation Procedure
 - a. Determine construction materials and thicknesses.
 - b. Determine R-Value of each material.
 - c. Sum the R-Values of all construction materials in section including, air spaces, outdoor air film, and indoor air film.
 - d. The U-Value of a section equals the inverse of the sum of the R-Values.

$$(EQ. 1-2) U\text{-Value} = \frac{1}{\Sigma R\text{-Values}}$$

SECTION 2.00 — ACT 222 ENERGY CODE COMPLIANCE

The Pennsylvania Energy Code applies to all new construction and all renovation projects where at least 25 percent of the existing building is being renovated.

It is the responsibility of the HVAC Design Department to ensure that the proposed building meets the requirements of Act 222.

A. REQUIREMENTS

1. The code requires that all applicable buildings meet the requirements of ASHRAE 90A-80, “Energy Conservation in New Building Design.”
2. Perform the ASHRAE 90A-80 Building Envelope Compliance Calculations using the Microsoft Excel Spreadsheet. Preliminary run should occur at the very start of the project, or a final run should occur when the compliance form is completed (approximately 50 percent through Working Drawing Phase).
3. References:
 - a. Degree Days: Use NOAA Weather Data or ASHRAE.
 - b. Building Degrees North Latitude: Use latest edition of ASHRAE Fundamentals.
 - c. Summer Outdoor Design Temperature: Use latest edition of ASHRAE Fundamentals 2.5 percent design dry-bulb (Act 222 Compliance Only).
 - d. Summer Indoor Design Temperature Use 78°F (ASHRAE 90A-80).

B. CALCULATION PROCEDURE - EXCEL SPREADSHEET

1. Input general project information.
2. Input building criteria and weather data.
3. Input building envelope areas for each exterior wall, glass, roof, skylight, and exposed floor type.
4. Input U-Values for all areas.

5. Input wall density in lbs/sq. ft.
 $D = \text{density} \times \text{thickness}$
6. Input roof TC Values.
(EQ. 1-3) $TC = \text{density} \times \text{thickness} \times \text{specific heat}$
7. Input shading coefficients for glass and skylights.
8. Calculate spreadsheet and print out.

C. OUTPUT EVALUATION

1. Preliminary Run (at start of Schematic Phase) - Compare the required ASHRAE winter U-Values and summer OTTV-Values for compliance. If any assumed values do not meet the required values, a warning will appear on the printout. If there are no warnings, the building complies and the calculation procedure is complete.
2. If a warning appears, calculate the insulation R-Value necessary to meet the required ASHRAE value indicated. Notify the Architect of your findings and make a final run.
3. If additional insulation is not a feasible solution, glass types may need to be changed to lower the U-Value or shading coefficient. Glass areas may also be reduced to lower the overall U-Value. The Architect must be notified immediately to make these changes.
4. When all building envelope areas, U-Values, and shading coefficients are final, make a final run on the Excel spreadsheet and send a copy to the Architect.

D. ACT 222 COMPLIANCE FORM

The HVAC Design Department must complete the "Certificate of Design" form, LIBI 455 with Revision 12/82, for every project that is required to meet the Pennsylvania Energy Code. This form is required by the Architect to receive Pennsylvania Department of Labor and Industry approval.

The form should be completed when approximately 50 percent through the Working Drawing Phase of the project. The following items should be checked to complete the form:

1. Building name, street address, owner name and address: This information should be obtained and verified by the Architect.
2. Design: Check the box stating, “I certify in my professional opinion ...”.
3. Include the signature, title, and address of the registered design professional responsible for reviewing the project. Include his engineering stamp on each copy of the form.
4. Design criteria: Check the box titled, “Building Design Information” stating compliance with ASHRAE Standard 90A-80.
5. Do not complete the section titled, “Inspection...”. This is to be completed by the Owner and Contractor at the completion of the project.
6. Complete the Act 222/Building Design information form. Refer to sample completed form at the end of this section.
7. The electrical lighting budget must be obtained from the electrical department to complete the form.
8. Deliver completed Act 222 compliance forms to the Architect. Include a copy of an updated Excel spreadsheet output using final U-Values and construction areas.

SECTION 3.00 — HEATING/COOLING LOAD ESTIMATING

A. PRELIMINARY INFORMATION

1. Obtain all envelope surface areas as described under Section 1.00 – Architectural Features.
2. Calculate U-Values for each envelope under Section 1.00, Item D, U-Value Calculations.

Use the following minimum:

- a. Use 0.10 BTUH/SF - °F as a minimum U-Value for exterior walls.
- b. Use 0.08 BTUH/SF - °F as a minimum U-Value for roofs.
- c. If design load calculations are a required submittal, ignore the above minimum and use the U-Values calculated for the ASHRAE 90A – 80 Compliance.
- d. Determine HVAC system type. Each type of HVAC system has design features that affect the method and data required to calculate building heating/cooling loads. These effects must be determined by the designer before proceeding with the calculations. The following are some of the items affected by the type of HVAC system:
 - 1) Building zoning
 - 2) Use of return air plenum.

B. CARRIER LOAD ANALYSIS PROGRAM

Use Carrier Hourly Analysis Program (HAP) for all heating/cooling load calculations unless use of another method of computer program is specifically authorized by the HVAC Department Manager.

Included are several definitions that are needed to clarify the procedure while running the Carrier HAP program.

1. Space: Specific room or area.

2. Zone: Consists of spaces served from a single air handling unit or unitary equipment.
 - a. Supply air temperatures: Cooling and heating.
 - b. Ventilation air loads.
 - c. Fan motor loads.
 - d. Coil bypass factors.

3. Building Zoning: Each space within the building must be zoned to a particular HVAC system type or equipment type. Zoning is accomplished by grouping spaces with similar exposures and separating interior and exterior spaces. This is especially important for single zone air conditioning systems such as packaged rooftop units or split system units. The HVAC system type should be determined before zoning is considered. Use the following procedure as a general guide to building zoning:
 - a. Separate spaces into air conditioned, heated only, and unconditioned. This will be helpful in determining partition loads.
 - b. Group air conditioned spaces by exterior exposure or interior.
 - c. Group each space by HVAC system type.
 - d. For single zone air conditioning systems, group all spaces with a common exposure to be served by a respective thermostat.
 - e. For variable air volume systems, group all spaces to be served by a single air handling unit.
 - f. For terminal systems, zoning is not critical since each space is considered a zone.

The step-by-step procedure included in this manual consists of specific information to be used as a standard for design. For a complete detailed explanation of HAP, refer to the online HAP Help Menu or consult the Carrier HAP User's Menu.

C. PROGRAM INPUTS

HAP is structured to mimic the standard Windows environment. Projects are broken into five basic categories: Weather, Spaces, Systems, Project Libraries, and Plants. Each category (with the exception of Plants) must be completed to generate heating/cooling loads.

A template HAP project has been created that reflects the JDB standards for design. The template project has been named JDB MASTER. The following information is the basis for all design projects.

1. Weather
 - a. Weather data for various cities throughout the world can be selected through this menu. ASHRAE weather data has been used to create the weather profiles. Under the JDB MASTER, York, Pennsylvania has been selected. The winter design Wet Bulb and Dry Bulb have been modified to 0°F. All other data is unmodified.
 - b. Simulation City (Function currently not available)

2. Project Libraries

Under this category, basic building information is input. Categories include Schedules, Walls, Roofs, Windows, Doors and Shades.

- a. Schedules for equipment, people, lighting, and thermostats are used to determine loads in individual spaces. Schedules should be set up for 24 hour or 12 hour, 7 a.m. to 7 p.m., operation at 100% for equipment, people, and lighting. Thermostat schedules should be set up for 12 hour occupied/unoccupied for typical operations. Schedules may be altered for special cases as approved by the HVAC Department Manager.

The following schedules are set in the JDB MASTER.

- 1) 100% (24 Hour, 100% diversity)
- 2) 100% 7-7 (12 Hour, 100% diversity)
- 3) Thermostat (12 hour, Occupied/Unoccupied Schedule)

- b. Wall types: JDB standard is 0.10 BTUH/SF - °F as a minimum U-Value for exterior walls. Use wall defined in JDB MASTER unless cooling/heating load calculations are required as a submittal. Color of wall should be medium. If cooling/heating load calculation submittals are required, use actual U-Values and colors.
- c. Roof types: JDB standard is 0.08 BTUH/SF - °F as a minimum U-Value for roofs. Use roof defined in JDB MASTER unless cooling/heating load calculations are required as a submittal. Color of roof should be dark. If cooling/heating load calculation submittals are required use actual U-Values and colors.
- d. Windows: JDB standard is 1/8” double pane clear glass with 1/4” air space, aluminum with thermal breaks. U-Value is 0.691 BTUH/SF - °F and Overall Shading Coefficient is 0.792. If cooling/heating load calculation submittals are required, use actual U-Values and tints. Internal shading should not be used unless approved by the HVAC Department Manager. JDB MASTER assumes window as 1 square foot.
- e. Doors: Two doors (6 foot and 3 foot) have been included in JDB MASTER. Edit to suit project requirements.
- f. Shades: As a general rule this section is not used. If required for project, consult with HVAC Department Manager.

3. Spaces:

Under this category, specific information is input for each space to determine heating/cooling loads. Categories include General, Internal Loads, Walls, Windows, Doors, Roofs, Skylights, Infiltration, Floors, and Partitions.

- a. General: General data for space such as space name, floor area, average ceiling height, and building weight is entered in this worksheet.

- 1) Space Naming: Input space name in the following format:

Room Number - Room Name

Ex: 110 - Executive Office

If room numbers are not available, use another identifying feature such as zone name or air handler tag.

- 2) **Building Weight:** Input value for overall building weight if known. Use medium as a standard for building weight if unknown.
 - 3) Input floor area and average ceiling height as determined by architectural floor plan. If ceiling height is not known, assume 9 feet.
- b. **Internal Loads:** Internal space loads generated by lighting, people, equipment, and miscellaneous loads are entered in this worksheet.
- 1) **Lighting:**
 - a) Input actual lighting wattage from Electrical Department if known. If value is unknown, refer to Watts per Square Foot Lighting Guideline attached at the end of this section.
 - b) Ballast Multiplier should equal 1.0.
 - c) Input fixture type as follows:
 - Recessed, not vented – recessed mounted fluorescent and incandescent fixtures.
 - Vented – return air fixtures or light troffers.
 - Free hanging – free hanging fluorescent, incandescent, high pressure sodium or metal halide.
 2. **People:**
 - a) Input specific number of people as an additional element if possible unless using square foot per person estimates.
 - b) Input actual number of people obtained from the Architect or Owner.

c) If actual number of people is not available, use the following sources of information:

- ◆ Furniture layout.
- ◆ ASHRAE 62-1989 estimated maximum occupancy. Carefully evaluate the correctness of these values.
- ◆ Minimum two (2) people per private office.
- ◆ Maximum 125 square feet per person for general open office space.

d) Input activity level as follows:

Seated at Rest	230S / 120L
Office Work	245S / 205L
Sedentary Work	280S / 270L
Medium Work	295S / 455L
Heavy Work	525S / 925L
User Defined	Consult ASHRAE Fundamentals Handbook

3. Equipment Loads: Input equipment loads per ASHRAE Fundamentals Handbook and attached JDB Equipment Loads.
4. Miscellaneous Loads: Additional sensible and latent loads for special cases as approved by HVAC Department Manager.
5. Set up all schedules for 24-hour or 12-hour, 7:00 AM to 7:00 PM, operation at 100% occupancy. Schedules can be altered for special cases as approved by the HVAC Department Manager.

c. Walls, Windows and Doors

- 1) Input gross wall areas by exposure. The gross wall area equals the area from finished floor to underside of structural deck. HAP will calculate the net wall area by subtracting the glass and door area.

- 2) Exposures can be input for each 45 degree wall orientation angle from north. Buildings are seldom positioned with a true north face even though floor plans may indicate this. Verify building orientation with Architectural Site Plan.
- 3) Input glass areas.
- 4) Input doors where required.
- 5) Select wall, window, and door types from the pull-down menus adjacent to the input screen. Note: Shades are not used unless approved by HVAC Department Manager.

d. Roof, Skylights

- 1) Input gross roof area and skylights for space, if required. This is not a required input. Skylights can be generated under the “Windows” section of the project library.
- 2) Select roof and skylight types from the pull-down menus adjacent to the input screen.

e. Infiltration

- 1) Use the crack method to determine peak infiltration airflow rates in CFM for each space. Use the following infiltration rates for windows and doors:

Fixed window	0.10 CFM/lf
Operable window - metal	0.50 CFM/lf
Double hung window - wood	0.65 CFM/lf
Exterior door - limited use	1.00 CFM/lf
Exterior door - frequent use	8.00 CFM/lf

- 2) Calculate crack length for fixed windows along rough opening perimeter.
- 3) Calculate crack length for operable windows along perimeter of operable portion. Add rough opening perimeter of fixed portion.
- 4) Include infiltration in heating load only. Do not include infiltration in cooling load.
- 5) Check the all hours option on when to include infiltration.

f. Floors

- 1) Check architectural drawings for proper installation of perimeter slab insulation.
- 2) Input perimeter of floor slab on or below grade, depth of slab below grade, and square foot of slab as a ground element.

g. Partitions

- 1) Partitions must be input as an additional element if required.
- 2) Calculate the partition wall area from finished floor to ceiling.
- 3) Include floors over unconditioned space and ceilings below unconditioned space.
- 4) Input the temperature of adjacent unconditioned space as a percentage of the indoor-outdoor temperature difference. Use the following values unless special conditions dictate otherwise:

Unconditioned:	50% TD Cooling, 100% TD Heating
Heated Only:	50% TD Cooling, 0% TD Heating
Heating to 55°F:	50% TD Cooling, 25% TD Heating

4. Systems

In this worksheet, various air systems can be input to determine the heating/cooling loads for the project. The following information should be used as the basis of design for the various systems. In the JDB MASTER template project, several types of air systems have been input with the standard variables.

a. General

1. System Description: Enter the system name in the following format.

Job Number - Air system tag or zone description

- Ex. 90015 AH-1
- Ex. 90015 Cafeteria
- Ex. 90015 Zone-1

2. Choose the appropriate type of equipment. If unknown, use the *undefined* option to determine the heating/cooling loads. This option allows more flexibility in design when the equipment type is not available in the program.
3. Enter the number of zones when applicable.

b. System Components

1. Ventilation Air

- a) Input ventilation air as CFM/person.
- b) Use 20 CFM/person for each zone block load calculation.
- c) Use zone block occupancy level and not the peak sum of people from each room to determine ventilation air requirements.
- d) Use ASHRAE 62-89 as a guide for determining required ventilation rates for special use areas such as cafeterias, auditoriums, and gymnasiums.

2. Economizer

- a) JDB Standard Economizer Cycle is Non-Integrated Dry – Bulb type with the upper cutoff temperature at 55°F and the lower cutoff temperature at 0°F. For use of other economizer options, consult with the HVAC Department Manager.

3. Ventilation Reclaim, Precool, Preheat, Humidification and Dehumidification

- a) Input values as required for project. Consult with HVAC Department Manager for typical values.

4. Central Cooling

- a) Input supply air as a discharge temperature input type. Use the following temperatures depending on HVAC system type:

Chilled Water:	55 ° F
Built-up DX:	55 ° F
Packaged DX:	58 ° F

- b) Capacity Control: As determined by the HVAC system type.
- c) Coil bypass factor: 0.10.

5. Central Heating

- a) Input supply air temperature based on the following HVAC system types:

Hot Water (160° F)	100° F
Steam	100° F
Electric	100° F
Fuel-Fired Furnace	100° F
Heat Pump	95° F
Heat Recovery Hot Water (105°F - 115°F)	85 °F

6. Supply Fan: Input supply fan total static pressure using the following HVAC system types:

◆ Terminal Equipment	1/2"
◆ Packaged Single Zone Unit Built-up Central Station	1-1/2"
◆ Air Handler-Single Zone	2"
◆ Packaged VAV Unit	2 1/2"
◆ Built-up Central Station Air Handler - VAV	3"
◆ Medium Velocity Air Handler	5"

- a) Use default value for total fan efficiency.
- b) Use draw-through fan configuration except for fan coil units or similar package terminal equipment.

7. Duct System: Input whether a return air plenum is used. If a plenum is used, input the following percentages for loads directed to plenum:
 - a) 20% of lighting load to plenum.
 - b) 35% of roof load to plenum.
 - c) 0% of wall load to plenum when plenum height < 50% of floor to ceiling height.
 - d) 25% of wall load to plenum when plenum height \geq 50% of floor to ceiling height.

8. Return Fan: Input return fan data if required for project.

c. Zone Components:

- 1) Input space to the appropriate zone.
 - 2) Thermostats: Input the following thermostat setpoints:

Occupied Cooling:	75°F
Unoccupied Cooling:	85°F
Heating:	72°F
 - 2) Input the direct exhaust airflow as 100% of the ventilation airflow.
 - 3) Supply Terminals: Select the appropriate type of VAV box or other supply terminal for each zone. Note: different terminal types may be selected for each zone on the same air system.
- d. Sizing Data: Choose the appropriate sizing data for the project. Zones should be sized for the sum of peak space air flows.

D. DESIGN LOAD CALCULATIONS

Procedure for design load calculations.

1. First Calculation Run – Maximum Space Cooling Loads:
 - a. Select all air systems to be run.

- b. Input user specified range of hours. Typically, use all months and hours for calculations unless zone peak is known.
- c. Under “Output Options,” output the following:
 - 1) Maximum space cooling loads.
 - 2) Zone cooling load summary.
 - 3) Design space heating loads.

Note: Never output design space cooling loads.

2. Second Calculation Run – Block Cooling Load:

- a. Determine block people diversity by dividing block maximum occupancy by sum of space peak occupancy from the first run zone cooling load summary.
- b. Use the global change option to change people schedule from 100 percent to available diversity schedule. Round percent diversity up.

Ex. Block Maximum Occupancy = 50 people
Sum of Space Peak Occupancy = 75 people
Diversity Percent = $75/50$ people = 0.66
Diversity Schedule = 70%

- c. Repeat steps 2a and 2b if block lighting diversity is required for zone.
- d. Select all systems to be run. Attempt to include all building zones to obtain a building peak block load.
- a. Under “Output Options,” output the following:
 - 1) Maximum space cooling loads.
 - 2) Zone cooling load summary.
 - 3) Design space heating loads.

3. Engineering Checks - Output:
 - a. Check ventilation rate in each zone for compliance with ASHRAE 62-1989 to ensure indoor air quality. Document findings in Project Memo for file.
 - b. Check that heating ventilation rate matches cooling ventilation rate.
 - c. If ventilation rate is less than 10 percent of supply air, increase rate to 10 percent for positive building pressurization.
 - d. If ventilation rate is less than exhaust air quantity, increase rate to match or exceed exhaust air rate.
 - e. Check square foot/ton and CFM/square foot to make sure data falls within typical values. Typical values are listed in Figure 7.
 - f. If data appears inaccurate, check all input sheets. Notify HVAC Department Manager before re-running loads.
 - g. It may be necessary to print out zone summaries for each space depending on system type or specific project requirements. Notify HVAC Department Manager to determine necessity.

| SECTION 4.00 — PIPING DESIGN

SECTION 4.01 – WATER SYSTEMS

A. GENERAL INFORMATION

1. Hydronic piping systems have two related but distinct concerns:
 - a. Size of pipe.
 - b. Flow-pressure relationship

Both are critical in designing functional hydronic piping.

B. PIPE SIZING CRITERIA

1. There are several concerns that govern the size of piping after the flow rate has been determined. Noise, erosion, and installation/operating costs all limit the maximum and minimum velocities in a piping system. Refer to ASHRAE Handbook of Fundamentals for a detailed description of these limitations.
2. General pipe sizing guidelines are as follows:
 - a. Do not exceed a velocity of 3 FPS for pipes smaller than 2" in diameter or a friction loss of 3 feet per 100 feet of piping for all pipe sizes. Do not exceed a velocity of 10 FPS in any piping. The table below represents the JDBE guideline for sizing hydronic piping.
 - b.

Pipe Sizing Standards

<u>Nominal Pipe Size</u>	<u>Max. Flow (GPM)</u>
1/2"	1.0
3/4"	3.0
1"	6.0
1 1/4"	11.0
1 1/2"	17.0
2"	40.0
2 1/2"	65.0
3"	115.0
4"	230.0
6"	700.0
8"	1400.0
10"	2400.0
12"	3500.0

SECTION 4.02 — STEAM SYSTEMS

A. GENERAL INFORMATION

1. The following information is required before determining pipe sizes:
 - a. The initial pressure of the supply steam.
 - b. The system flow rate.
 - c. The total pressure drop allowed between source and end of system.
 - d. The maximum velocity of the steam.
 - e. The equivalent length of piping from boiler to farthest heating unit.

B. INITIAL SUPPLY STEAM PRESSURE

1. Low Pressure Steam
 - a. Low pressure steam is typically used for HVAC heating applications. Pressure ranges from 5 to 15 psig.
 - b. Use 15 psig as a standard low pressure steam supply for HVAC applications to allow an adequate pressure at the farthest piece of equipment.
2. High Pressure Steam
 - a. High pressure steam is typically used for process applications. Pressure ranges from 50 to 150 psig and higher.
 - b. Steam pressure for process applications should be determined by the process equipment requirement.

C. SYSTEM FLOW RATE

1. Determine system flow rate from boiler requirements in lbs/hr.
 - a. If lbs/hr are not available, the heating capacity (MBH) can be used as follows:

$$\text{lbs/hr} = \text{MBH} / (\text{latent heat of vapor at supply steam pressure (psia)} \times 1000)$$

latent heat of vapor (h)fg can be found in the steam tables.

2. Use the same method to determine steam flow rates for terminal heating equipment.

D. TOTAL PRESSURE DROP

1. Total pressure drop of system should not exceed 20 percent of the initial supply pressure (psig).
2. For preliminary pipe sizing, limit the pressure drop/100 ft of pipe length to 1.0 psi.

E. MAXIMUM STEAM VELOCITY

1. Steam velocity should be maintained between 4,000 to 6,000 fpm for quiet operation.
2. Steam velocity should never exceed 12,000 fpm.
3. When steam condensate flows against steam, the velocity should be less than 6,000 fpm to minimize water hammer sound and prevent water retention in the supply steam.

F. EQUIVALENT PIPE LENGTH

1. Use 1.5 times the pipe straight length for short to medium piping runs.
2. Use 1.25 times the pipe straight length for long piping runs.

G. STEAM SUPPLY PIPE SIZING

1. 0-25 psig Steam:
 - a. Using previously established flow rate, steam pressure, and pressure drop, enter Figure 10 of ASHRAE's 1997 Fundamentals Handbook to determine a preliminary pipe size, velocity, and pressure drop (psi/100ft). Note, this velocity is the equivalent steam velocity at 0 psig.

- b. Using the preliminary steam velocity at 0 psig and the supply steam pressure, enter Figure 11 to determine the steam velocity at the supply steam pressure.
 - c. This corrected velocity is the actual steam velocity at the supply steam pressure. This velocity should conform to the requirements of Part E above. If the velocity is greater than the requirements of Part E, select a larger pipe size.
 - d. Using the pressure drop (psi/100ft) and equivalent pipe length, verify the total pressure drop of the system meets the requirements of Part D. If it does not, select a larger pipe size.
2. 30-150 psig Steam:
- a. Using previously established flow rate, steam pressure, and recommended velocity range, enter Figures 10A to 10D (use the table with the corresponding steam pressure) to determine pipe size and pressure drop (psi/100ft).
 - b. By using Figures 10A to 10D, velocity correction is not required. Therefore, the pipe size can be selected within the velocity ranges specified in Part E.
 - c. Using the pressure drop (psi/100ft) and equivalent pipe length, verify the total pressure drop of the system meets the requirements of Part D. If it does not, select a larger pipe size.

H. STEAM CONDENSATE PIPE SIZING

1. Low Pressure Condensate (0-30 psig):
 - a. The majority of steam condensate systems used in HVAC applications are vented, dry systems using gravity return to a feedwater tank or local pumping station. The piping system is at atmospheric pressure with liquid condensate and a mixture of air and steam vapor.
 - b. At low pressure the percent of flash steam is minimal.
 - c. Gravity condensate piping should be sized for a pressure drop in the range of 0.25 – 0.50 psi/100 ft. This converts to a pipe slope of approximately 1/16 – 1/8 inch/ft.

- d. Using the condensate flow rate (assume equal to the steam flow rate) and pipe slope, enter Table 17 of ASHRAE's 1997 Fundamentals Handbook to determine the steam condensate pipe size.
2. High Pressure Condensate (> 30 psig):
 - a. At high pressure the percent of flash steam must be accounted for since it occupies a large portion of the condensate pipe and prohibits liquid condensate flow. Flash steam recovery should be considered.
 - b. Use Figure 56 of Spirax Sarco's Steam Hook-Ups manual to determine the steam condensate pipe size.
 - c. For a vented gravity return, use 0 psi for return line pressure.
 3. Piping Connections:
 - a. Check valves should be installed in branch lines where connected to main condensate return line.
 4. Condensate Lift:
 - a. Condensate can be lifted by upstream steam pressure: i.e., 1 psig of steam can lift 2.31 feet vertically (assuming no backpressure in the return line).
 - b. Do not lift condensate when using temperature regulated coils: i.e., modulating control valves. Steam trap must discharge strictly by gravity and must be located a minimum of 18 inches below the bottom of the coil to provide ½ psig differential pressure for discharge.

I. STEAM TRAPS (GENERAL)

1. Float & Thermostatic Steam Trap:
 - a. Use for low pressure steam systems (0-30 psig).
 - b. Can be used up to 75 psig but water hammer results.
 - c. High air venting capability.
 - d. Use for drip legs, end of mains, and riser drains.

- e. Use for on-off controlled heating coils.
 - f. Use for temperature regulated heating coils.
2. Thermodynamic Steam Trap:
- a. Use for high pressure steam systems (>75 psig).
 - b. Use exclusively for drip legs, end of mains, and riser drains.
 - c. Not suited for low pressure systems or high backpressure conditions.

Note: These represent the two traps most widely used for low pressure and high pressure steam applications. Other trap types are available. For applications other than those listed above consult Department Manager, ASHRAE Handbooks, or Spirax Sarco Manuals.

J. STEAM TRAP SELECTION

1. Float & Thermostatic Steam Trap:
- a. Use safety factor of 2 times the condensate load for drip legs, end of mains, and riser drains to determine the required steam trap capacity. This allows sufficient capacity during warm-up. Usually the smallest available size trap will have adequate capacity.
 - b. Use safety factor of 2 times the condensate load for on-off heating coils to determine the required steam trap capacity.
 - c. Use safety factor of 3 times the condensate load for temperature regulated heating coils to determine the required steam trap capacity.
 - d. Select the steam trap size that has a capacity equal to or greater than the required condensate load times the safety factor. Use 0.5 psi differential pressure.
 - e. Use two traps in parallel for heating coils with outdoor air quantity greater than 50%.
2. Thermodynamic Steam Trap:
- a. Use safety factor of 2 times the condensate load for drip legs, end of mains, and riser drains to determine the required steam trap capacity. This allows sufficient capacity during warm-up.

- b. Select the steam trap size that has a capacity equal to or greater than the required condensate load times the safety factor. Use the steam main pressure. Usually the smallest available size thermodynamic trap will have adequate capacity for drip legs, end of mains, and riser drains.

K. CONDENSATE PUMP/RECEIVER (GENERAL)

- 1. Two types of pumps:
 - a. Electric powered pump
 - b. Pressure powered pump (uses high pressure steam or compressed air as motive force.)
- 2. Packaged with integral receiver adequately sized to store incoming condensate during discharge cycle.
- 3. Discharge cycle controlled by float mechanism
- 4. Use duplex unit for stand-by availability or to use in conjunction with primary pump during heavy condensate loads.
- 5. Route vent piping up through the roof or to the exterior to relieve flash steam and to keep return system at atmospheric pressure. Refer to manufacturer literature for vent sizing.

L. CONDENSATE PUMP/RECEIVER (SELECTION)

- 1. Use a safety factor of 1.5 to 2 times the required condensate load to determine required pump capacity.
- 2. Unless it is required to pump condensate long distances, select a pump with adequate discharge pressure only to elevate and deliver condensate to a gravity return pipe back to boiler feedwater pump.
- 3. Use a pressure powered pump if high pressure steam or compressed air is readily available and adequate floor space is available for the equipment.
- 4. Use an electric powered pump if high pressure steam or compressed air is not readily available and limited floor space is available for the equipment.

5. Use electric-powered pump as the last choice since their use can be problematic due to low NPSH available and seal failure caused by the high temperature liquid.
6. Electric powered pumps generally have lower condensate capacities than pressure powered pumps.
7. Care should be taken when selecting receivers for electric pumps. Verify $NPSH_A$ and $NPSH_R$. This may require receivers to be mounted at significant heights above pumps.

4.03 COOLING COIL CONDENSATE SYSTEM PIPE SIZING

- A. Use the following chart to size condensate drain lines for cooling air coils:

Condensate Pipe Sizing Standards

Nominal Pipes Size	Connected Cooling Load in Tons
$\frac{3}{4}$ "	0 – 7
1"	8 – 15
1 $\frac{1}{4}$ "	16 – 30
1 $\frac{1}{2}$ "	31 – 50
2"	51 – 170
3"	170 – 300
4"	301 – 430
5"	431 – 700

- B. Condensate Trap Size: Refer to the attached detail for proper condensate trap for either Blow-thru or Draw-thru units.

4.04 FUEL OIL SYSTEMS

- A. General

The following information is required when sizing fuel oil systems.

1. Fuel oil type.
2. Quantity of oil being pumped (gph).
3. Total suction pipe length.
4. Vertical lift from fuel oil tank to the pump.

5. Temperature of oil being pumped to determine viscosity.

B. Design Assumptions

1. The suction imposed upon the pump must be:
 - a. 10 inches of mercury or less at the oil terminal block connection when the pump is integral with the boiler.
 - b. 12 inches of mercury or less at the pump centerline when the pump is remote from the boiler.
 - c. Assume pumping temperature to be 40°F. At this temperature, viscosity is 68 SSU for No. 2 fuel oil.

C. FUEL OIL PUMP SIZING

1. If an overhead fuel oil piping distribution system is to be used, select the flow rate for the duplex jockey pump based upon the following:

$$\begin{aligned} &\text{Required Boiler Flow (gph) times the number of boilers =} \\ &\quad \text{Total Required Flow in GPH} \\ &\text{TGPH} / 60 \text{ min. per hour} = \text{Total GPM} \end{aligned}$$

2. Determine the required head for the pump based upon the total friction loss in the system.

D. FUEL OIL PIPE SIZING

1. Determine suction lift.
 - a. Determine the vertical distance (feet) from the bottom of the suction pipe to the pump centerline for remote pumps or to the oil terminal block connection on the boiler. Use the attached Cleaver Brooks Chart No. 3 to determine the suction lift in inches of mercury.
2. Pressure drop through valves, fittings, strainers, etc.
 - a. Pressure drop varies for each individual system. Assume 2 inches of mercury for the loss through valves, fittings, strainers, and other miscellaneous devices.

3. Determine the maximum allowable pressure drop in the fuel oil suction line by subtracting the suction lift and fitting pressure drop from the applicable design assumption.

10 inches of mercury for integral oil pump
12 inches of mercury for remote oil pump

4. From Cleaver Brooks Charts Nos. 4 and 5, determine the suction pipe size based upon the maximum allowable pressure drop determined above. Total pressure drop must be equal to or less than the maximum allowable pressure drop.

Example:

Fuel Oil Flow Rate: 1.35 gph for each boiler

Total Flow Rate: 2 boilers x 1.35 = 2.7 gph

Total Suction Pipe Length: 120 ft.

Total Suction Lift: 5.5 ft.

- (1) From Chart #2, Suction Lift equals 4.2 inches of mercury.
- (2) Assume 2 inches of mercury for valve, fitting, and strainer pressure loss
- (3) For a remote fuel oil pump, the maximum allowable suction line loss equals:

$$\begin{array}{r}
 12.0'' \\
 4.2'' \\
 \underline{2.0''} \\
 5.8'' \text{ of mercury}
 \end{array}$$

- (4) From Charts Nos. 4 and 5, 8.1 gph in a ½" pipe size equals 0.8 inches of mercury per 100 ft.

Total Pressure Drop = 0.96" of mercury

Use ½" fuel oil supply.

Use ½" fuel oil return pipe.

SECTION 6.00 — PUMP SELECTION

6.01 WATER SYSTEMS

A. GENERAL INFORMATION

1. The following information is required before pump selection can be made:
 - a. System flow rate.
 - b. System pressure drop.
 - c. Pump configuration/type.

B. SYSTEM FLOW RATE

1. Chilled Water System
 - a. **Standard** – Determine system flow rate from chiller evaporator requirements. Refer to Section 9.00, “Chiller Selection and Design”.
 - b. **Primary/Secondary** – Determine primary system flow rate from chiller evaporator requirements. Determine secondary system flow rate by adding all chilled water coil design flow rates.
 - c. Use 2.4 GPM/ton for preliminary selection.
2. Condenser Water System
 - a. Determine system flow rate from chiller condenser requirements.
 - b. Use 3.0 GPM/ton if condenser requirement is not specified.
3. Cooling Tower Water System
 - a. Determine system flow rate from chiller condenser requirements if chiller and tower are in series, from cooling tower requirements if chiller and tower are decoupled.
 - b. Use 3.0 GPM/ton if condenser/tower requirements are not specified.

4. Water Source Heat Pump Loop
 - a. Determine system flow rate from closed circuit evaporative cooler requirement.
 - b. Use 3.0 GPM/ton if cooler requirement is not specified.
5. Hot Water System
 - a. **Standard** – Determine system flow rate by adding all hot water coil design flow rates.
 - b. **Primary/Secondary** – Determine primary system flow rate from boiler requirements. Determine secondary system flow rate by adding all hot water coil design flow rates.
 - c. Use 0.10 GPM/MBH for preliminary selection (based on 20°F temperature rise).

C. SYSTEM PRESSURE DROP

1. Choose piping critical path (i.e., path with the largest pressure drop).
2. Add pressure drops of applicable hydraulic components along critical path:
 - a. **Equipment** – Chiller, boiler, cooling tower, heat exchanger, coils, etc.
 - b. **Pipe Friction Loss** – Use calculated pressure drop or 3 Ft.WG/100 LF of pipe, whichever is larger.
 - c. **Pipe Fittings** – Use 25% of pipe friction loss for long piping runs and 50% of pipe friction loss for short piping runs.
 - d. **Control Valves**
 - e. **Pipe Accessories** – Air purger, suction diffuser, strainer, etc.
 - f. **Elevation Head** – Open piping systems only.
3. Apply correction factor if ethylene glycol solution is used (1987 ASHRAE Handbook, Figure 31, p. 13.24).
4. Add 10 percent and round up to nearest multiple of 5 or at least 5 ft. WG higher than summation of individual components.

D. PUMP TYPES (SEE SPECIFICATIONS FOR OTHER ACCEPTABLE MANUFACTURERS)

1. ***Inline (Type II)*** – 0-20 GPM. Bell and Gossett Booster Series.
2. ***Inline (Type III)*** – 20-80 GPM. Bell and Gossett Series 60.
3. ***Inline (Types IV, V)*** – 80-2000 GPM. Use only when there is insufficient space for end suction or split case pump. Bell and Gossett Series 80 & 90.
4. ***End Suction*** – 80-800 GPM. Bell and Gossett Series 1510.
5. ***Split Case (Horizontal or Vertical)*** – >800 GPM. Aurora Series 411 & 413.

E. PUMP SIZE SELECTION

1. Impeller/Motor Speed
 - a. ***1750 RPM*** – Use for general applications.
 - b. ***1150 RPM*** – Use for low head/high flow or low net positive suction head applications.
 - c. ***3500 RPM*** – Use for high head/low flow applications. (May not be suitable for some chiller applications.)
2. Plot design head versus design flow rate on pump curve.
3. Use Bell and Gossett System Syzer Calculator to plot system curve.
 - a. Align design flow rate and design system head.
 - b. Read required head for other flow rates. Plot these points to determine system curve.
4. Determine impeller size.
 - a. If design head and design flow do not intersect directly on impeller curve, select next larger size impeller.
 - b. Impellers are trimmed in 1/8 inch increments.
 - c. If pump curve for selected impeller size is not shown, plot by interpolation.

5. Intersection of system curve and pump curve is system operating point.
6. Determine motor size.
 - a. View highest flow condition for selected pump curve.
 - b. Choose motor horsepower from this point, not at design flow point. (This is to ensure that pump will be non-overloading.)
7. For open piping systems, check net positive suction head (NPSH).
 - a. Trace vertically downward from operating point to NPSH curve to determine minimum required NPSH.
 - b. Estimate actual NPSH from system layout.

$$\text{NPSH} = P_b \pm Z - H_f - V_p + E_p$$

where,

P_b = Barometric pressure

= 33.78 ft. WG for water at standard barometric pressure
(open systems only)

Z = Elevation head in feet

H_f = Pipe friction losses from point of elevation head
difference to pump suction in ft. WG

V_p = Vapor pressure of water in ft. WG

E_p = Expansion tank pressure in ft. WG (closed systems only)

- c. NPSH Actual must be greater than NPSH Required.

F. COMPUTER SELECTION PROGRAMS

1. The following is a list of computer pump selection programs available for use:

Bell & Gossett - E.S.P.

TACO - Taconet Link - Pump Selection Program

2. When selecting pumps with computer selection programs, care must be taken to select motor size for non-overloading conditions.
3. Include both input and output data printouts in the design documentation file.

G. INSTALLATION DETAILS

1. Provide concrete inertia bases on all pumps as standard. Refer to Section 21.00 — “Vibration and Sound Control.”
2. Vertical split case pumps may be installed directly on grade with a housekeeping pad.
3. Other pump types may be installed directly on grade with a housekeeping pad as approved by the Department Manager. Housekeeping pad locations must be carefully coordinated with structural concrete work.

SECTION 7.00 — EXPANSION AND AIR CONTROL

7.01 EXPANSION TANK SELECTION — CLOSED SYSTEMS

A. GENERAL

1. Expansion tanks serve two important functions in a closed hydronic system. They provide a location for the thermal expansion of the fluid media of the system as well as a point of constant pressure in the hydronic system.
2. There are three common types of expansion tanks: closed tanks with an air/water interface, open tanks with an air/water interface, and diaphragm expansion tanks. For most hydronic systems, a diaphragm type expansion tank will be used.

B. SIZING OF DIAPHRAGM-TYPE EXPANSION TANKS FOR A CLOSED SYSTEM

1. The following equation should be used to size the diaphragm expansion tank.

$$V_t = V_s \cdot \left[\frac{\left(\frac{v_2}{v_1} \right) - 1 - 3 \alpha \cdot \Delta t}{1 - \left(\frac{P_1}{P_2} \right)} \right]$$

V_t = Volume of expansion tank, (gal.)

V_s = Volume of water in system, (gal.)

Δt = ($t_2 - t_1$)

t_1 = Lower temperature, (°F)

t_2 = Higher temperature, (°F)

P_1 = Minimum Operating Pressure (equals fill pressure + 14.7 psig), (psia)

P_2 = Maximum Operating Pressure (at highest point + 2 psig + 14.7 psig), (psia)

v_1 = Specific volume of water at lower temperature, (ft³/lb)

v_2 = Specific volume of water at higher temperature, (ft³/lb)

α = Linear coefficient of expansion, (in./in * °F)

v = Specific volume = $\frac{1}{(\text{Density}) \text{ lb/ft}^3}$

2. For sizing of other types of expansion tanks, refer to ASHRAE Systems and Equipment Handbook.

C. SIZING CRITERIA

1. Expansion tanks in a closed system should be sized to maintain 2 psi at the highest point in the hydronic system.
2. Temperatures for design should be based upon the following for each system:
 - a. Chilled Water Systems:

Lower temperature = System Design Temp. = 44 - 46°F
Higher temperature = Ambient Temperature: Interior 75°F
Exterior 95°F
 - b. Hot Water Systems:

Lower temperature = System Fill Temp. = 50°F
Higher temperature = System Design Temp. = 180°F
3. Refer to the attached sheets for the properties of water, ethylene glycol, and propylene glycol.
4. Determine the total volume of water for the system, including piping, chillers, boilers, and coils.
5. As well as determining the water volume of the hydronic system, the Diaphragm Expansion tank calculation has been input into a Microsoft Excel spreadsheet. Refer to the attached sheet for an example of the required inputs.

7.02 EXPANSION COMPENSATION

A. GENERAL

Thermal expansion of pipes in hydronic and steam systems must be accounted for. As a guideline on straight runs of pipe, expansion compensators or loops should be used every 75 feet.

Refer to ASHRAE Handbook of Fundamentals for the different means of thermal expansion control.

7.03 AIR CONTROL

A. GENERAL

Air or gas in a hydronic system can have an adverse affect on system operation.

The following steps should be taken to prevent air-related problems such as corrosion, air bound terminal units, and noise.

1. Air Vents – Air vents should be used to remove trapped pockets of air at system high points and at coil locations.
 - a. Use automatic air vents on air handling unit coils.
 - b. Use manual air vents on terminal unit coils (i.e., fan coils, VAV boxes).
 - c. A manual air vent should be installed at the system's highest point.
2. Air control is also required to remove the air dissolved in the fluid medium. Two typical types of devices are used to remove the entrained air: centrifugal air separators and air purgers.
 - a. Air separators should be installed on all hot water heating systems.
 - b. Air purgers should be installed on all chilled water systems.
 - c. These devices are not required on open piping systems.

SECTION 8.00 – BOILER SELECTION – STEAM & HOT WATER

A. GENERAL INFORMATION

1. The following information is required before boiler selection can be made:
 - a. Block Heating Load.
 - b. System Configuration (i.e., number of boilers required).
 - c. Space Requirements.
 - d. Operation and Maintenance Requirements (personnel capability).
 - e. Regulatory Requirements for Emissions, Fuel Usage/Storage.
2. Definitions. The following are the different types of boilers.
 - a. **Boiler**
Pressure vessel that generates steam or hot water by means of heat transferred from an external source.

There are four main types of boilers: Cast Iron, Fire Tube, Water Tube, and Electric Boilers.

- b. **Fire Tube Boilers**
External shell of boiler is a pressure vessel filled with water. Fuel is burned in the combustion chamber and the hot flue gases pass through tubes surrounded by water. There are two typical types of fire tube boilers: Fire Box and Scotch Marine.
 - 1) **Fire Box Boiler**
The boiler shell of the fire box sits on top of a water-jacketed combustion chamber.
 - 2) **Scotch Marine Boiler**
The combustion chamber is circular and located inside the shell of the boiler.
- c. **Water Tube Boilers**
Water is confined to the tubes of the boiler. Combustion takes place around tubes in the combustion chamber. Water tube boilers have a fast response to changes in demand due to the small water volume of the tubes.

Flexible Water Tube

Similar to above, good thermal shock protection.

d. ***Cast Iron Boilers***

Individual cast iron sections are mechanically joined together to form water tight/pressure tight assemblies. The sections provide passages for the water and flue gases/products of combustion. Boiler capacity is dependent upon the number of sections.

e. ***Electric Boilers***

Typical boiler types include inversion resistant element boilers and electrode boilers. Capacity is controlled by staging electric elements to transfer heat to the hot water heating system.

There are several different types of burners that may be used on fuel-fired equipment.

f. ***Forced Draft/Power Burner***

A burner in which either gas or air or both are supplied at a pressure exceeding: for gas – the line pressure, and for air – the atmospheric pressure. This added pressure is applied at the burner. A burner for which air for combustion is supplied by a fan ahead of the appliance is commonly designated as a forced draft burner.

1) ***Pre-mixing.*** A power burner in which all or nearly all of the air for combustion is mixed with the gas as primary air.

g. ***Induced Draft Burner***

A burner that depends on draft induced by a fan that is an integral part of the appliance and is located downstream of the boiler.

h. ***Injection (Bunsen) Type Burner***

A burner employing the energy of a jet of gas to inject air for combustion into the burner by a jet of gas.

i. ***Fan Assisted***

A burner that uses either induced or forced draft.

B. BOILER SIZING

1. General Information

a. Determine the number of boilers required on the project. Some limitations/considerations that must be taken into account are:

- 1) Redundancy
- 2) Physical size for retrofits/renovations
- 3) Owner requirements
- 4) Future

2. System Sizing

- a. ASHRAE Standard 90.1 limits the size of heat equipment by the following formula:

Calculated Heat Load (CHL): See Section 3.00

ASHRAE allows for a 10% safety factor to be added onto the calculated heat load. This is the adjusted heat load (AHL).

$$(CHL \times 10\%) + CHL = AHL$$

ASHRAE allows for a 30% additional size increase to the adjusted heat load to allow for the pickup loads the building may experience.

$$\text{Pick Up Load} = (AHL \times 30\%)$$

$$\text{Total System Size} = AHL + \text{Pick Up Load}$$

Example:

$$CHL = 560 \text{ MBH}$$

Adjusted Heat Load:

$$560 \text{ MBH} + 560 \text{ MBH} \times 10\% = 616 \text{ MBH}$$

Pick Up Load:

$$616 \text{ MBH} \times 30\% = 184.8 \text{ MBH} \approx 185 \text{ MBH}$$

Total System Size:

$$616 \text{ MBH} + 185 \text{ MBH} = 801 \text{ MBH}$$

3. For multiple boiler installations, base boiler size on total system size divided by number of boilers required.

4. Equipment type: Based on project constraints, use the following types of boilers based on total system size.
 - a. Water Tube: 50,000 Btuh to 350,000 Btuh
 - b. Flexible Water Tube: 350,000 Btuh to 21,000,000 Btuh
 - c. Cast Iron: 240,000 Btuh to 6,000,000 Btuh
 - d. Fire Tube: As approved by HVAC Department Manager
5. Select burner types as required by project and equipment type.

C. CODE REQUIREMENTS

1. 1996 International Mechanical Code
 - a. Top Clearance

3' minimum	Boiler with top man holes or exceeding 5,000,000 Btuh input
2' minimum	Package boilers with capacity less than 5,000,000 Btuh input
 - b. Side Clearance 18" minimum. Note PA Boiler Code requires 30" clearance; JDB Standard = 36" clearance; Reduction below 36" as approved by HVAC Department Manager.
 - c. Shut Off Valves All boilers to have OS & Y shutoff valves on supply and return piping.
 - d. Pressure/Safety Relief Valves: Sized 10 psi greater than boiler operating pressure or 25% of boiler operating pressure, whichever is greater.
 - e. Pressure/Safety Relief Valve Piping: Pipe size to match relief valve discharge size piped within 3 inches above finished floor.

- f. Low Water Cutoff: All hot water boilers.
- g. Pressure & Temperature Gauges: All hot water boilers.

2. Pennsylvania Boiler Code

- a. Low water fuel cutoff with a manual reset for high pressure boilers. Automatic low water fuel cut-off required for low pressure steam boilers.
- b. Pressure relief/safety valve. Refer to Section 3.51 for different working pressure.
- c. Electric boiler grounded by same size lines as incoming power line.
- d. Electric boiler Safety screen and signs around high voltage lines.
- e. Electric boilers Safety/relief valve sized 3 ½ pounds per hour for each kilowatt maximum rating.
- f. Ladders and Walkways required over boilers that are more than 8'-0" tall.
- g. Clearances 30" clearance around all sides.
72" overhead clearance above finished floor.
42" overhead clearance over boilers without walkways.
7'-0" overhead clearance over boilers with walkways.

Note: JDB Standard = 36" clearance; Reduction below 36" as approved by HVAC Department Manager.

- h. Safety valve piping must be piped outside if the boilers generate more than 500 pounds per hour of steam.

- i. Blow off tanks Vent pipe at least four times the area of the inlet pipe shall be vented to the atmosphere.

Manhole for access and cleaning is required.
- j. Egress – Two means of reasonably remote egress must be provided for:
 - 1) Boiler rooms containing high pressure boilers and blowoffs.
 - 2) High pressure steam tunnels.
 - 3) Boiler rooms over 600 square feet containing low pressure boilers.
 - 4) One means of egress shall lead directly to the exterior or by means of a stairway leading to grade.
- k. Water gauge glasses – Required on each steam boiler.

3. Pennsylvania Department of Environmental Protection

- a. Flue gas emission control and monitoring is required on boiler plants sized greater than 10,000 MBH. The system shall reduce nitrogen oxide (NOx) and carbon monoxide (CO) below the following emissions:
 - 1) 30 ppmdv NOx at 3% O₂ when firing gas.
 - 2) 90 ppmdv NOx at 3% O₂ when firing No. 2 fuel oil; maximum 1/2% sulfate content.
 - 3) 400 ppmdv CO at 3% O₂

4. Pennsylvania Department of Labor and Industry – Boiler Submission Drawings.

The drawings must be a minimum size of 18" by 24" and drawn at 1/4" = 1'-0" scale. The following items must shown on the approval drawings:

- a. Floor plan and boiler room section.

- b. Proposed location of the following:
 - 1) Boilers
 - 2) Drums
 - 3) Headers
 - 4) Doors
 - 5) Steam, Air, Water Gages
 - 6) Safety Devices
 - 7) Blowoffs
 - 8) All Necessary Piping
 - 9) All Other Parts and Appurtenances
 - c. Exitways must be shown for the following:
 - 1) Boiler Rooms
 - 2) Blowoff and Ash Pits or Alleys
 - 3) High Pressure Steam Line Tunnels and Confined Spaces
 - d. Adequate ways down from platforms.
 - e. Walkways located over boilers.
 - f. All clearance dimensions above, around, and between all boilers, equipment, and any other construction.
5. ASME Section IV, General Boiler Requirements – Refer to the following sections. The Pennsylvania Boiler Code references this section.

SECTION 9.00 — CHILLER SELECTION AND DESIGN

9.01 PACKAGED AIR COOLED CHILLER SELECTION

9.02 WATER COOLED CHILLER SELECTION

9.03 ABSORPTION CHILLER SELECTION

9.04 REFRIGERATION SYSTEM MACHINERY ROOM *DESIGN* (2006 International Mechanical Code)

A. SCOPE

1. This section describes design procedures for refrigeration system machinery rooms containing systems with the following characteristics:
 - a. Low Probability Systems – Indirect Closed Systems or Double Indirect Systems. Most chillers are considered low probability.

B. PRELIMINARY INFORMATION

1. Determine refrigerant type utilized by system. Determine refrigerant classification. Refer to Table 1103.1 (2006 IMC).
2. Determine occupancy group classification. Seven occupancy classifications are defined in 2006 IMC.
 - a. *Institutional occupancy* is that portion of the premises from which, because they are disabled, debilitated, or confined, occupants cannot readily leave without the assistance of others. Institutional occupancies include, among others, hospitals, nursing homes, asylums, and spaces containing locked cells.
 - b. *Public assembly occupancy* is that portion of the premises where large numbers of people congregate and from which all occupants cannot quickly vacate the space. Public assembly occupancies include, among others, auditoriums, ballrooms, department stores, and passenger depots.

- c. *Residential occupancy* is that portion of the premises in which occupants, because they are sleeping, may be unaware of a hazard. Residential occupancies include, among others, dormitories, hotels, multi-unit apartments, and private residences.
 - d. *Commercial occupancy* is that portion of the premises where people transact business, receive personal service, or purchase food and other goods. Commercial occupancies include, among others, office and professional buildings, restaurants, and markets, but not department stores. Other commercial occupancies are work or storage areas that do not qualify as an industrial occupancy.
 - e. *Large mercantile occupancy* is a premise or that portion of a premise where more than 100 persons congregate on levels above or below street level to purchase merchandise.
 - f. *Industrial occupancy* is that portion of the premises where only authorized persons have access, which is used to manufacture, process, or store goods, including, among others, chemicals, food, ice, meat, and petroleum.
 - g. *Mixed occupancy* is where two or more classes of occupancies share the same building. When each occupancy is isolated from the rest of the building by tight walls, floors, and ceilings and by self-closing doors, the requirements for each occupancy shall apply to that portion of the building. For example: cold storage spaces in a hotel might be classified as an industrial occupancy while the rest of the building would remain a residential occupancy. When the various occupancies are not so isolated, the occupancy having the most stringent requirements shall be the governing occupancy.
3. Determine type of refrigeration system classification. Two system classifications are defined in 2006 IMC according to the degree of probability that a leakage of refrigerant could enter an occupied area. Refrigerating systems are defined by the method employed for extracting or delivering heat as follows:
- a. A *direct system* is one in which the evaporator or condenser of the refrigerating system is in direct contact with the air or other substances to be cooled or heated.
 - b. An *indirect system* is one in which a secondary coolant cooled or heated by the refrigerating system is circulated to the air or other substance to be cooled or heated. Indirect systems are distinguished by the method of application given below.

- 1) An *indirect open spray system* is one in which a secondary coolant is in direct contact with the air or other substance to be cooled or heated.
 - 2) A *double indirect open spray system* is one in which the secondary substance for an indirect open spray system mentioned above is heated or cooled by the secondary coolant circulated from a second enclosure.
 - 3) An *indirect closed system* is one in which a secondary coolant passes through a closed circuit in the air or other substance to be cooled or heated.
 - 4) An *indirect, vented closed system* is one in which a secondary coolant passes through a closed circuit in the air or other substance to be cooled or heated, except that the evaporator or condenser is placed in an open or appropriately vented tank.
4. Determine if machinery room is required. Refer to 2006 IMC Section 1104 for maximum quantities of refrigerants allowed. Determine “Low” or “High” probability system. When the quantity exceeds Table 1103.1, a machinery room is required.
 5. Use Table 1103.1 to determine type of machinery room required, *general or special*, and maximum refrigerant amounts.

C. MACHINERY ROOM, GENERAL REQUIREMENTS (TYPE A1, B1 REFRIGERANTS)

1. Layout equipment with proper access for service, maintenance, and operations. Incorporate manufacturer’s recommended clearances. (ASHRAE 15)
2. Maintain a minimum height of 7.25 feet under equipment and piping in all service clearance areas and operation passageways. (ASHRAE 15)
3. Confirm with Architect that room is equipped with tight fitting doors opening outward. Doors shall be self-closing if opening into the building. Confirm that there are no open passageways to permit escaping refrigerant to reach other parts of the building. (IBC)
4. Determine ventilation system requirements. Refer to paragraph E. (IMC)

5. No open flames that use combustion air from the machinery room shall be installed in the room. Fuel burning appliances cannot be located in a refrigeration system machinery room unless provisions in Section 1105.5 are met. (IMC)
6. Provide refrigerant detector with an audible and visual alarm. The detector or sampling tube drawing air to a detector shall be located where a refrigerant leak will concentrate. (IFC)
7. Confirm with architect there are two exit doors or access doors for machinery rooms larger than 1,000 square feet. All portions of machinery room shall be within 150 feet of an exit or exit access doorway. (IBC)

D. MACHINERY ROOM, SPECIAL REQUIREMENTS (TYPE A2, A3, B2, B3 REFRIGERANTS)

1. Special requirements are in addition to those listed under paragraph C.
2. No flame producing device or continuously operating hot surface over 800°F shall be installed in the room. (IMC)
3. Confirm with Architect that doors communicating with the building are approved, self-closing, tight-fitting fire doors. (IBC 1015.4)
4. Confirm with Architect that walls, floors, and ceilings are constructed tight with noncombustible materials. Room shall be one-hour fire rated. (ASHRAE 15)
5. Notify Architect that an exit door is required to directly open to the outer air. A vestibule is allowed. (ASHRAE 15)
6. Exterior openings shall not be installed under any fire escape or open stairway. (ASHRAE 15)
7. All piping penetrating interior walls, ceiling, or floor shall be tightly sealed with silicone foam fire stop. (ASHRAE 15)
8. Ventilation in ammonia machinery rooms shall conform to the emergency ventilation rate and operate continuously. (IMC)

Exceptions:

- a. The room shall be equipped with a vapor detector to automatically start the ventilation system and actuate an alarm at a detection level not to exceed 1,000 ppm.

- b. The room shall conform to Class 1, Division 2, of the National Electrical Code.
- 9. Remote controls immediately outside the room: (IMC, IFC)
 - a. Break glass type switch for off-only control of refrigeration equipment.
 - b. Break glass type switch for on-only control of the machinery room ventilation fans.
- 10. Confirm with architect, refrigerant units or systems having a refrigerant circuit containing more than 220 pounds of A1 or 30 pounds of any other group refrigerant shall be provided with emergency signs, charts and labels in accordance with NFPA 204. (IFC)

Refer to paragraph E for ventilation rates.

- 11. For refrigerants of Groups A2, A3, B2 other than ammonia, or B3, the room shall conform to Class 1, Division 2, of the National Electrical Code. (IMC)

E. MACHINERY ROOM VENTILATION (IMC)

- 1. Machinery room must be designed for two distinct ventilation rates: normal and emergency.
 - a. Normal Ventilation Rate. Design for the larger of:
 - 1) 0.5 CFM per square foot.
 - 2) 20 CFM per person.
 - 3) CFM required to maintain a maximum temperature rise of 18°F.

- b. Emergency Ventilation Rate. Design according to equation:

$$Q = 100 \times G^{0.5}$$

Where: Q = Airflow Rate (CFM)
G = Mass of largest refrigerant system
in Machinery Room (lbs.)

- 2. The normal ventilation system must operate continuously during building occupied periods.

3. The emergency ventilation system must be automatically activated by the alarm output of a refrigerant leak monitoring system.
4. The design of the ventilation system shall incorporate the following design criteria:
 - a. The normal ventilation system shall have exhaust inlets located at ceiling level to exhaust heat and smoke.
 - b. The emergency ventilation system shall have exhaust inlets located within two feet of the floor level.
 - c. Outdoor air intakes should be located at or near floor level and positioned to sweep air across machinery room. Airflow should flow lengthwise along and between refrigeration equipment.
 - d. Discharge air must be located at least 20 feet away from outdoor air intakes, operable windows, building exists, or occupied areas.
 - e. Separate exhaust fans and exhaust air ductwork must be used for the ventilation system.
 - f. Common exhaust systems using a two-speed fan and automatic damper can also be applied.
 - g. Air supply and exhaust ducts to the machinery room shall serve no other area.

F. REFRIGERANT PRESSURE RELIEF PIPING

1. Each pressure relief device or fusible plug must be piped directly to the outside of the building.
2. The termination of the relief piping must be located at least 15 feet above grade and at least 20 feet from any outdoor air intake, operable window, building exits, or occupied area.
3. Relief piping material shall be steel or copper tubing.
4. Relief piping shall be equipped with a flexible connection at the refrigeration equipment.

5. Relief piping shall be equipped with a drip leg capable of holding one gallon of liquid. A drain valve shall be attached to the bottom of the drip leg to remove liquid. All relief piping shall be sloped to drain liquid back to drip leg.
6. Purge units used on low pressure refrigeration equipment shall be piped to the refrigerant relief vent.

SECTION 10.00 — COOLING TOWER SELECTION AND DESIGN

10.01 COOLING TOWER SELECTION

A. GENERAL INFORMATION

1. Determine manufacturer for basis of design. Standard – Baltimore Air Coil.
2. The following information is required before cooling tower selection can be made:
 - a. Cooling tower flow rate.
 - b. System water and air temperatures.
 - c. Location.

B. COOLING TOWER FLOW RATE

1. Determine cooling tower flow rate from chiller condenser requirements. Refer to Section 9.00, “Chiller Selection and Design.” Use 3.0 GPM/ton for preliminary selection.

C. SYSTEM WATER AND AIR TEMPERATURES

1. *Entering Water Temperature* – Determine temperature from chiller condenser requirements. Refer to Section 9.00, “Chiller Selection and Design.” Use 95°F for preliminary selection.
2. *Range* – Determine system range by subtracting leaving water temperature from entering water temperature. Determine leaving water temperature from chiller condenser requirements. Refer to Section 9.00, “Chiller Selection and Design.” Use 10°F for preliminary selection.
3. *Approach* – Determine system approach by subtracting design wet bulb temperature from leaving water temperature. Use ASHRAE’s 1 percent mean coincident wet-bulb for design wet-bulb temperature.

D. LOCATION

1. Determine location of cooling tower based on tower discharge and intake, sound, service area, local codes, and architectural aesthetics.

E. TOWER SELECTION

1. Determine cooling tower type based on system GPM, cost, and location.
2. Enter equipment selection tables with entering water temperature, range and approach and determine system selection factor.
3. Use system selection factor and cooling tower flow rate to determine the cooling tower selection from the cooling tower capacity tables. If a single cell does not meet the required capacity, then use a double cell cooling tower. If three or more cells are required, then divide the required cooling tower flow rate by the number of cells and select towers with new flow rate.

E. COOLING TOWER ACCESSORIES

1. Make-up Water
 - a. Contact cooling tower manufacturer sales representative to determine water evaporation rate.

For preliminary selection $\frac{\text{Heat Req (BTU/HR)}}{\text{Evap. rate (GPM)}} = \frac{970 \text{ BTU/16 x 8.34 lb/gal x 60 min/hr}}{\text{Make-up water} = (2) \text{ evap rate}}$

- b. Check required time to fill system.

$\frac{\text{System capacity (gallon)}}{\text{fill rate (GPM) x 60 min/hr.}} = \text{_____ Hrs.}$

Acceptable range – 2 to 24 hours depending on job.

2. Bleed Lines
 - a. Provide 1/2-inch indoor bleed lines with shutoff valves from CTWR to CTWS to prevent the exterior CTWR lines from freezing.
3. Net Positive Suction Head
 - a. Check net positive suction head (NPSH) of condenser (cooling tower) pump. Refer to Section 6.00, “Pump Selection.”

4. Freeze Protection
 - a. When a remote sump is not utilized, supplementary heat must be supplied to the cooling tower sump water and all other exposed water piping and make-up lines that do not drain during system shutdown.
 - b. Supplemental Heat:
 - 1) Electric immersion heaters.
 - 2) Steam coils.
 - 3) Electric heat tape.

5. Capacity Control
 - a. Systems with small water capacities require greater cooling tower capacity control.
 - b. Capacity Control Options:
 - 1) Single speed fan motor.
 - 2) Dual speed fan motor.
 - 3) Multiple fan motors.
 - 4) Variable speed cooling tower pumps.
 - 5) Cooling tower by-pass valve.

SECTION 11.00 – AIR HANDLING UNIT SELECTION

11.01 UNIT SIZE SELECTION

A. GENERAL INFORMATION

1. Determine manufacturer for basis of design. Use Trane *Modular Climate Changers* unless directed otherwise by Project Manager. This decision must include input from the building owner.
2. Determine design conditions from the heating/cooling load estimates. Refer to Section 3.00.
3. The following information is required before complete unit selection can be made:
 - a. Air distribution system type.
 - b. Unit supply airflow rate.
 - c. Minimum outdoor airflow rate.
 - d. Unit components.
 - e. Unit configuration.

B. AIR DISTRIBUTION TYPE

1. ***Constant Volume*** – Determine unit supply airflow rate from the sum of the peak room airflow rates.
2. ***Variable Air Volume*** – Determine unit supply airflow rate from the air handling unit zone block load.

C. UNIT SUPPLY AIRFLOW RATE

1. Add a contingency factor of 10 percent of airflow rate calculated.
2. Round total supply air CFM up to closest two significant digits.

D. MINIMUM OUTDOOR AIRFLOW RATE

1. Determine minimum outdoor airflow rate using ASHRAE 62 “Ventilation for Acceptable Indoor Air Quality.” Refer to Section 16.01, “Room Air Quantities.”

2. Determine total exhaust airflow rates.
3. Use the higher value calculated from Steps 1 and 2 or a minimum of 10 percent of total supply air CFM.
4. Round minimum outdoor air CFM up to closest two significant digits.

E. UNIT COMPONENTS

1. Select modular air handling unit components based on air distribution type, use of economizer cycle, and percentage of minimum outdoor air to supply air. Components are listed in direction of airflow.

2. Constant Volume, No Economizer

- a. Mixing Box
- b. Bag/Cartridge Filter Section
- c. Heating Coil ⁽¹⁾
- d. Access Section
- e. Cooling Coil
- f. Reheat Coil ⁽²⁾
- g. Fan Section

⁽¹⁾ Design as preheat coil with freeze protection when outdoor air exceeds 40 percent.

⁽²⁾ Only required when using dehumidification cycle.

3. Constant Volume, Economizer

- a. Mixing Box ⁽¹⁾⁽²⁾
- b. Return Fan Section ⁽¹⁾⁽²⁾
- c. Relief Air Section ⁽¹⁾⁽²⁾
- d. Outdoor Air Mixing Box
- e. Bag/Cartridge Filter Section
- f. Heating Coil ⁽³⁾
- g. Access Section
- h. Cooling Coil
- i. Reheat Coil ⁽⁴⁾
- j. Supply Fan Section

⁽¹⁾ Not required when separate return fan is designed in air distribution system.

⁽²⁾ Not required when gravity relief air system is designed.

⁽³⁾ Design as preheat coil with freeze protection when outdoor air exceeds 40 percent.

(4) Only required when using dehumidification cycle.

4. Variable Air Volume, No Economizer

- a. Mixing Box
- b. Bag/Cartridge Filter Section
- c. Heating Coil ⁽¹⁾
- d. Access Section
- e. Cooling Coil
- f. Fan Section ⁽²⁾

(1) Design as preheat coil with freeze protection when outdoor air exceeds 15 percent.

(2) Include variable inlet guide vanes or variable speed drive.

5. Variable Air Volume, Economizer

- a. Mixing Box ⁽¹⁾⁽²⁾
- b. Return Fan Section ⁽¹⁾⁽²⁾⁽⁴⁾
- c. Relief Air Section ⁽¹⁾⁽²⁾
- d. Outdoor Air Mixing Box
- e. Bag/Cartridge Filter Section
- f. Heating Coil ⁽³⁾
- g. Access Section
- h. Cooling Coil
- i. Supply Fan Section ⁽⁴⁾

(1) Not required when separate return fan is designed in air distribution system.

(2) Not required when gravity relief air system is designed.

(3) Design as preheat coil with freeze protection when outdoor air percentage exceeds 15 percent.

(4) Include variable inlet guide vanes or variable speed drive.

6. Constant Volume, 100% Outdoor Air

- a. Mixing Box
- b. Bag/Cartridge Filter Section
- c. Preheat Coil
- d. Access Section
- e. Cooling Coil
- f. Reheat Coil ⁽¹⁾
- g. Fan Section

(1) Only required when using dehumidification cycle.

F. UNIT CONFIGURATION

1. Use horizontal draw-through unit where possible.
2. Floor mount air handling unit where possible.
3. If space is restricted, a vertical draw-through unit may be used.
4. If floor space is not available, air handling unit may be suspended or roof mounted.

G. SELECT UNIT SIZE

1. Select units with cooling coils for a maximum coil face velocity of 550 FPM.

$$\text{Min. Coil Face Area Req. (Sq.Ft.)} = \frac{\text{Total Supply Air (CFM)}}{\text{Max. Face Velocity (FPM)}}$$

$$\text{Actual Face Velocity (FPM)} = \frac{\text{Total Supply Air (CFM)}}{\text{Coil Face Area (Sq.Ft.)}}$$

2. Units with heating only coils may be selected for a maximum face velocity of 700 FPM. Verify fan performance for increased airflow rates.

11.02 WATER COIL SELECTION

A. GENERAL INFORMATION

1. Determine design conditions from the heating/cooling load estimates. Refer to Section 3.00.
2. Obtain the following information:
 - a. Coil Type
 - b. Coil Entering Air Temperatures
 - c. Coil Leaving Air Temperature or Required Capacity
 - d. Entering Fluid Temperature
 - e. Design Fluid Temperature Difference
 - f. Maximum Coil Pressure Drop

3. The following general parameters should be used in selecting water coils:
 - a. Full face area coils should be used where possible. Modified face area coils should only be considered for low capacity requirements or when full face coil selections are not adequate.
 - b. Coils should be 1/2 inch or 5/8 inch copper tube with aluminum fins. Copper fins may be considered in corrosive atmospheres.
 - c. Select coils with same side coil connections.
 - d. Use drainable type coils. Cleanable type may be considered when periodic tube cleaning is required.
 - e. Do not use Trane coil turbulators for initial design selection. Turbulators may be used when no other coil combinations meet required capacities.

B. CHILLED WATER COOLING COILS

1. **Coil Type:** Use Trane Type UW, UU, W, or WA with Sigma-Flo (SF) fins. Use Prima-Flo (PF) only if air pressure drop is a problem.
2. **Entering Air Temperature:** Calculate dry bulb and wet bulb temperatures based on mixed air conditions using return air and outdoor air temperatures using Psychometric Chart. Conditions may be obtained directly from Zone Cooling Load Summary if total supply air and ventilation airflow rates are correct (See Section 3.00).
3. **Leaving Air Temperature:** Use 55°F leaving air handling unit. Adjust coil leaving air temperature down 2°F to 53°F to compensate for fan motor heat. Leaving air temperature may be obtained directly from Zone Cooling Load Summary (See Section 3.00).
4. **Entering Fluid Temperature:** Use 45°F for chilled water.
5. **Design Fluid Temperature Rise:** Use 10°F temperature rise. For primary-secondary piping systems using 2-way coil control valves, use 12°F temperature rise.
6. **Maximum Coil Pressure Drop:** Use 15 ft. W.C. as a maximum water pressure drop through coil.
7. Select coil based on fewest rows first, then fewest fins per foot. This will result in most economical selection.

C. HOT WATER HEATING COILS

1. **Coil Type:** Use Trane Type UW, UU, UA, W, or WA with Sigma-Flo (SF) fins. Use Prima-Flo (PF) only if air pressure drop is a problem.
2. **Entering Air Temperature:** Calculate mixed air temperature based on return air temperature and 0°F outdoor air temperature.
3. **Leaving Air Temperature:** Calculate the leaving air temperature based on entering air temperature and required heating coil capacity. Heating coil capacity may be obtained from Zone Heating Load Summary and should include zone heat loss plus ventilation load. If required heating capacity results in an air temperature rise of less than 10°F, use 10°F as a minimum.
 - a. For air handling units using a separate preheat coil, calculate the required heating coil capacity based on the difference between the leaving air temperature of the preheat coil and the leaving air temperature of the heating coil required to meet the zone heating load.
 - b. For reheat coils, the heating coil capacity required to reheat the air from the cooling coil leaving air temperature (usually 55°F) up to the minimum room temperature (72°F), must be calculated as a minimum heating coil capacity.
4. **Entering Fluid Temperature:** Depends on the heating system type used. The following are several standard values:
 - a. Constant Temperature Hot Water: 180°F
 - b. Scheduled Temperature Hot Water: 160°F
 - c. Heat Recovery Hot Water: 105°F
5. **Design Fluid Temperature Drop:** Use 20°F for conventional hot water systems. Use 10°F for heat recovery systems.
6. **Maximum Coil Pressure Drop:** Use 15 ft. W.C. as a maximum water pressure drop through coil.
7. Select coil based on fewest rows first, then fewest fins per foot. This will result in most economical selection. Check that coil uses same side connections (especially one row coils).

11.03 STEAM COIL SELECTION

A. GENERAL INFORMATION

1. Determine design conditions from the heating/cooling load estimates. Refer to Section 3.00.
2. Obtain the following information:
 - a. Coil Type
 - b. Coil Entering Air Temperature
 - c. Coil Leaving Air Temperature or Required Capacity
 - d. Entering Steam Pressure
 - e. Return System Backpressure
3. The following general parameters should be used in selecting steam coils:
 - a. Full face area coils should be used where possible. Modified face area coils should only be considered for low capacity requirements when full face coil selections are oversized.
 - b. Steam coils should be non-freeze distributing tube type for even coil temperatures across entire face area.
 - c. Select coils with same end connections.

B. STEAM HEATING COILS

1. **Coil Type:** Use Trane Type NS non-freeze steam distributing type with Sigma-Flo (SF) fins.
2. **Entering Air Temperature:** Calculate mixed air temperature based on return air temperature and 0°F outdoor air temperature.
3. **Leaving Air Temperature:** Calculate leaving air temperature based on entering air temperature and required heating coil capacity. Refer to hot water heating coils for complete description.
4. **Entering Steam Temperature:** Depends on the steam system operating pressure. Determine effect of control valve pressure drop.

Entering Coil Steam Pressure = Steam System Pressure - Control Valve Pressure Drop.

The following are several standard values:

- a. 5 PSI Steam: 2 PSI Entering Steam Pressure
 - b. 15 PSI Steam: 5 PSI Entering Steam Pressure
 - c. 30 PSI Steam: 10 PSI Entering Steam Pressure
5. **Return System Backpressure:** Use a return pressure of 0 PSIG (atmospheric) unless a known backpressure situation is present.
 6. Select coil based on fewest fins. All NS coils are one row.

11.04 REFRIGERANT COIL SELECTION

A. GENERAL INFORMATION

1. Determine design conditions from the heating/cooling load estimates. Refer to Section 3.00.
2. Obtain the following information:
 - a. Coil Type
 - b. Coil Entering Air Temperatures
 - c. Coil Leaving Air Temperature or Required Capacity
 - d. Maximum Coil Air Pressure Drop
3. The following general parameters should be used in selecting refrigerant coils:
 - a. Full face area coils should be used where possible. Modified face area coils should only be considered for low capacity requirements or when full face coil selections are not adequate. Do not exceed 550 FPM velocity on coil selection.
 - b. Select coils with same side coil connections.

B. REFRIGERANT COOLING COILS

1. **Coil Type:** Use Trane Type UF or F with Sigma-Flo (SF) fins. Use Prima-Flo (PF) only if air pressure drop is a problem. Use intertwined coils for part load control.
2. **Entering Air Temperature:** Calculate dry bulb and wet bulb temperatures based on mixed air conditions using return air and outdoor air temperatures using Psychometric Chart. Conditions may be obtained

directly from Zone Cooling Load Summary if total supply air and ventilation airflow rates are correct (See Section 3.00).

3. **Leaving Air Temperature:** Use 55°F leaving air handling unit. Adjust coil leaving air temperature down 2°F to 53°F to compensate for fan motor heat. Leaving air temperature may be obtained directly from Zone Cooling Load Summary (See Section 3.00).
4. Select coil based on fewest rows first, then fewest fins per foot. This will result in the most economical selection.
5. Select associated condensing unit based on a 95°F ambient air temperature. Obtain computer selection matched to cooling coil from unit manufacturer. If manual selection is required, select unit from manufacturer's capacity curves. Enter chart at total cooling capacity required and at the intersection of outdoor ambient temperature determine suction temperature.

Suction temperature must be between the indoor coil frost limit and compressor high suction limit. Typical acceptable suction temperature ranges are from 35°F to 50°F.

11.05 PREHEAT COIL SELECTION

A. GENERAL INFORMATION

1. Determine design conditions from the heating/cooling load estimates. Refer to Section 3.00.
2. Obtain the following information:
 - a. Coil Type
 - b. Coil Entering Air Temperatures
 - c. Coil Leaving Air Temperature or Required Capacity
 - d. Entering Fluid Temperature
 - e. Design Fluid Temperature Difference
 - f. Maximum Coil Pressure Drop
3. The following general parameters should be used in selecting water coils:
 - a. Full face area coils should be used where possible. Modified face area coils should only be considered for low capacity requirements or when full face coil selections are not adequate.

- b. Coils should be 1/2 inch or 5/8 inch copper tube with aluminum fins. Copper fins may be considered in corrosive atmospheres.
- c. Select coils with same side coil connections.
- d. Use drainable type coils. Cleanable type may be considered when periodic tube cleaning is required.
- e. Do not use Trane coil turbulators for initial design selection. Turbulators may be used when no other coil combinations meet required capacities.

C. HOT WATER PREHEAT COILS

- 1. **Coil Type:** Use Trane Type UW, UU, UA, W, or WA with Sigma-Flo (SF) fins. Use Prima-Flo (PF) only if air pressure drop is a problem.
- 2. **Entering Air Temperature:** Calculate mixed air temperature based on return air temperature and 0°F outdoor air temperature.

Preheat coils are required when entering air temperature is below 40°F or in a constant volume system when outdoor air exceeds 40% or 15% in a VAV system.

- 3. **Leaving Air Temperature:** Calculate the leaving air temperature based on entering air temperature and required heating coil capacity. Heating coils should be capable of heating total airflow from the 0°F to 55°F.
- 4. **Entering Fluid Temperature:** Depends on the heating system type used. The following are several standard values:
 - a. Constant Temperature Hot Water: 180°F
 - b. Scheduled Temperature Hot Water: 160°F
 - c. Heat Recovery Hot Water: 105°F

- 5. **Design Fluid Temperature Drop:** Use 20°F for conventional hot water systems. Use 10°F for heat recovery systems.
- 6. **Maximum Coil Pressure Drop:** Use 15 ft. W.C. as a maximum water pressure drop through coil.
- 7. Select coil based on fewest rows first, then fewest fins per foot. This will result in most economical selection. Check that coil uses same side connections (especially one row coils).

11.06 AHU FAN SELECTION

A. GENERAL INFORMATION

1. Fan Types – Determine the fan type which best suits the application. Fans can generally be classified as one of two types: centrifugal or axial.
 - a. Common AHU Fan Types:
 - 1) Centrifugal Airfoil
 - 2) Centrifugal Backward Inclined
 - 3) Centrifugal Forward Curved
 - 4) Plug Fan
 - 5) Airfoil Vane Axial (Trane Q Fan)
2. Fan Drives – Fan drives can be direct drive or belt drive depending on the fan type and unit size. Belt drive fans should be the first choice.
3. Design Conditions – Determine the design conditions the fan will operate under. The following information is required:
 - a. Fan type and drive type
 - b. System design airflow rate (CFM)
 - c. System design total static pressure (Inches WG)
 - d. Project altitude
 - e. Airflow temperature

B. SYSTEM AIRFLOW RATE

1. Determine system airflow rate from application. Refer to Section 3.00, “Cooling and Heating Load Estimate” and Section 11.01, “Unit Size Selection.”
2. Round design airflow CFM up to closest two significant digits. Coil and fan CFM should be equal.

C. SYSTEM TOTAL STATIC PRESSURE

1. Determine the total system static pressure by summing the friction losses of the ductwork system including fitting, inlets or outlets, and equipment losses. Refer to Section 15.00, “Ductwork Design.”

2. Determine system effects for the fan inlet and outlet ductwork configurations. Fans are normally tested and rated with open inlets and a section of straight duct on the outlet. If good inlet and outlet configurations are not present, the fan performance will not be as rated. The system effect, measured in additional static pressure, must be used to compensate for poor inlet and outlet configurations. The system effect factors can be determined using the ASHRAE Fundamentals Handbook or AMCA Publication 201. System effect factors must be added to the calculated system static pressure.
3. Add a contingency factor of 10 percent of calculated total static pressure.
4. Round total static pressure up to the closest 1/8 inch water gauge.
5. Include static pressure losses through AH unit in calculating total static pressure.

C. FAN SIZE SELECTION

1. Fan Performance Curves – Use manufacturer’s fan performance curves to determine fan size. Plot system airflow rate versus total static pressure to determine operating point on performance curves. Select fan size and speed in region of maximum efficiency. Do not select fan operating to the left of or near the fan surge line. Determine fan speed and motor brake horsepower requirements.
2. Fan Performance Tables – Use manufacturer’s fan performance tables to determine fan size. Interpolate fan speed and motor brake horsepower from system airflow rate and total static pressure columns or rows. Select fan size with maximum efficiency. Typically two or more fan sizes will meet the required conditions. Select the smallest size fan with the smallest required motor horsepower.
3. Fan motor selection – Add a contingency factor of 25 percent to the fan brake horsepower to determine motor horsepower. For backward inclined and airfoil fan wheels, select a non-overloading fan motor size.
4. Fan noise – The most efficient operating fan selection is usually the most quiet for a given line of fans. If acoustical performance is critical, the actual sound power levels should be evaluated. Refer to Section 21.00, “Vibration and Sound Control.”
5. Elevated temperatures and high altitudes – Refer to the manufacturer’s literature for correction factors for elevated operating temperatures and high altitudes. Consider cold starting conditions and all intermediate conditions when selecting fan. Correction factors involve changes in air

density and are usually applied to system static pressure and fan brake horsepower.

6. High pressure drop filters (HEPA, etc.) – The operation of the fan must be considered when a large amount of static pressure is added. When the filter is dirty, the fan must not operate in the surge area.

D. COMPUTER SELECTION PROGRAMS

1. The following is a list of computer AHU selection programs available for use:
 - a. York – YorkWorks
 - b. Trane – MCC (from rep)
2. When selecting fans with computer selection programs, care must be taken to select the proper motor size including the contingency factor. Most computer programs will only increase motor size as the fan brake horsepower exceeds the motor size.
3. Include both input and output data printouts in the design documentation file.

E. INSTALLATION DETAILS

1. Provide flexible duct connections on the inlet and outlet ductwork of all fans except roof mounted fans.
2. Provide vibration isolation on all fans. Internal isolation is preferred, but external isolation of the AH unit is acceptable. Refer to Section 21.00, “Vibration and Sound Control.”

SECTION 12.00 — FAN COIL UNIT SELECTION**A. GENERAL INFORMATION**

1. Determine space heating and cooling capacity requirements. Refer to Section 2.00.
2. Determine unit configuration: vertical or horizontal.
3. Determine heating coil type: hot water, electric, or none.
4. Determine ventilation system type. If using directly connected wall grilles, use 25 percent outdoor air selections. Use 0 percent outdoor air selections if a separate ventilation system is being designed.
5. Select fan coil unit from standard unit selections. Standard chilled water fan coil selections have been made for the following unit types:
 - a. Vertical – Hot Water Heating – 25% Outdoor Air
 - b. Vertical – Hot Water Heating – 0% Outdoor Air
 - c. Vertical – Electric Heating – 25% Outdoor Air
 - d. Vertical – Electric Heating – 0% Outdoor Air
 - e. Horizontal – Hot Water Heating – 25% Outdoor Air
 - f. Horizontal – Hot Water Heating – 0% Outdoor Air
 - g. Horizontal – Electric Heating – 25% Outdoor Air
 - h. Horizontal – Electric Heating – 0% Outdoor Air

B. STANDARD FAN COIL UNIT SELECTIONS

1. Select fan coil size from appropriate standard unit selection schedule using the cooling coil sensible capacity. Read down schedule until coil sensible capacity meets or exceeds the space sensible cooling load including ventilation.
2. Check that the fan coil heating coil capacity meets or exceeds the space heating load including ventilation. If the space heating load cannot be met with the standard selection, a non-standard fan coil selection must be made. Refer to paragraph D.
3. For ventilation rates other than 25 percent outdoor air or 0 percent outdoor air, a non-standard fan coil selection must be made. Refer to paragraph D.

4. For drawing identification and scheduling, use the fan coil tag numbers in the standard schedule where possible. Multiple units may use the same tag numbers. When requested and approved by the Project Manager, fan coil units may use sequential tag numbers.
5. For projects using several fan coil configurations, heating coil types, or ventilation rates, additional standard tag numbers may be developed.

C. BASIS OF STANDARD FAN COIL UNIT SELECTIONS

1. Standard fan coil selections schedules were developed for the eight different configurations, heating coil types, and ventilation rates listed in paragraph A.5. Each schedule contains a fan coil performance selection for each available size based on the Trane Company's product line. Performance data was obtained using the Trane Company's computer selection program.
2. The following standard input data was used in selecting the fan coil units:

a. Cooling Coil Input Data:

Coil Type:	A
Entering Water Temperature:	45°F
Design Water Temperature Rise:	12°F
Minimum Flow Rate:	1.0 GPM

25% Outdoor Air

Entering Dry Bulb Temperature:	80°F
Entering Wet Bulb Temperature:	67°F

0% Outdoor Air

Entering Dry Bulb Temperature:	75°F
Entering Wet Bulb Temperature:	63°F

b. Heating Coil Input Data:

Hot Water

Coil Type:	L
Entering Water Temperature:	180°F
Design Water Temperature Drop:	20°F
Minimum Flow Rate:	1.0 GPM

Electric

Coil Type: E

25% Outdoor Air

Entering Air Temperature: 54°F

0% Outdoor Air

Entering Air Temperature: 65°F

c. Vertical Unit Input Data:

Motor Type: G9 (High Efficiency)

Motor Speed: H (High)

Filter Type: TA (Throwaway)

d. Horizontal Unit Input Data:

External Static Pressure: 0.25"

Motor Type: G4 (High Static Pressure)

Motor Speed: H (High)

Filter Type: TA (Throwaway)

D. NON-STANDARD FAN COIL SELECTIONS

SECTION 12.01 — UNIT VENTILATOR SELECTION

A. General

1. Determine space heating and cooling capacity requirements.
2. Determine system type:
 - a. Ventilation air provided by separate system
 - b. Ventilation air provided through unit
3. Unit configuration:
 - a. If ventilation air is provided by a separate system, configure unit to provide the heating coil before the cooling coil. These systems will not have ethylene glycol in the chilled water systems.

- b. If ventilation air is provided through the unit, configure unit to provide the heating coil after the cooling coil. This allows for a dehumidification cycle. Use a minimum of 25% ethylene glycol in the chilled water system for freeze protection.

B. STANDARD UNIT VENTILATOR SELECTIONS

1. Select unit ventilator size from appropriate standard unit selection schedule using the cooling coil sensible capacity. Read down schedule until coil capacity meets or exceeds the space sensible cooling load including ventilation.
2. Check that unit ventilator heating coil capacity meets or exceeds the space heating load including ventilation. If the load cannot be made with the standard selection, consult HVAC Department Manager.
3. For ventilation rates that vary from standard, consult HVAC Department Manager.
4. For drawing identification and scheduling, use the UV tag number in the standard schedule where possible. Multiple units may use the same tag numbers. When requested and approved by the Project Manager, UV's may use sequential tag numbers.

C. BASIS OF STANDARD UNIT VENTILATOR SELECTIONS

1. Standard UV selections were developed for two different types of systems. Typical sizes range from 750 to 1500 cfm. Each UV was based on the Trane Co. Unit Ventilator and performance data was obtained from the Trane Co.

See the attached schedule for Unit Ventilator Selections and standard schedules.

SECTION 13.00 – PACKAGED AIR CONDITIONING UNIT SELECTION

13.01 ROOFTOP UNITS

A. GENERAL INFORMATION

1. Determine zone block cooling load and zone heating load (if unit will be used for heating). Refer to Section 3.00.
2. From cooling and heating loads, determine:
 - a. Total required cooling capacity (MBH).
 - b. Sensible cooling capacity (MBH).
 - c. Total heating capacity (MBH).
 - d. Supply air volume (CFM).
 - e. Outdoor air volume (CFM).
 - f. Entering dry bulb temperature.
 - g. Entering wet bulb temperature.

B. UNIT SELECTION

1. Outdoor air volume between 0-30%:
 - a. Select unit at the Air Conditioning and Refrigeration Institute (ARI) nominal rated capacity and airflow, i.e.:

80°F DB/67°F WB Entering Air Temperature
95°F Ambient Air Temperature
400 cfm/nominal ton
 - b. Using the data from Part A, enter the manufacturer's tables and select the unit as close to the required capacities as possible. Where required capacities fall between two standard unit sizes, the smaller unit will generally be the better choice if it is not less than 10% of required capacity. A closely matched or smaller unit will prevent compressor cycling and minimize high humidity problems when the unit fan is set to the "on" position. Use engineering judgement.

2. Outdoor air volume greater than 30%:
 - a. Since the sensible capacity of the unit decreases as entering air temperatures increase, use actual entering air temperatures and ARI nominal rated airflow. This will prevent the unit from being grossly undersized.
 - b. Refer to Part 1b for unit selection.

C. UNIT HEATING

1. Verify available heating capacity is greater than required heating capacity.
2. If using gas or electric heat, use stages of heat. Full modulation may be available for close temperature control applications.

D. FAN MOTOR SELECTION

1. A packaged rooftop unit is equipped with a given fan with various fan motors available. Using calculated static pressure and ARI nominal rated airflow, enter the manufacturer's fan tables to find the motor brake horsepower and rpm.
2. For forward curved centrifugal fans, add 25% to the brake horsepower for overload safety, round up, and select the next largest standard motor size.
3. For backward inclined or airfoil type fans, select a non-overloading motor throughout the entire associated rpm curve.
4. Refer to Section 14.00 for a more detailed discussion on fan motor selection.

E. UNIT SCHEDULING

1. List ARI nominal rated cfm.
2. List catalog cooling/heating capacities.
 - a. If using a custom packaged rooftop unit with special cooling/heating requirements, list calculated cooling/heating capacities.
3. List catalog electrical data.

13.02 SPLIT SYSTEM UNITS

A. GENERAL INFORMATION

1. Determine zone block cooling load and zone heating load (if unit will be used for heating). Refer to Section 3.00.
2. From cooling and heating loads, determine:
 - a. Total required cooling capacity (MBH).
 - b. Sensible cooling capacity (MBH).
 - c. Total heating capacity (MBH).
 - d. Supply air volume (CFM).
 - e. Outdoor air volume (CFM).
 - f. Entering dry bulb temperature.
 - g. Entering wet bulb temperature.

B. INDOOR UNIT SELECTION

1. Outdoor air volume between 0-30%:
 - a. Select unit at the Air Conditioning and Refrigeration Institute (ARI) nominal rated capacity and airflow, i.e.:

80°F DB/67°F WB Entering Air Temperature
95°F Ambient Air Temperature
400 cfm/nominal ton
 - b. Using the data from Part A, enter the manufacturer's tables and select the unit as close to the required capacities as possible. Where required capacities fall between two standard unit sizes, the smaller unit will generally be the better choice if it is not less than 10% of required capacity. A closely matched or smaller unit will prevent compressor cycling and minimize high humidity problems when the unit fan is set to the "on" position. Use engineering judgement.

2. Outdoor air volume greater than 30%:
 - a. Since the sensible capacity of the unit decreases as entering air temperatures increase, use actual entering air temperatures and ARI nominal rated airflow. This will prevent the unit from being grossly undersized.
 - b. Refer to Part 1b for unit selection.

C. UNIT HEATING

1. Verify available heating capacity is greater than required heating capacity.
2. If using electric heat, use stages of heat. Full modulation may be available for close temperature control applications.
3. Refer to Air Handling Unit, Hot Water and Steam Coil Selection, if required.

D. FAN MOTOR SELECTION

1. A split system unit is equipped with a given fan with various fan motors available. Using calculated static pressure and ARI nominal rated airflow, enter the manufacturer's fan tables to find the motor brake horsepower and rpm.
2. For forward curved centrifugal fans add 25% to the brake horsepower for overload safety, round up, and select the next largest standard motor size.
3. For backward inclined or airfoil type fans, select a non-overloading motor throughout the entire associated rpm curve.
4. Refer to Section 14.00 for a more detailed discussion on fan motor selection.

E. COMPRESSOR/CONDENSER UNIT

1. Using the data from Part A, select the appropriate compressor/condenser unit that is matched to the indoor air handling unit.
2. Select the outdoor unit at the 95°F outdoor ambient conditions for locations in this area. For other areas, refer to ASHRAE Fundamentals Handbook to determine an area's maximum dry bulb design temperature.

F. UNIT SCHEDULING

1. List ARI nominal rated cfm.
2. List catalog cooling/heating capacities.
 - b. If using a custom split system unit with special cooling/heating requirements, list calculated cooling/heating capacities.
3. List catalog electrical data.
4. List compressor/condensor unit information.

SECTION 14.00 — FAN SELECTION

A. GENERAL INFORMATION

1. Fan Types – Determine the fan type which best suits the application. Fans can generally be classified as one of two types: centrifugal or axial. The ASHRAE Systems and Equipment Handbook further subdivides fan types according to Table 1. The following is a list of fan types currently included in the JDB Engineering master specifications according to fan classification:
 - a. Centrifugal Fans:
 - 1) Centrifugal Airfoil
 - 2) Centrifugal Backward Inclined
 - 3) Centrifugal Forward Curved
 - 4) Utility Fan
 - 5) Cabinet Fan
 - 6) Ceiling Fan
 - 7) Inline Fan
 - b. Axial Fans:
 - 1) Wall Propeller
 - 2) Upblast Propeller
 - 3) Tubeaxial
 - 4) Vaneaxial
 - c. Special Designs:
 - 1) Tubular Centrifugal
 - 2) Centrifugal Roof Fan
 - 3) Centrifugal Wall Fan
 - 4) Centrifugal Upblast Fan
 - 5) Centrifugal Kitchen Fan
 - 6) Makeup Air Fan
2. Fan Drives – Fan drives can be direct drive or belt drive depending on the fan type and size. Belt drive fans should be the first choice.

3. Design Conditions – Determine the design conditions the fan will operate under. The following information is required:
 - a. Fan type and drive type
 - b. System design airflow rate (CFM)
 - c. System design total static pressure (Inches WG)

B. SYSTEM AIRFLOW RATE

1. Determine system airflow rate from application.
2. Add no contingency factor to airflow rate.
3. Round design airflow CFM up to closest two significant digits.

C. SYSTEM TOTAL STATIC PRESSURE

1. Determine the total system static pressure by summing the friction losses of the ductwork system including fitting, inlets or outlets, and equipment losses. Refer to Section 15.00, “Ductwork Design.”
2. Determine system effects for the fan inlet and outlet ductwork configurations. Fans are normally tested and rated with open inlets and a section of straight duct on the outlet. If good inlet and outlet configurations are not present, the fan performance will not be as rated. The system effect, measured in additional static pressure, must be used to compensate for poor inlet and outlet configurations. The system effect factors can be determined using the ASHRAE Fundamentals Handbook or AMCA Publication 201. System effect factors must be added to the calculated system static pressure.
3. Add a contingency factor of 10 percent of calculated total static pressure.
4. Round total static pressure up to the closest 1/8 inch water gauge.
5. Use a minimum total static pressure of 0.5 inches water gauge for ducted fan systems and 0.375 inches water gauge for non-ducted fan systems.

C. FAN SIZE SELECTION

1. Fan Performance Curves – Use manufacturer’s fan performance curves to determine fan size. Plot system airflow rate versus total static pressure to determine operating point on performance curves. Select fan size and speed in region of maximum efficiency. Do not select fan operating to the left of or near the fan surge line. Refer to Figure 1. Determine fan speed and motor brake horsepower requirements.
2. Fan Performance Tables – Use manufacturer’s fan performance tables to determine fan size. Interpolate fan speed and motor brake horsepower from system airflow rate and total static pressure columns or rows. Select fan size with maximum efficiency. Typically two or more fan sizes will meet the required conditions. Select the smallest size fan with the smallest required motor horsepower.
3. Fan Motor Selection – Add a contingency factor of 25 percent to the fan brake horsepower to determine motor horsepower. For backward inclined and airfoil fan wheels, select a non-overloading fan motor size.
4. Fan Noise – The most efficient operating fan selection is usually the most quiet for a given line of fans. If acoustical performance is critical, the actual sound power levels should be evaluated. Refer to Section 21.00, “Vibration and Sound Control.”
5. Elevated Temperatures and High Altitudes – Refer to the manufacturer’s literature for correction factors for elevated operating temperatures and high altitudes. Consider cold starting conditions and all intermediate conditions when selecting fan. Correction factors involve changes in air density and are usually applied to system static pressure and fan brake horsepower.

D. COMPUTER SELECTION PROGRAMS

1. The following is a list of computer fan selection programs available for use:
 - a. Penn Ventilator – Fansizer
 - b. Trane – CDS – Product Selection Programs
 - c. Greenheck – CAPS
 - d. Bayley – Quickfan
2. When selecting fans with computer selection programs, care must be taken to select the proper motor size including the contingency factor. Most computer programs will only increase motor size as the fan brake horsepower exceeds the motor size.

3. Include both input and output data printouts in the design documentation file.

E. INSTALLATION DETAILS

1. Provide flexible duct connections on the inlet and outlet ductwork of all fans except roof mounted fans.
2. Provide vibration isolation on all fans except roof mounted fans. Floor mounted fans should use spring isolators. Suspended fans should use spring hangers. Refer to Section 21.00, "Vibration and Sound Control."

SECTION 15.00 — DUCTWORK DESIGN

A. GENERAL INFORMATION

1. Ductwork is an enclosed path through which air is conveyed from one location to another. There are several factors that must be considered during design for proper system operation. They include space available, noise levels, space air diffusion, duct leakage, the effect of duct heat losses or gains, balancing, fire and smoke control, and installation and operating costs.

Poorly designed ductwork can result in unhappy clients. High noise levels, poor air diffusion, improperly balanced systems, and high costs can all affect repeat client design work.

The fundamental theory of ductwork design is described in Chapter 32 of the 1997 ASHRAE Handbook of Fundamentals. This section will not cover the theory of ductwork design, but will give a hands-on approach to designing duct distribution systems.

2. There are several methods of designing ductwork, including equal friction, static regain, constant velocity, and the T-method.

- a. Equal Friction Method (this method is the most commonly used in sizing ductwork)

The equal friction method sizes ducts on a constant pressure loss per unit length basis.

- b. Static Regain Method

The static regain method is based on duct sizing such that the static pressure increase (static regain) at each take-off offsets the pressure loss in the succeeding section of duct. Static regain is achieved by reducing velocity; therefore, this approach leads to larger duct sizes.

- c. Constant Velocity Method

The constant velocity method is used in sizing ducts that move particulate such as duct collection exhaust systems and kitchen exhaust systems. Duct sizes are selected to maintain a uniform velocity through the entire system.

d. T-Method

The T-method was developed in 1988 as a means of optimizing duct designs. This is an iterative calculation procedure and is not a practical design approach for typical HVAC system design.

3. The equal friction and constant velocity design methods are the standard methods used at JDB Engineering, Inc. (JDBE). JDBE sizing procedures for these methods are presented below. If other design methods are required, consult with the HVAC Department Manager and the ASHRAE Handbook of Fundamentals.

B. HVAC DUCT DESIGN PROCEDURES

1. The following is a summary of the steps to be taken in laying out a duct distribution system. Specific design considerations are listed at the end of this section.
- a. Review floor plan layouts and sections. Determine ceiling heights, plenum space available, type/depth of light fixtures space requirements, steel spacing, fire-rated and smoke-rated wall locations.
 - b. Sketch the duct layout which provides the most economical installation, yet meets JDBE Standard Design Criteria.
 - c. Locate diffusers, registers, and grilles to provide good air distribution (Refer to Section 16.0).
 - d. Size the ductwork by the selected design method.
 - e. Calculate the system static pressure loss for the longest run. Use Excel spreadsheet, "fancalc.xls" or calculate by hand. Fitting loss coefficients are located in the ASHRAE Handbook of Fundamentals.
 - f. Resize ducts as required to balance system pressures and maintain velocity requirements to prevent objectionable noise levels.
2. Equal Friction Sizing Method
- a. Use 0.08" of static pressure loss per 100 feet of ductwork for a low pressure system. Typical air velocity for these systems should range between 500 and 1500 feet per minute.

- b. Where medium and high pressure duct systems are required, air velocities exceed 2000 FPM and static pressure ranges from 0.15" to 0.5" SP/100 feet, consult with the HVAC Department Manager to review systems concepts before use and layout of these systems.
- c. Minimum sizing guidelines for low pressure ductwork and ductwork downstream of VAV boxes:

Interior Duct Dimensions (unlined)	Recommended Maximum CFM
6 / 6	150
12 / 6	350
12 / 12	900
18 / 12	1500
18 / 18	2500
24 / 12	2100

3. Constant Velocity Method

- a. Ductwork is sized on constant duct velocity to keep airborne particulate entrained.
- b. Use round duct where possible for these systems.
- c. The following velocities are typical applications. Actual material and velocity requirements should be verified before design.

Recommended Minimum Duct Velocities		
Material Conveyed	Branch Ducts (FPM)	Main Ducts (FPM)
Metal working dust	4500	4000
Wood-working	4000	3500
Light dusts	4000	3500
Vapors, gases, fumes, very fine dusts	1500 - 2000	
Fine dry dusts	3000 - 3500	
Average industrial dusts	3500 - 4000	
Coarse particulate	3500 - 4500	
Large particulate, heavy loads, moist materials, pneumatic conveying	4500 and up	

Refer to Industrial Ventilation Handbook 23rd Edition Table 3-2 for examples of different materials and velocity requirements.

C. KITCHEN EXHAUST DUCTS

- 1. The International BOCA Code requires kitchen exhaust ducts to maintain a velocity of 1500 FPM minimum.

2. Duct access panels are required for cleaning.
3. Stainless steel ductwork should be used for exhaust ducts.
4. Kitchen exhaust hoods should be designed to meet BOCA Code and manufacturers' requirements.
5. Industrial capture hood design
 - a) Refer to the Industrial Ventilation Handbook, Chapter 3, for design of exhaust hoods specific to the application.

D. DESIGN CONSIDERATIONS

1. Space Concerns
 - a. Adequate space must be provided in the ceiling plenum to accommodate ductwork layouts. Many different services are provided overhead and the different utilities must be coordinated. Light fixtures, plumbing and fire protection piping, and cable trays may all run in a plenum space.
 - b. When planning duct layouts, remember the following considerations.
 - 1) Typical recessed lighting requires 12 inches for the fixture and removal clearance. Use 12 inches of lighting space when laying out ductwork unless notified by the Electrical Department. The table below lists typical fixture heights. This table does not indicate space required for fixture removal.
 - a) Typical Fixture Mounting Depths
 - 2 x 4, 2 x 2, 1 x 4 lensed troffers: 6"
 - 2 x 4, 2 x 2, 1 x 4 parabolic troffers: 8"
 - Recessed downlights:
 - Inc.: 12"
 - Halogen: 16"
 - Compact Fluorescent
 - Vertical Lamp: 14"
 - Horizontal Lamp: 9"
 - High Intensity Downlight (HID): 20"

- 2) Duct insulation – Insulation can add up to 4 inches of required space, depending upon the application (see the following section).
- 3) In new construction, request a minimum of 34" of plenum space. This will allow for a maximum of an 18-inch deep supply duct.
- 4) Do not plan on running ductwork between steel and lighting fixtures. Changes throughout the job will create a coordination problem.

2. Duct Heat Gain or Loss

- a. Duct heat gain or loss can be prevented with proper insulation application. The following table lists JDBE standard insulation thickness for duct insulation, material type, jackets and vapor retarder in the JDBE Master Spec.

Indoor Duct & Plenum Application		Outdoor Duct & Plenum Application
Supply	1 1/2"	2"
Return	1"	2"
Outdoor Air	2"	Not Insulated

3. Duct Leakage

- a. If unsealed ductwork is used (not typical), the quantity of airflow distributed must account for the duct leakage.
- b. If ductwork is sealed, leakage can be ignored in most systems. If exact airflow is critical, refer to ASHRAE Fundamentals, Chapter 32, to determine duct leakage rates.

4. System Component Design Velocities

- a. The table below summarizes typical HVAC component design velocities.

Duct Element	Face Velocity, FPM
Louvers	
Intake:	
7000 cfm and greater	400
Less than 7000 cfm	500
Exhaust:	
5000 cfm and greater	500
Less than 5000 cfm	700
Filters	
Panel filters:	
Viscous impingement	200 to 800
Dry-type, extended-surface	
Flat (low efficiency)	Duct velocity
Pleated media (intermediate efficiency)	Up to 750
HEPA	250
Renewable media filters:	
Moving-curtain viscous impingement	500
Moving-curtain dry media	200
Electronic air cleaners:	
Ionizing type	150 to 350
Heating Coils	
Steam and hot water	500 to 1000 200 min., 1500 max.
Electric:	
Open wire	Refer to mfg. data
Finned tubular	Refer to mfg. data
Dehumidifying Coils	
	400 to 500
Air Washers	
Spray type	300 to 600
Cell type	Refer to mfg. data
High-velocity spray type	1200 to 1800

5. Noise Control

- a. The major noise sources in HVAC systems are diffusers, registers, grilles, fans, ducts and duct fittings, and system vibration.
- 1) Sound control for each individual component is listed under the appropriate design manual section.

- b. Duct design and layout directly affect the amount of noise generated in an HVAC system.

Duct velocity affects the amount of aerodynamic noise that is created by the system. The tables below represent the maximum airflow velocities that should be used to achieve the following RC (Room Criteria) design values.

Maximum Recommended Duct Airflow Velocities Needed to Achieve Specified Acoustic Design Criteria			
Main Duct Location	Design RC (N)	Maximum Airflow Velocity, fpm	
		Rectangular Duct	Circular Duct
In shaft or above drywall ceiling	45	3500	500
	35	2500	3500
	25	1700	2500
Above suspended acoustic ceiling	45	2500	4500
	35	1750	3000
	25	1200	2000
Duct located within occupied space	45	2000	3900
	35	1450	2600
	25	950	1700

Notes:

1. Branch ducts should have airflow velocities of about 80% of the values listed.
2. Velocities in final runouts to outlets should be 50% of the values or less.
3. Elbows and other fittings can increase airflow noise substantially, depending on the type. Thus, duct airflow velocities should be reduced accordingly.

Maximum Recommended “Free” Supply Outlet and Return Air Opening Velocities Needed to Achieve Specified Acoustic Design Criteria		
Type of Opening	Design RC (N)	“Free” Opening Airflow Velocity, fpm
Supply air outlet	45	625
	40	560
	35	500
	30	425
	25	350
Return air opening	45	750
	40	675
	35	600
	30	500
	25	425

Note: The presence of diffusers or grilles can increase sound levels a little or a lot, depending on how many diffusers or grilles are installed and on their design, construction, installation, etc. Thus, allowable outlet or opening airflow velocities should be reduced accordingly.

The following list of spaces shows the typical RC design values.

Recommended Noise Criteria of Acceptability for Rooms	
Type of Room or Space	RC Criteria
Recording or broadcast studios	10 – 20
Concert halls	15 – 20
Theatres, performance	20 – 25
Classrooms	25 – 30
Hospital rooms	25 – 35
Cinemas	30 – 35
Apartments, hotel rooms, residences	30 – 35
Offices, private	30 – 35
Corridors	30 – 35
Churches	30 – 35
Courtrooms	35 – 40
Libraries	35 – 40
Offices, open plan	35 – 40
Lobbies, waiting rooms, lounges	35 – 40
Restaurants, cafeterias	40 – 45
Washrooms	40 – 45
Stores (department stores, supermarkets)	40 – 50
Gymnasiums, pools	45 – 55
Tabulation/computer rooms	45 – 60
Manufacturing areas	50 - 70

6. Duct Layout

- a. Consider the following when laying out ductwork to reduce aerodynamic noise generated by the ductwork.
 - 1) Ducts connected to fans should, if possible, have 4 to 5 duct diameters of straight length before turns and/or takeoffs.
 - 2) Duct silencers should be selected with a static pressure loss of 0.35" or less. (Refer to Sound and Vibration Control Section)
 - 3) Fan-powered VAV boxes should not be used in noise critical applications.
 - 4) Use turning vanes in elbows and large branch takeoffs (reduces turbulence).

- 5) Place grilles, registers, and diffusers as far from elbows and branch takeoffs as possible.
- 6) Minimize use of volume dampers near grilles, registers, and diffusers (prevents damper rattling from radiating into space).
- 7) Provide flexible connections at all air handling equipment and when large ducts pass through walls (prevents vibration transmission).
- 8) 45-degree boot takeoffs should be used at all duct branch takeoffs.

7. Duct Liner

- a. Duct liner can be used to alleviate noise transmitted through ductwork. Refer to ASHRAE Applications Handbook “Sound and Vibration Control” to determine sound attenuation.
- b. Note that lined ductwork is not externally insulated.
- c. When using duct liner, specify the inside clear dimensions of the ductwork. Do not give the sheet metal size.
- d. For low pressure ducts and ductwork downstream of VAV boxes, use the following guidelines.

Sheet Metal Size	Inside Dimension With 1/2" Liner	1/2" Liner Max CFM	Inside Dimension With 1" Liner	1" Liner Max CFM
12 / 6	11 / 5	200	10 / 4	150
12 / 12	11 / 11	700	10 / 10	500
18 / 12	17 / 11	1200	16 / 10	950
18 / 18	17 / 17	2150	16 / 16	1800
24 / 12	23 / 11	1650	22 / 10	1400

8. Flexible Ducts

- a. Flexible ducts are used at terminal device connections and in concealed applications from branch duct to diffuser.
- b. Use the following table for sizing flex duct to diffusers and VAV boxes.

Flex Size	Diffuser CFM Range	VAV Box CFM Range
6" Ø	75 – 150	–
7" Ø	–	0 – 150
8" Ø	151 – 300	151 – 300
10" Ø	301 – 500	301 – 500
12" Ø	501 – 800	501 – 1200
14" Ø	801 – 1200	1201 – 1600
Maximum flex duct length is 12'-0" for diffusers and 6'-0" maximum for VAV boxes.		

9. Testing, Adjusting, and Balancing
 - a. Balancing is required to ensure that the proper airflow is delivered to the space. Provide volume dampers at branches and mains to help facilitate balancing (supply and return).
 - b. Volume dampers are not required in supply ductwork on VAV systems.

SECTION 16.00 – AIR DISTRIBUTION

16.01 ROOM AIR QUANTITIES

A. SIZING CRITERIA

1. The quantity of air supplied to a space or zone is based on the area’s sensible cooling load requirement (for cooling and heating).
2. Space/zone loads are calculated by using Carrier’s HAP Program (refer to Section 3.00).
3. From the load program, use the zone sizing summary sheet to obtain the peak sensible cooling and heating load. DO NOT USE THE AIRFLOWS GIVEN IN THIS SUMMARY.
4. Calculate the required airflow by using the following formula:

$$Q = 1.08 (\text{cfm})(\Delta T) \text{ or } \text{cfm} = \frac{Q}{1.08 (\Delta T)}$$

cfm = Airflow quantity in cubic feet per minutes

Q = Sensible cooling or heating load (BTUH)

1.08 = Constant for air

(refer to ASHRAE Fundamentals for full description)

$\Delta T = (T_{RM} - T_{SA})$

T_{RM} = Desired Room Temperature – For cooling, use 75°F
For heating, use 72°F

T_{SA} = Supply Air Temperature –

For chilled water AHU, use 55°F

For DX AHU, use 58°F

For heating, use Design Supply Air Temperature

5. From Part 4, round airflow quantity to nearest “5” cfm. Verify in constant volume systems that space air quantities equal air handling unit cfm. For VAV systems, air handling unit diversity factor should not be less than 80% unless approved by Department Manager.

B. EXHAUST AIR

1. Toilet Rooms – The following guidelines should be used to determine the quantity of exhaust air from toilet rooms.
 - a. 1998 International Mechanical Code requires 75 cfm minimum per water closet or urinal.

- b. Based on square footage at space, a quantity of 2 cfm/square foot or 10 air changes per hour should be used.

The larger of the two quantities should be used.

Makeup air should be supplied to toilet room through door louver, transfer duct, or door undercut.

C. ELECTRIC ROOMS WITH TRANSFORMERS

- 1. Obtain transformer sizes from Electrical Department (i.e., 150 Kva, 30 Kva, etc.)
- 2. Determine heat load.

$$Q_{\text{tot}} = (\text{Transformer size}) \times \text{PF} \times 1000 \text{ watts/KW} \times 3.412 \text{ BTUH/watt}$$

$$Q = Q_{\text{tot}} \times 'X'$$

$$Q_{\text{tot}} = \text{Total uncorrected heat load}$$

$$\text{PF} = \text{Power Factor} = 0.9$$

$$X = \text{\% of heat loss of transformer}$$

(dry type = 3%; others, see Electrical Department)

$$\text{cfm} = \text{Exhaust air quantity}$$

$$\Delta T = (T_{\text{room}} - T_{\text{transfer air}})$$

Multiply cfm x 75% diversity factor

- 3. Adequate quantities of makeup air must be transferred to the space from outdoors or conditioned interior space.

D. MAKEUP AIR

- 1. Transfer air ducts are to be sized on 0.05" static pressure loss for total transfer air quantity (recommendation: 500 FPM, maximum – 800 FPM).
- 2. Makeup air louvers from outdoors should not exceed 650 feet per minute face velocity. (Typical design range of 500 feet per minute)

16.02 DIFFUSER, REGISTER, AND GRILLE SELECTION

A. GENERAL INFORMATION

1. The following information must be known prior to selection of diffusers, registers, and grilles.
 - a. Airflow required (see Section 16.01)
 - b. Room/area layout
 - c. Type of ceiling system
 - d. Type of air handling system (CV or VAV)
 - e. Architectural requirements
 - f. Use of space/noise requirements

B. DEVICE SELECTION

1. Supply Air Diffusers, Registers, and Grilles
 - a. The type and quantity of supply air outlets must be determined based on air quantity required, distance available for throw or radius of diffusion, room layout, ceiling and lighting layout, and special architectural concepts.
 - b. Chapter 31 of the ASHRAE Fundamentals Handbook reviews the different concepts for locating diffusers, registers, and grilles for different diffuser types. Please refer to this chapter for layout alternatives.
 - c. In general, diffusers should be spaced so that, at a terminal velocity of 50 FPM, air flows converge from different diffusers. Diffusers should not be located so close to a wall that terminal velocity exceeds 75 FPM.
 - d. Supply air outlets should be selected so that the static pressure drop does not exceed 0.10".
 - e. Maximum allowable NC for a diffuser is 35. Spaces that have a noise criteria which is stricter than NC 35 should be selected to meet the required NC values. Refer to Section 15.00 for recommended NC values for different spaces.

- f. Select devices from JDBE standard or manufacturers' literature.

C. SUPPLY AIR OUTLETS

- 1. The following list of Supply Air Outlets are JDBE's standard for design and recommended use. Please note that the device may be appropriate for several different uses or may be used in ways not listed. Manufacturer and model listed are JDBE Basis of Design.

- a. CD – Ceiling Diffuser

Anemostat Model XDF. 1- through 4-way blow used in plaster or lay-in ceilings. Typically used in constant volume systems.

- b. VCD – Vaned Ceiling Diffuser

Tuttle & Bailey Agitair RC. Alternative square diffuser for use in VAV systems. 1- through 4-way blow available. Typically not the best choice for VAV systems.

- c. PCD – Panel Ceiling Diffuser

Anemostat XDP. 1- through 4-way blow available. Used in 2' x 2' and 2' x 4' lay-in acoustic ceilings. Typically used in constant volume systems.

- d. RCD – Round Ceiling Diffuser

Anemostat Model C-27. Adjustable, vertical and horizontal throw. Used in high throw and high ceiling situations.

- e. PFC – Perforated Face Diffuser

Anemostat PREO. Used in applications requiring large cfm and low velocities and throws.

- f. LAD – Linear Air Diffuser

Anemostat SLAD. Used in vertical or horizontal orientations. Used where architectural requirements dictate. Good use in entrance vestibules.

- g. VSD – VAV Slot Diffuser

Trane VLSD. Used in VAV applications. Good airflow distribution at varying rates. 1- or 2-way blow available.

h. BSR – Barrel Supply Register

Tuttle & Bailey Model STRJ. Rotating barrel register for high throw/high ceiling industrial applications.

i. SSR – Sidewall Supply Register

Anemostat X2HO. Used in all environments when overhead distribution is not practical. Often used with exposed ductwork.

2. The table below reflects JDBE standard selection for CD and PCD diffusers.

(Panel) Ceiling Diffuser Schedule							
CFM Range	Throat Size	Flex. Size	Radius of Diffusion*				NC** Value
			4-Way	3-Way	2-Way	1-Way	
50 – 99	6 / 6	6	2 – 5	3 – 6	3 – 7	5 – 9	25
100 – 300	9 / 9	8	4 – 6	4 – 7	5 – 8	7 – 12	25
301 – 500	12 / 12	10	5 – 8	6 – 9	7 – 11	9 – 15	30
501 – 800	15 / 15	12	6 – 10	7 – 12	8 – 14	13 – 19	35
801 – 1200	18 / 18	14	8 – 13	10 – 15	12 – 17	N/A	35

* Terminal velocity of 300 FPM, resulting room velocity less than 50 FPM.

** Based on an 8 db room absorption at a sound power level of 10^{-12} watts. NC value includes wide open opposed blade damper in the diffuser.

*** All diffusers are 4-way blow unless noted otherwise.

3. The following list of Return Air Inlets are JDBE’s Standard for Design. Manufacturer and model number listed are JDBE’s Basis of Design.

a. PFR – Perforated Face Return

Anemostat Model 3PR00. Matching return for PFD.

b. LAR – Linear Air Return

Anemostat SLAR. Matching return for LAD.

c. VSR – VAV Slot Return

Trane Model VLSD. Matching return for VSD.

d. SRR/SER – Sidewall Return/Exhaust Register

Anemostat X3HOD. Used in commercial and industrial environments where ceiling application is not available.

- e. RR/ER – Return/Exhaust Register

Anemostat GC50. Ceiling return/exhaust register used in ducted returns in commercial/industrial environment.

- f. HDRR – Heavy Duty Return Register

Anemostat EHDOD. Used in environments where the register may be damaged (i.e., gyms, auditoriums, industry, etc.)

- g. SRG/STG – Sidewall Return/Transfer Grille.

Anemostat X3HD. Used where integral balancing damper is not required.

- h. RG/TG/EG – Return/Transfer/Exhaust Grille

Anemostat GC5. Ceiling application where integral balancing damper is not required (plenum returns/exhaust ducts with single inlet, etc.).

- 2. The following tables are JDBE’s standard for RG/EG/TG and RR/ER selections.

Ceiling Exhaust & Return Register Schedule			
CFM Range	Size	Max. SP.* ("H20)	Max. NC* Value
0 – 100	6 / 6	0.09	30
101 – 200	8 / 8	0.08	30
201 – 400	10 / 10	0.08	33
401 – 600	12 / 12	0.07	32
601 – 800	18 / 12	0.07	32
801 – 1000	24 / 12	0.07	32
1001 – 1400	18 / 18	0.08	35
1401 – 2000	24 / 24	0.06	34

* Includes effects of opposed blade damper

Ceiling Return, Transfer & Exhaust Grille Schedule			
CFM Range	Size	Max. SP. ("H20)	NC* Value
0 – 100	6 / 6	0.04	20
101 – 200	8 / 8	0.04	20
201 – 300	10 / 10	0.03	20
301 – 500	12 / 12	0.04	20
501 – 1100	18 / 18	0.04	25
1101 – 2000	24 / 24	0.04	30

16.03 VARIABLE AIR VOLUME SYSTEM DESIGN

16.04 ASHRAE STANDARD 62 VENTILATION RATE COMPLIANCE

A. GENERAL INFORMATION

1. ASHRAE Standard 62-1999, “Ventilation for Acceptable Indoor Air Quality,” prescribes two methods for designing HVAC systems that achieve acceptable air quality. These are:
 - a. Ventilation rate procedure (Section 6.1)
 - b. Indoor air quality procedure (Section 6.2)
2. The ventilation rate procedure will be used on all projects, unless special approval has been granted by the department manager. Design criteria, assumptions, and calculations shall be documented and kept in the project design file.

B. ACCEPTABLE OUTDOOR AIR

1. Determine acceptability of outdoor air quality by comparing contaminant levels listed in U.S. EPA “*National Air Quality and Emissions Trends Report, 1989*” for location of the facility to those listed in Table 1 of ASHRAE Standard 62-1999.
2. If the location of the facility is not listed in the EPA Emissions Trends Report, choose the nearest location listed.
3. If the outdoor air contaminant levels exceed the Table 1 values, it could be treated to control the offending contaminants. (Applicable standards).

C. VENTILATION REQUIREMENTS

1. General – Table 2 lists outdoor air requirements for various types of occupied spaces. If other code requirements exceed the values listed in Table 2, the more stringent code requirement will be used for design. Otherwise, the Table 2 value will be used.

For industrial areas not covered in Table 2, refer to *Threshold Limit Values (TLV's) and Biological Exposure Indices for 1986-87*, American Conference of Governmental Industrial Hygienists.

2. Occupant Density – Use actual number of people obtained from the architect or owner. If actual number of people is not available, use estimated maximum occupancy densities from Table 2.
3. Single Space – For situations where the air handling system serves only one space, multiple the Table 2 outdoor air requirement by the number of people. The product of the two is the outdoor air requirement on the air handling system.
4. Multiple spaces – For situations where the air handling system serves multiple spaces, the system outdoor air quantity shall be calculated using equation 6-1.

$$Y = X/[1+X-Z] \quad (6-1)$$

$Y = V_{ot}/V_{st}$ = Corrected fraction of outdoor air in system supply.

$X = V_{on}/V_{st}$ = Uncorrected fraction of outdoor air in system supply.

$Z = V_{oc}/V_{sc}$ = Fraction of outdoor air in critical space.

Utilize the “Airflow Balancing Spreadsheet” described in Section B to conduct multiple space calculations.

5. Variable Occupancy – Where peak occupancies of less than three hours duration occur, the outdoor air flow rate may be determined on the basis of average occupancy for the duration of air system operation. However, the average occupancy may not be less than one-half the maximum.

D. AIRFLOW BALANCING SPREADSHEET

1. General – Use Excel to run Spreadsheet. The spreadsheet is located on the network under the f:/Excel/JDB/Masters directory, Filename: Std. 62a.xls. A sample spreadsheet is shown on Figure 1. See Figure 2 for visual interpretation of spreadsheet.

2. Spreadsheet Input Instructions:

- a. Column A: People diversity percentage.

The average occupancy as described in Section C, Part 5. Use a minimum of 50 percent.

- b. Column B: Number of people.

Do not necessarily use take-off quantities from cooling load calculations. The total at the bottom of the column should equal the maximum total expected instantaneous occupancy. An educated guess must be made to estimate critical space occupant densities. Consideration should generally be given to maximizing the number of people in spaces with high occupant densities.

- c. Column C: Required CFM per person.

ASHRAE Standard 62-1999, Table 2 values.

- d. Columns D through G: Entering Air – All air entering the space except infiltration and secondary air.

1) S MAX: Maximum volume of primary supply air from the air handling system.

2) S MIN: Minimum volume of primary supply air from the air handling system. This cannot equal zero. Input minimum setting of VAV box or expected minimum flow rate based on internal heat gain. If constant volume system, S MAX = S MIN.

3) T MAX: Unvitiated transfer air from adjacent space at maximum primary supply airflow.

4) T MIN: Unvitiated transfer air from adjacent space at minimum primary supply airflow.

- e. Columns H and I: Refrigerated Air – All air that does not return to any central air handling equipment.

1) 2ARY: Secondary airflow from a plenum (e.g. from a fan-powered box)

- 2) RCA: Recirculated airflow that remains within the occupied space (e.g. from a fan coil or induction system.)
- f. Columns J through L: Leaving air – All air leaving the occupied space except exfiltration and secondary air.
 - 1) RA: Air returned to the system under analysis.
 - 2) EA: Air directly exhausted from the space.
 - 3) TA: Unvitiated transfer air to adjacent spaces (Max.)
- g. Column M: Percent pressurization.

Automatically calculated from previous inputs.
- h. Column N: Required outdoor air.

Automatically calculated from previous inputs. This is the single space requirement from ASHRAE Standard 62: Column A x B x C.
- i. Column O: Actual outdoor air.

Automatically calculated from previous notes.
- j. Input scheduled air handler supply air, return air, exhaust air, and outdoor air values in allotted cells at bottom of spreadsheet.
3. Output Interpretation: If flag at bottom sheet says “system meets ASHRAE 62 requirements,” air system ventilation rates are adequate. If it says “system does not meet ASHRAE 62 requirements,” ventilation rates are not adequate. Suggestions for meeting requirements:
 - a. Increase minimum supply airflow rates (5 min) for areas with high occupant densities.
 - b. Introduce greater quantities of transfer air into areas with high occupant densities.
 - c. Re-evaluate occupant distribution (Column B).
 - d. Increase scheduled outdoor air quality on air handling unit.

SECTION 17.00 – CONTROL VALVE SELECTION

17.01 STEAM CONTROL VALVE SIZING

- A. To determine the C_v of the steam control valve, use the following equation:

$$C_v = \frac{Q \times \sqrt{v}}{63.5 \times \sqrt{h}}$$

- h = critical pressure drop in psi
 $h = 0.5 \times (14.7 + P_{\text{main}})$
- For modulating control valve, “ h ” equals the smaller of the following two equations:

$$h = 0.8 \times (P_{\text{main}} - P_{\text{return}})$$

$$h = 0.5 \times (14.7 + P_{\text{main}})$$

- P_{main} = Steam main pressure
 - P_{return} = Condensate return pressure
 - Q = Steam load in MBH
 - V = Specific volume of steam pressure (cu. ft./lb.)
- B. For two-position valves, the valve should be line size. If a smaller valve is required, calculate C_v required by using the following formula:

$$h = 0.2 \times (P_{\text{main}} - P_{\text{return}})$$

- C. C_v must be increased by 7% for every 100°F of superheat

17.02 HYDRONIC SYSTEM CONTROL VALVE SIZING

- A. To calculate capacity index (C_v) for a hydronic control valve, use the following formula:

$$C_v = \frac{\text{gpm} \times \sqrt{g}}{\sqrt{h}}$$

- gpm = Gallons per minute of coil
- G = Specific gravity of fluid
- $G = 1$ for water
- $G = 1.035$ for 25% ethylene glycol
- h = Pressure drop across valve (psi)
- h_{coil} = Water pressure drop across coil in psi
- $h = 0.5 \times (h_{\text{coil}})$

B. In variable speed pumping systems, adequate three-way valves must be provided to maintain 40% of the total system flow.

SECTION 20.00 — ICE STORAGE SYSTEMS

20.01 GENERAL INFORMATION

Utility rate structures are generally set up such that demand charges are higher during the utility on-peak or daytime hours than at night during the utility off-peak hours. If the on-peak demand for a building's heating, ventilating, and air conditioning system can be reduced, the system's operating cost can, therefore, also be reduced. A method of reducing demand is to reduce the chiller capacity available to the facility during the on-peak period. However, limiting chiller capacity without providing for the cooling of the facility by some other means results in building temperature control problems.

One such method for reducing the on-peak chiller capacity, is the use of ice storage. With this method, the chiller is run at night during the off-peak period to make ice. The ice is then used during the day to help cool the facility. Several different sizing methods and control schemes can be used with ice storage depending on system economics and utility rate structures.

Probably the most often used method, due to its shorter payback, is the partial ice storage system. With this method, only enough ice to satisfy about 50 percent of the building cooling requirements is stored. During periods when the on-peak cooling load exceeds 50 percent, the chiller is run to assist the stored ice in cooling the facility. This reduces the chiller KW requirements by about 50 percent.

Many utilities are offering their customers incentives in the form of rebates to install systems of this type. These rebates further reduce the payback on the system as well as assist the utility in reducing its on-peak demand and, therefore, its generating capacity requirements.

A. COOLING LOAD ESTIMATING

1. Use the Carrier E20-II, Hourly Analysis Program (HAP) Version for all cooling load calculations unless use of another method or computer program is specifically authorized by the project manager. Refer to Section 3.00, "Heating/Cooling Load Estimating," for a detailed explanation of the use of this particular program.
2. Selection of the chiller and ice storage tanks requires that the Ton-Hour requirements of the facility be calculated. Once the load analysis program has determined the design day for the facility, the Ton-Hour requirements can be determined. Using the same Carrier (HAP) program that was used for the heating/cooling load calculations, the equipment schedules for the facility are modified to give the best possible equipment load simulation possible. The cooling load calculations are then run for each hour of the design day. The sum of the hourly cooling loads for the design day

occupied cycle become the facility Ton-Hour requirements. The better the assumptions made for the equipment schedules such as lighting, computer equipment, people, etc., the better the results. Refer to Section 3.00, "Heating/Cooling Load Estimating," for a detailed explanation of the use of the Carrier (HAP) program.

3. Note that the method outlined above results in a load profile for a typical design day. You may wish to determine the load profile for some other period of time, such as a typical week. The time period selected will impact the Ton-Hour requirements and, therefore, will affect the chiller size and the number of ice tanks required. Typically, the longer the period of time designed for, the smaller the chiller can be. Unless specifically authorized by the HVAC Department Manager, ice storage design should be based upon a 24 hour charge/discharge period.

B. FULL VERSUS PARTIAL ICE STORAGE SYSTEM

1. In a Full Ice Storage System, enough ice is made during the off-peak hours to satisfy all of the on-peak cooling requirements. In a Partial Ice Storage System, enough ice is made to satisfy some percentage of the on-peak cooling requirements.
2. Whether an ice storage system is partial or full is determined by the system economics. A full storage system requires more ice storage and, therefore, has a higher first cost than does a partial system. Unless the savings generated by the full storage system results in a shorter payback than the partial system, a partial ice storage system should be utilized. Most economic studies result in a partial ice storage system, designed for about 50 percent of the facility Ton-Hour requirements, being selected.

C. CHILLER PRIORITY VERSUS ICE PRIORITY

1. In an Ice Priority System, the ice is the primary cooling medium and the chiller is used to handle any peak loads that occur during the occupied cycle. In this system, as much of the ice is used as possible during the occupied cycle. In a Chiller Priority System, the chiller is the primary cooling source and the ice is used to handle peak loads that occur during the occupied cycle.
2. Whether a system is designed for ice or chiller priority is normally determined by the utility rate structure. Since chillers are less efficient while making ice than when in the standard cooling mode, it is better not to make more ice than necessary during the off-peak period if the difference in utility rates during the on-peak and off-peak periods is minimal. In this case, a chiller priority system may prove more economical.

3. A study of the rate structure being provided by the local electric utility for the facility in question is necessary in order to select the best system (ice priority or chiller priority) for the project.

D. EQUIPMENT SELECTION METHOD

1. The following method for determining the required number of ice tanks is based upon the Calmac Ice Storage System. The attached sample graphs used for the calculations can be found in the Calmac catalog.
2. The attached spreadsheet has been developed to assist in determining the size of the chiller required as well as to assist in determining the number of ice tanks required for the system.
3. Proper selection of equipment requires an analysis of the system in both the ice charging mode and the ice discharge mode. The method described is a trial and error solution. Several attempts may be required to achieve the required solution.

20.02 ICE CHARGING MODE

- A. Using the Lotus Spreadsheet, insert the number of daily Ton-Hrs calculated using the Carrier HAP program as described previously. Note that the calculation is based upon a partial ice storage system and assumes that approximately 50 percent of the building Ton-Hr requirements are to be provided by the stored ice. This can be changed by modifying the constant in the equation from 0.5 to some other value. The Ton-Hrs to be provided by the stored ice in the system are then automatically calculated.
- B. Assume the number of ice tanks that may be required for the system. This can be determined by dividing the Ton-Hrs previously calculated by either 150, 80, or 72 depending on whether a Calmac model 1190, 1100, or 2090 ice storage tank is to be utilized. Normally the model 1190 Calmac storage tank should be utilized. The Ton-Hrs should, therefore, be divided by 150 Tons/Tank. Input the assumed number of tanks into the spreadsheet by rounding up to the next larger tank quantity. The program then calculates the Tons/Tank. The spreadsheet assumes the number of ice making hours to be ten (10). If some other value is to be used, the spreadsheet constant must be changed. It is important that the electric rate schedule for the building be analyzed to determine the on-peak and off-peak time periods before deciding the number of hours that are available for making ice. Keep in mind, that the more hours available to make ice the better, since it reduces the size of the chiller required.

- C. Next input the calculated building peak cooling load in tons. The program then estimates the flow rate per tank in GPM. Note that the program assumes a ten (10) degree temperature drop through the chiller. Once again, this value can be changed if the system design calls for a different temperature drop. Keep in mind, that if the temperature drop through the chiller is reduced, the flow increases. The chiller must be checked to make sure it is designed to handle the increased flow rate. The spreadsheet is currently set up assuming an ice priority system with a total system temperature rise of fifteen (15) degrees.
1. In estimating the flow rate, the program determines the cooling load that is being handled by the chiller by using the value given to it for the portion of the load handled by the ice. It then assumes that the chiller is only capable of producing 65 percent of its nominal rating when in the ice making mode.
- D. At this point, go to the ice charging curve graph for the model tank being utilized. Using a five (5) degree temperature rise through the ice tanks when in the charging mode and the flow rate through each ice tank predicted by the program, locate the Charging Rate in Tons/Tank from the graph. Insert this value into the spreadsheet.
1. Note the percentage of Ton-Hrs that the program predicts will be stored by the ice system. If this value exceeds the desired value, try reducing the number of storage tanks and repeat the calculations. If more storage is required, then increase the number of tanks and repeat the calculations.
 2. If increasing the number of tanks does not improve the storage capacity, the temperature rise through the ice tanks can be increased. Be careful, however, since this tends to lower the Average Entering (Charging) Brine Temperature, which will decrease the chiller capacity while making ice. Refer to steps E and F below.
 3. Once satisfied with the predicted results, move on to step E.
- E. From the Calmac Ice Charging Graph for the model tank being utilized, determine the Average Entering (Charging) Brine Temperature and the Minimum Entering (Charging) Brine Temperature. Enter these values into the spreadsheet.
- F. Select a chiller based upon the estimated nominal chiller capacity predicted by the program. From the manufacturer's literature, determine the derated chiller capacity based upon a leaving chilled water temperature equal to the Average Entering (Charging) Temperature predicted from the Calmac Ice Charging Graph. Enter this capacity into the spreadsheet. The spreadsheet will then determine the Ton-Hrs that can be provided by the chiller during the ice making mode. Compare this value to the Tons-Hrs required to charge the tanks. If the chiller does not have enough capacity, increase the chiller size as necessary.

1. Since ice is typically made at night, the condenser water temperature entering the chiller or the air temperature entering the air cooled condenser can be derated from its normal value. Typically 75 degree entering condenser water temperature or 85 degree entering condenser air temperature is utilized.

20.03 ICE DISCHARGE MODE

SECTION 21.00 — VIBRATION AND SOUND CONTROL

21.01 VIBRATION ISOLATION

A. General

HVAC systems have many components that may have an impact on building sound power levels. Vibrating equipment is one of the most common noise sources in a building.

By properly isolating vibrating equipment from the building structure, the transmission of unwanted noise can be greatly reduced.

B. Vibration Isolators

There are several types of vibration isolators that can be used to reduce vibration transmission levels. Typically, a vibration isolator is selected based upon the required static deflection and weight of the equipment. However, other factors such as cost, life, and suitability should be evaluated.

The following list summarizes the types of vibration isolators commonly used in HVAC applications:

- Rubber mounts and pads
- Glass fiber pads
- Spring isolators
- Restrained spring isolators
- Air springs
- Rubber and spring hangers

Refer to ASHRAE HVAC Applications Hand Book for a detailed description of each vibration isolator.

C. Vibration Isolation Selection for Typical HVAC Applications

Vibration of HVAC systems has been studied for many years and typical solutions and recommendations have been developed.

The table following this section, adapted from the ASHRAE Hand Book, recommends required isolator deflection and type for specific scenarios. This chart should be used as the minimum amount of vibration isolation on all projects.

Flexible connectors should be used at all piping, electrical, and duct connections that are attached to isolated equipment. Flexible connectors provide flexibility to permit proper isolator function, protect equipment from strain from misalignment,

thermal expansion or contraction, and attenuate noise transmitted through piping and ductwork.

D. Vibration Isolator Selection (By Department Manager authorization only)

Several simple steps can be used to size vibration isolators for scenarios not listed above.

1. Establish the total weight and lowest expected forcing frequency of the equipment to be isolated.
2. From the following table, select the required static deflection based on RPM and Required/Desired Vibration Isolation Effectiveness.

Equipment Speed (rpm)	Effective static deflection (in.) required to obtain Various percentages of vibration isolation							
	99%	97%	95%	90%	85%	80%	75%	60%
3600	0.27	0.09	0.06	0.03	0.02	0.02	0.01	0.01
2400	0.62	0.21	0.13	0.07	0.05	0.04	0.03	0.02
1800	1.1	0.37	0.23	0.12	0.08	0.07	0.05	0.04
1600	1.4	0.47	0.29	0.15	0.11	0.08	0.07	0.05
1400	1.8	0.62	0.38	0.20	0.14	0.11	0.09	0.06
1200	2.5	0.84	0.51	0.27	0.19	0.15	0.12	0.09
1100	2.9	1.0	0.61	0.32	0.22	0.17	0.15	0.10
1000	3.6	1.2	0.74	0.39	0.27	0.21	0.18	0.12
900	4.4	1.5	0.91	0.48	0.33	0.26	0.22	0.15
800	5.6	1.9	1.2	0.61	0.42	0.33	0.28	0.19
700	7.3	2.5	1.5	0.79	0.55	0.43	0.36	0.25
600	9.9	3.4	2.1	1.1	0.75	0.59	0.49	0.34
550		4.0	2.4	1.3	0.89	0.70	0.58	0.41
500		4.8	3.0	1.6	1.1	0.85	0.71	0.49
400		7.6	4.6	2.4	1.7	1.3	1.1	0.77
350		9.9	6.0	3.2	2.2	1.7	1.4	1.0
300			8.2	4.3	3.0	2.4	2.0	1.4
250				6.2	4.3	3.4	2.8	2.0

3. Based on weight and required static deflection, select the appropriate isolator type.

Rubber pads are effective to approximately 0.1" static deflection.

Rubber mounts and fiberglass pads are effective from 0.1" ≈ 0.5" of static deflection.

Spring mounts should be utilized on static deflections greater than or equal to 0.75". Type of spring mounts, either restrained or unrestrained, should be based on specific application.

4. In general, as the unsupported structural span increases over 20 feet, greater care should be given to the selection of the isolator. Typically, as span increases, so does the required static deflection. The isolator must be able to compensate for deflection of the structure from the equipment load.

Typically, the isolator must be at least 0.10 times as stiff, as compared to the floor stiffness in spans over 20 feet. Example:

For rooftop units on spans over 20 feet, the isolator deflection should be 15 times the deflection of the structural member if it is equal to or less than 0.25 inches.

If the roof deflection is greater than 0.25 inches, supplemental stiffening should be used or the rooftop unit should be moved.

If a 10,000 lb. piece of equipment causes an additional floor deflection of 0.1 inches, floor stiffness is 100,000 lb./in., an isolator with a stiffness of 10,000 lb./in. must be used.

Consult with the Structural Department to determine the deflection caused by the equipment.

21.02 DUCT SILENCER SELECTION

A. GENERAL INFORMATION

HVAC systems are often the biggest factor in determining background sound levels. Building mechanical systems can create noise problems in occupied areas in three major ways. These are:

1. Airborne, radiated transmission of machinery noise through walls, etc.
2. Structure-borne transmission from mechanical vibration.

3. Duct-borne noise created by air handling system components from either:
 - a. Excessive turbulence that causes breakout noise or duct “rumble.”
 - b. Fan discharge sound power.

The only type of noise controlled by a duct silencer or sound trap is the fan discharge sound power. Therefore, proper selection of a duct silencer does not guarantee acoustical integrity.

B. PROCEDURE FOR SELECTION

The procedure for selection of a duct silencer can be broken down into a series of steps:

1. Determine the Design Goal

The system noise control goal is a factor of space usage characteristics. For example, recording studios, office areas, and restaurants all have different desired background sound levels. The background sound criteria used in this procedure will be the NC (Noise Criteria) curves. These curves define acceptable limits of a given noise source across the spectrum of audible frequency octave bands that must not be exceeded to ensure a level of acoustical comfort. Typical NC-design goals and the NC-curves themselves are included in the appendix of this procedure.

2. Prediction of Fan Sound Power

- a. The best method of obtaining fan sound power data at specified conditions across the audible spectrum is from the manufacturer. If this data is not available, however, it can be calculated by a three-step procedure:

- 1) Use equation (1) to calculate a base level across all frequency bands.

$$L_w = 10 \bullet \log Q + 20 \bullet \log P \quad (1)$$

Where:

L_w = Sound Power (dB)

Q = Airflow Volume (cfm)

P = Fan Static Pressure (inches w.g.)

- 2) Add to this number the specific sound power levels from Table 5 in the appendix. (From 1987 ASHRAE Systems and Applications Handbook.)
 - 3) From Table 4 in the appendix, determine which octave band contains the Blade Frequency Increment (BFI). Find the BFI in Table 5 and add it to the total for the specified frequency band.
- b. The addition of these three values represents the fan sound power and can be referred to as Source L_w .
 - c. If the silencer is being selected for a VAV system, it is important to add a correction factor across all frequency bands to account for off-peak operation. See Table 7 in appendix.
3. Calculate Ductwork Attenuation
 - a. Ductwork (both lined and unlined), duct fittings, and duct outlets all help in attenuating acoustical energy generated by the fan. Tables that contain data regarding sound attenuation for various types of ducts and branch take-offs are included in the appendix.
 - b. It is generally acceptable to calculate ductwork attenuation only to the outlet closest to the fan. This method assumes that terminals further downstream have better attenuation from longer duct runs. It will also be assumed that duct elbow attenuation and regeneration noise cancel each other out. Therefore, elbows are ignored.
 4. Prediction of Room Absorption or “Room Effect”

At this point, the sound power level (L_w) at the outlet has been predicted. This level must now be converted to a sound pressure level (L_p) that the occupant perceives. The L_w - L_p conversion is a function of room volume, source, furnishings, and linear distance from source to listener. There are two acceptable methods of calculating the “room effect”:

- a. Theoretical: $L_p = L_w + 10 \cdot \log(Q/4\pi r^2 + 4/R) + 10$ (2)

Where:

Q = Directivity Factor (=2 for ceiling or sidewall source)

r = Distance from Source to Listener (ft.)

R = Room Constant. This can be calculated in two ways:

1) $R = \frac{S\bar{a}}{1-\bar{a}}$ [Theoretical] (2a)

Where:

S = Surface Area (sq. ft.)

\bar{a} = Room Averaged Absorption Coefficient

2) $R = \sum S\bar{a}$ [Sabin] (2b)

Where:

S = Surface Area (sq. ft.)

\bar{a} = Material Absorption Coefficient

3) Thus, there is a different value for R in each octave band. Some typical absorption coefficients for various materials are given in the appendix. A chart exists that can take the place of the equation (2) calculations. It is located in the appendix.

b. Schultz: $L_p = L_w - 5 \cdot \log V - 3 \cdot \log f - 10 \cdot \log r + 25$ (3)

Where:

V = Room Volume (cu. ft.)

f = Center Band Frequency (Hz.)

r = Distance from Source to Listener (ft.)

This is an empirically developed equation and is typically only used when exact material finishes are unknown or when a value must be quickly predicted.

5. Select Duct Silencer

Now that the acoustical energy transmitted from the source (fan) to the listener has been estimated, a silencer may be selected. The background levels from the NC-curve are subtracted from the perceived sound pressure level at the various octave bands. The difference is the amount of attenuation required from the silencer. This value is referred to as Dynamic Insertion Loss (DIL).

For example:	Fan Sound Power (Source L_w)
	Ductwork Attenuation
	- Room Effect
	=====
	Sound Pressure Level (L_p)
	- NC-Curve Values
	=====
	Required Attenuation (Required DIL)

6. Duct Silencer Placement

Proper placement of the duct silencer is just as critical as proper selection. Regenerated noise is an inherent problem with duct silencer installation. The silencer's self-noise should always be less than or equal to the fan sound power at its location in the ductwork. Silencers should also never be placed over occupied areas. Guidelines for sound trap placement are included in the appendix.

Note: For a quick estimate of duct silencer requirements, calculations for the 250 Hz frequency band are sufficient.

SECTION 22.00 — ESTIMATING

22.01 PRELIMINARY ESTIMATES

A. GENERAL

Preliminary estimates are calculated before any design has been completed. Estimates are based on a given “dollars per square foot.” Use the estimating spread sheet “CostH.xls” located in the project directory.

The following list is a summary of basic systems cost based on dollars per square foot. Review costs used with the HVAC Department Manager and Project Manager before delivering costs to the client.

The following list is a summary of basic systems cost based on dollars per square foot. Review costs used with the HVAC Department Manager and Project Manager before delivering costs to the client.

<u>System Components</u>	<u>\$ / SF</u>
Automatic Temperature Controls	\$2.00 - \$3.00
Duct Work Only	\$4.00
Chilled Water Plant & Piping	\$4.00
Hot Water Plant & Piping	\$2.50
 <u>Complete Systems</u>	
<u>\$ / SF</u>	
Packaged Air Conditioning	
– New	\$6.00 - \$8.00
– Renovation	\$8.00 - \$12.00
VAV (Chilled & Hot Water Plants)	
– New	\$13.00 - \$16.00
– Renovation	\$18.00 - \$20.00
VVT (Chilled & Hot Water Plants)	
– Renovation	\$12.00 - \$14.00
Single zone System (Chilled & Hot Water Plants)	\$12.00 - \$14.00
 Estimating Check	
Complete Building HVAC System	
– Chilled Water / Hot Water System	\$4000 / ton of cooling
– Packaged System	\$2500 / ton of cooling

Fire Protection

- Office (ceiling) \$1.75 / SF
- Factory (no ceiling) \$2.00 / SF
- Factory – High Density \$2.25 / SF

- Add Site Piping if required to all systems above \$0.50 - \$0.70

Contingency Factor

10% to 20% should be used on preliminary estimates

22.02 FINAL ESTIMATES

A. GENERAL

1. Final estimates are calculated when design has been completed. Estimates are based on a take-off estimate of the design documents. Means Construction Cost Data should be used to obtain Material and Labor Costs. Use the estimating spreadsheet, “CostH.xls” in the project directory.
2. Review final estimate with the HVAC Department Manager before delivering to the client.
3. The final items should be used to help develop a detailed final estimate.
 - a. Pounds of ductwork – square feet of insulation should be calculated by using the Excel spreadsheet, “Ductest.xls,” located in the f:/Excel/JDBE/Masters subdirectory.
 - b. All piping lengths should be increased by 25% to account for fittings and valves.
 - c. For large equipment, such as AHU, chillers, boilers, etc., costs should be obtained from the unit manufacturer based on the equipment options used in system design.
 - d. Estimating contingency should range from 0% to 10%.

SECTION 23.00 — GENERAL DRAFTING STANDARDS

A. GENERAL INFORMATION

1. This portion of the manual establishes the JDB Engineering drafting standards which must be met for acceptable drawing quality. Any deviations from this standard must be approved by the Project Manager.
2. Purpose of Drawings
 - a. To supply the necessary information required for the performance of work and to serve as a record of the work performed.
3. Approach
 - a. Drawings shall be accurate, clear, concise, legible, free from unnecessary repetition and ornamentation, and have a good appearance.

B. SHEET LAYOUT

1. Drawing Size
 - a. Use drawing size to match the Client's where applicable.
 - b. Use JDBE standard 30" by 42" drawing border for projects where JDBE is the sole designer, unless directed otherwise by the Project Manager.
2. Drawing Planning Sheets
 - a. The Lead Designer shall prepare drawing planning sheets in the preliminary phase of the project. Include all proposed floor plans, sections, details, and schedules.
 - b. Review planning sheets against architectural floor plans for possible drawing spacing conflicts.
 - c. No drafting shall start until the drawing planning sheets and drawing index have been approved by the Project Manager.

3. Order of Sheets and Sheet Numbering
 - a. Arrange the different disciplines so that HVAC drawings are first followed by the Plumbing, Fire Protection, and Electrical drawings.
 - b. Arrange sheets in the following order:
 - 1) JDBE site plan (if required).
 - 2) Single Line Diagram (Electrical only).
 - 3) Floor plans.
 - 4) Large scale floor plans.
 - 5) Details.
 - 6) Schedules.
 - c. Number sheets in accordance with the following guidelines:
 - 1) Use M-1, M-2, etc., where plumbing and/or fire protection and HVAC are required on the same project, where the project is small, and where the project can be bid as a combination construction project.
 - 2) Use H-1, H-2, etc., where heating or ventilation or air conditioning or a combination of the three is required by itself or as part of a “separate” construction bid contract. HVAC-1, HVAC-2, etc., will NOT be used as a sheet number designation because it requires that the drawing number be reduced to an unacceptable size.
 - 3) Use P-1, P-2, etc., where plumbing is required by itself or as part of a “separate” construction bid contract.
 - 4) Use FP-1, FP-2, etc., where fire protection is required by itself or as part of a “separate” construction bid contract.
 - 5) Use E-1, E-2, etc., where electrical is required.
 - 6) Where different disciplines share the same sheet, for example on a site utility plan, combine the first letters of the disciplines in their normal order, such as HP where HVAC and plumbing share the sheet, or HPE where HVAC, plumbing, and electrical are together. Shared sheets shall be numbered independently of each discipline’s construction drawings; that is, if HVAC and plumbing share a site plan, it will be numbered HP-1 and the first

sheet of their other drawings will be numbered H-1 or P-1 as required.

4. Orientation and Position
 - a. Generally, orient plans to match the orientation of the plot plan. Building north should be either the top or the left of the sheet; but in all cases, the JDBE drawings shall match the orientation of the Architect's drawings. **Maintain the same "north" orientation on all plans for a given project.**
 - b. Show floor plans in the upper left-hand corner of the sheet leaving the remainder of the space for sections, details, etc.
 - c. Group schedules together on separate sheets unless directed otherwise by the Project Manager.
 - d. Sequence and arrange sheets and plans, sections, schedules and details to follow a logical order of presentation so that reference to other sheets will be held to a minimum.
 - e. Show building column line designations along the top and left-hand side of the floor plan if possible.
5. Match Lines
 - a. Clearly note match lines on partial plans with the drawing number for continuation.
 - b. When plans are the same, match lines shall be at the same location for all departments.
 - c. Locate match lines carefully so that the clarity of the drawings will not be compromised.
6. Scale
 - a. Use the smallest scale possible to present the information with the required clarity.
 - b. Generally, floor plans shall be 1/8" scale; equipment room layouts and sections shall be 1/4" scale; and to-scale details shall be minimum 1/2" or 3/4" scale. Use the same scale where the same room will be required on both Mechanical and Electrical drawings.
 - c. Do NOT oversize sections and details.

7. Graphic Scale
 - a. Graphic scales will NOT be used except when required on government projects.
 - b. Show graphic scales for each different scale floor plan, detail, layout, or section shown on drawing.
8. Key Plan
 - a. Key plans shall be used when the area of construction is a portion of the overall building. Key plan orientation shall match that of floor plan.
 - b. Shade or crosshatch the portion of the “key plan” which matches the portion shown on the floor plan.
 - c. Show north arrow on key plan. Do NOT show north arrow on floor plans or room layouts. When no key plan is used, north arrows shall be shown to the immediate left of the floor plan title.
 - d. Key plans shall be consistent throughout all departments and shall match those provided by the Project Manager or Architect.
 - e. Key plans shall be located in the lower right-hand corner of each applicable drawing.
9. JDBE Company Logo
 - a. Place the JDBE company logo on each drawing.
 - b. Place logo in the same location on each drawing and as located on the drawing planning sheets.
 - c. Always place JDBE job number at right-hand of logo.
 - c. JDBE job number must be included on every project drawing.
10. Engineer Stamps
 - a. Allow space for the Architect's and Engineer's seals on each drawing.
 - b. Each seal space shall be 2" by 2" and shall be located as shown on the drawing planning sheets.

- c. Only the responsible engineer shall seal the drawings.
- d. Do NOT use stick-on engineer's seals.
- e. If required by our contract, the responsible Engineer shall stamp all drawings issued for bid and/or construction with his/her seal in the space provided on each drawing.
- f. Do NOT stamp preliminary issues unless the issue is for the purpose of obtaining permits from regulatory agencies and is required by the agency.

11. Submissions

- a. For interim issues, such as Owner review, L & I review, etc.:
 - 1) Identify issue in revision block. Label date and description of submission (i.e., L & I Approval, Owner Review).
 - 2) Issue identification shall be removed from the revision block at the time of the first "working issue" (for material purchase or pricing or bid).
- b. For working issues, such as material purchase, pricing, bidding or construction:
 - 1) Make a record mylar or paper sepia prior to making any revisions to a drawing which has previously been issued for pricing or bidding or construction.
 - 2) After the record print is made and before any revisions are made to the drawing, insert the next revision **number** and, if possible, the revision description in the revision block. Do NOT date or initial the revision block at this time.
 - 3) Erase the "clouds" for the previous revision from the drawing. The small triangles containing the previous revision numbers shall remain.
 - 4) Each new revision shall be clouded to indicate what was revised.
 - 5) A small triangle containing the current revision **number** shall be placed inside or immediately adjacent to the "clouded" area.

- 6) The first working issue (Issue for Material Purchase or Issue for Pricing or Issue for Bid or Issue for Construction) shall be "0" (zero). Subsequent revisions will follow as 1, 2, 3, etc.

C. TITLE BLOCKS

1. Drawing Index

- a. The Project Manager will maintain an up-to-date file of all drawing numbers and titles.
 - b. Prior to starting a new drawing, the number and exact title shall be coordinated with the Project Manager to verify that the number has not been previously assigned.
2. Place the project number, drawing number, designer/draftsman initials, and title block on the drawing prior to starting any drafting.
 3. Complete issue date, Engineer stamps, and revision blocks at end of project.

D. GENERAL DRAFTING TECHNIQUE

1. Lettering

- a. Do NOT mix styles of lettering on a drawing and, if possible, on all drawings for a discipline. All lettering shall be **freehand** for *notes, dimensions and references*, and **template** for *detail titles, sheet titles, title blocks, sections and elevations*.
- b. Letters shall be heavy enough to print clearly. Increase line weight as the letter size increases.
- c. All lettering shall be uppercase with single vertical strokes. Lettering shall be minimum size indicated and shall extend from the full height from the lower to upper guideline.
- d. Minimum size for hand lettering will be 3/32" high with 1/16" high spaces between horizontal lines for:
 - 1) Notes
 - 2) Pipe Sizes
 - 3) Duct Sizes
 - 4) Conduit Sizes

- 5) Room Names (Underlined)
- 6) Match Line Call-Outs

e. Use the following lettering heights and pen thicknesses for drawing titles:

	<u>Hand Size/Pen#</u>
1) Floor Plan Titles	240 Leroy, #2 or #2-1/2
2) Section Titles	240 Leroy, #2 or #2-1/2
3) Detail Titles	240 Leroy, #2 or #2-1/2
4) Sheet Titles	*240 Leroy, #2 or #2-1/2
5) General Sheet Notes Title	240 Leroy, #2 or #2-1/2

* Where approved by Project Manager, limited title space may determine size of lettering.

f. **ALL DRAWING TITLES SHALL BE UNDERLINED. UNDERLINE SHALL BE 1/16" BELOW TEXT.**

g. Indicate scale under all drawing titles. Lettering size shall be same as for Notes. Freehand lettering is acceptable.

h. Floor plan titles and cross section or section titles shall be lettered starting from the left side of the object. Do NOT center titles under the object. Detail titles should be at center.

i. Review requirements for lettering styles and sizes on government projects with Project Manager prior to beginning drafting.

2. Lines

a. The intent of the drawing will determine what phase of the presentation should receive the major emphasis, which, in turn, should stand out in contrast with respect to the items of less importance.

b. Make major construction lines heavy enough to contrast with all other line work.

c. Use a line weight similar to a number "1" ink pen for piping, conduit, ductwork and related equipment.

- d. Use a line weight similar to a number “2” ink pen for sanitary sewer, rainwater conductor, and storm sewer piping.
- e. Use thin dark lines similar to a number “0” ink pen for items of secondary importance to the purpose of the drawing, such as backgrounds and dimension lines, etc.
- f. Indicate existing work which will remain with a solid line similar to a number “00” ink pen.
- g. Indicate existing items being removed with a dashed line with a line weight similar to a number “00” ink pen.
- h. Arrowheads for dimensions, leader lines, reference, etc., shall be simple and sharp with the point placed so as to avoid misinterpretation. Arrowheads shall be three times longer than their width.
- i. Leader lines shall be similar to a number “00” ink pen. Draw leader lines from the first word in the Note or the last word in the Note, but NOT from the middle of the Note.
- j. Show piping as a single line. When directed by the Project Manager, double line piping may be used on piping 3” diameter and larger on minimum 1/4” scale drawings for accuracy of required clearances.
- k. Show ductwork as a double line unless approved otherwise by the Project Manager. Draw ductwork to full size including insulation if present. Dimension of ductwork shall be inside clear dimension.

3. Dimensions

- a. Use inches to show dimensions of all ductwork, louvers, grilles, registers, piping and conduit.
- b. Use inch marks (") with all pipe and conduit dimensions.
- c. Do NOT use inch marks (") with duct dimensions. Use (##) between dimensions.
- d. Use inches to show dimensions of less than one foot.
- e. Use feet and inches to show dimensions greater than one foot, except as instructed in 3a.

4. Notes

- a. Place general notes on drawing when required.
- b. Long notes, repeat notes, and/or numerous notes may be typed and placed on the drawing by plotting on original from CADD.
- c. Sequentially number notes with a matching reference on the plan, section, or detail.

Example:

General Notes	(on Plan, Section, or Detail)
---------------	-------------------------------

- | | | |
|----|-----------------------------|--------|
| 1. | Refer to Specifications | Note 1 |
| 2. | All sheet metal ductwork... | Note 2 |

- d. Multi-discipline notes and drawings with demolition notes shall use the following designations:

- 1) DH1 Demolition HVAC
- 2) DP1 Demolition Plumbing
- 3) DM1 Demolition Mechanical
- 4) DE1 Demolition Electrical
- 5) H1 HVAC
- 6) P1 Plumbing
- 7) M1 Mechanical
- 8) E1 Electrical

5. Elevations

- a. Elevations for all items aboveground within a building shall be referenced to a common datum agreed upon at the start of job.
- b. Use survey grade elevations for elevation datum for site work and underground work. Use the same elevation datum as assigned by the Architect; or, use an assigned elevation of 100.00 for lowest floor elevation where no survey grade elevation is available and if the Architect has not assigned an elevation datum.
- c. All underground pipe elevations are to be inverts (INSIDE BOTTOM OF PIPE); all aboveground pipe elevations are to BOTTOM of pipe; all duct elevations are to BOTTOM of ductwork (including insulation); all lighting fixtures are to BOTTOM of fixture, etc.

6. Stick-ons
 - a. Do NOT use stick-ons unless specifically approved by the Project Manager.
 - b. Clear acetate or paper paste-ups for Xerox 2500 reproduction are acceptable. Acetates and paper paste-up originals must be the darkest, clearest copies available to insure that the Xerox final drawing complement the other drawings in the package.
7. Room Names and Numbers
 - a. Show all room names and numbers identified on architectural drawings.
 - b. Show room names and numbers similar on all drawings for all disciplines. Project Manager shall establish the correct method to comply with architectural drawings.
 - c. When it is impossible to show names and numbers on the plan, the **number only** is acceptable.
8. Cross Sections and Sections
 - a. The drafting of cross sections and sections shall be coordinated with the other design groups so that common design/drafting needs can be utilized.
 - b. Cross sections and sections shall be drawn at a scale sufficient to show the required detail, usually 1/4" scale. The drawn scale shall be indicated below the cross section or section title.

9. Details

- a. Details shall be identified by **name only**. *No symbol shall be used.*
- b. Details shall be drawn at a scale sufficient to show the required detail. The drawn scale or the wording "Scale: None" shall be indicated below the detail title.

SECTION 25.00 — QUALITY CONTROL

25.01 1993 BOCA BUILDING CODE CHECKLIST

1993 BOCA BUILDING CODE CHECKLIST – HVAC		FORM QC-25.01
PROJECT NO.:	DESIGNER:	
PROJECT NAME:	DATE:	

CHAPTERS 3 & 4	USE AND OCCUPANCIES & SPECIAL USE AND OCCUPANCIES
----------------	---

- Identify use and/or occupancy classification. Verify with Architect. _____
- Identify particular requirements for the specific use and/or occupancy defined above.

Y/N

- Are smoke control systems required? Are their controls required to be accessible by the fire department? (Malls, atriums, etc.)
- Are specific control sequences required?
- Are smoke barriers required? (Malls, atriums, underground structures, etc.)
- Are smoke compartments required? (Underground structures; use Group I-2, etc.)
- Are special ventilating systems required? (Public garages, projection rooms, etc.)
- Are duct mounted smoke detectors required? (HPM facilities, etc.)
- Are any gas detection monitors required? (HPM facilities, etc.)
- Are there limitations to the manner in which ductwork can be routed? (Stages, HPM facilities, underground structures, etc.)
- Is water treatment required? (Public pools, etc.)
- Are explosion vents required?

CHAPTER 7	FIRE RESISTANT MATERIALS AND CONSTRUCTION
-----------	---

- Are pipe penetrations of fire-rated walls properly protected via approved through-penetration protection systems, or is the assembly tested in accordance with ASTM E119. (Section 709.6 – Penetrations)

Note: Insulation and coverings on the penetrating item shall not pass through the assembly unless these materials maintain the required fire resistance rating of the assembly in accordance with Section 709.6.2.

- Are duct penetrations of fire-rated walls properly protected via fire dampers and approved through-penetration protection systems, or is the assembly tested in accordance with ASTM E119. (Section 709.6 – Penetrations and Section 717.0 – Fire Dampers)
- Is the annular space between penetrating items of fire-rated walls and the rated wall properly protected? (Section 709.7 – Annular Space Protection)
- Are shafts required? Shafts connecting four or more stories shall be 2-hour rated, 1 hour for less than four stories. Shafts shall have a rating not less than the floor assembly penetrated but shall not be required to exceed 2 hours. (Section 710.0 – Vertical Shafts and Section 713.3 – Floor Opening Enclosure)

Note: Section 403.3.3.2 – Shaft Enclosures (High Risk Buildings): The rating for shafts may be reduced to 1 hour if sprinklers are installed in the shaft at the top and at alternate floor levels.

- Are smoke dampers required? (Section 712.5 – Smoke Dampers)
- Are pipe and duct penetrations of rated and unrated floor/ceiling and / or roof/ceiling assemblies properly protected? (Section 713.4 Penetration Protection)

CHAPTER 9	FIRE PROTECTION SYSTEMS
-----------	-------------------------

- If a smoke control system is required, is it in accordance with BOCA? (Section 921.0 – Smoke Control Systems)
- Are smoke and heat vents required? (Section 922.0 – Smoke and Heat Vents)

CHAPTER 10	MEANS OF EGRESS
------------	-----------------

- Exits and exit access corridors shall not be used as air ducts or plenums except as noted in accordance with BOCA. (Section 1005.7 – Egress Elements for Air Movement)
- Grandstands may require a smoke control system. (Section 1013.0 – Grandstands)
- Penetration of stairways, except for services to the stairway, is prohibited. (Section 1014.11.2 – Penetrations)
- Natural and mechanical ventilation of smokeproof enclosures (enclosed interior exit) or stair pressurization. (Section 1015.0 – Smokeproof Enclosures)

CHAPTER 11 ACCESSIBILITY

- Are controls, operating mechanisms, and hardware accessible? (Section 1108.8 – Controls, Operating Mechanisms and Hardware)

CHAPTER 12 INTERIOR ENVIRONMENT

- Is every space intended for human occupancy provided with either natural or mechanical ventilation? (Section 1205.2 – Ventilation Required)
- Does natural ventilation meet the requirements of Section 1208.0 – Natural Ventilation?
- Does mechanical ventilation meet the requirements of Section 1209.0 – Mechanical Ventilation, which refers to BOCA Mechanical Code?
- Ventilation of special spaces (roofs, attics, crawl spaces). (Section 1210.0 – Ventilation of Special Spaces)

CHAPTER 13 ENERGY CONSERVATION

- Is the building in compliance with ASHRAE 90A, 90B, or CABO Model Energy Code? (Section 1301.2 – Codes and Standards)
- Do HVAC equipment and systems comply with BOCA Mechanical Code? (Section 1307.1 – General)

CHAPTER 21 MASONRY

- Are fireplaces and chimneys constructed in accordance with this Section and the BOCA Mechanical Code? (Section 2114.0 – Fireplaces and Chimneys)

CHAPTER 28 MECHANICAL SYSTEMS

- Are all mechanical equipment and systems constructed, installed, and maintained in accordance with BOCA Mechanical Code? (Section 2801.2 – Mechanical Code)
- Are plenums properly constructed? (Section 2805.1 – Plenums)
- Have you met the requirements for drying rooms, waste and linen handling systems, refuse vaults, medical gases and oxygen systems? (Sections 2806 thru 2810)

CHAPTER 30 ELEVATORS AND CONVEYING SYSTEMS

- Are hoistway enclosures properly vented? (Section 3007.0 – Hoistway Enclosures and Venting)

CHAPTER 31	SPECIAL CONSTRUCTION
------------	----------------------

- Is installed HVAC equipment protected from flooding? (Section 3107.0 – Flood Resistant Construction)

25.02 1993 BOCA MECHANICAL CODE CHECKLIST

1993 BOCA MECHANICAL CODE CHECKLIST – HVAC		FORM QC-25.02
PROJECT NO.:	DESIGNER:	
PROJECT NAME:	DATE:	

CHAPTER 3	AIR DISTRIBUTION SYSTEMS
-----------	--------------------------

- 1. Check that exits and exit access corridors are not serving as supply or return air ducts or plenums. (M-303.1.2)
- 2. Check that flexible ducts do not pass through any wall, floor, ceiling, or fire resistance rated assembly. (M-305.3)
- 3. Check location of outdoor air intakes:
 - a. Minimum 10 feet from lot lines or adjacent buildings. (M-308.1)
 - b. Minimum 25 feet (Code states 10 feet) from vents, chimneys, plumbing vents, streets, alleys, parking lots, and loading docks.

(Code allows location within 10 feet if intake is minimum 2 feet below source.) (M-308.1.1)
 - c. Exhaust air not directed toward walkways. (M-308.1.2)
- 4. Check location of smoke detectors:
 - a. Supply air systems greater than 2,000 CFM. (M-309.2.1)
 - b. Return air systems greater than 15,000 CFM. (M-309.2.2)
 - c. Exhaust (relief) air systems greater than 50 percent of supply air in systems greater than 15,000 CFM. (M-309.2.2)
 - d. At each floor in the branch return duct to return risers serving two stories or more in systems greater than 15,000 CFM. (M-309.2.2.1)

CHAPTER 4	MECHANICAL EQUIPMENT
-----------	----------------------

- 1. Is a convenience outlet provided for all mechanical equipment or appliances on same level within 75 feet? (M-409.2)

CHAPTER 6	BOILERS AND WATER HEATER
-----------	--------------------------

- 1. Check that a shutoff valves is installed on supply and return piping to each boiler. (M-604.1)
- 2. Check for steam boiler that an equalizing line is installed between the supply header and return header. No valve shall be installed as to cut off equalizing line. (M-606.1)
- 3. Check for installation of automatic low water cutoff. (M-607.1)
 - a. All steam boilers.
 - b. Hot water boilers over 400,000 BTUH.
- 4. Check for steam blowoff valve for steam boilers. (M-608.0)
- 5. Check for installation of expansion tank on hot water systems. (M-609.0)

CHAPTER 8	GAS PIPING SYSTEMS
-----------	--------------------

- 1. Check that inside building gas piping does not run in or through supply air ducts, clothes chutes, chimneys, vents, dumbwaiters, or elevator shafts. (M-809.3)
- 2. Check that gas valves are not installed in any air plenum. (M-809.3.1)
- 3. Check that an exterior shutoff valve is provided for each structure. (M-811.2)
- 4. Check that gas meter is equipped with shutoff valve on the supply side of the meter. (M-811.3)
- 5. Check that each appliance has a shutoff valve. (M-811.4)

CHAPTER 9	FLAMMABLE AND COMBUSTIBLE LIQUID STORAGE AND PIPING SYSTEMS
-----------	---

- 1. Check that all underground storage tanks over 1,000 gallons and piping systems are monitored for leak detection. (M-905.4)
- 2. Check that underground pipe is installed at minimum depth of 18 inches. (M-907.3)

- 3. Check that no shutoff valves are installed on fuel oil return piping. (M-909.4)
- 4. Check that a shutoff valve is installed on the fuel oil supply line at the entrance to the building. (M-911.1)

CHAPTER 10	COMBUSTION AIR
------------	----------------

- 1. Check that inside air available for each fuel-burning appliance is available at a rate of 40 cubic feet of room air per 1,000 BTUH input rating. (M-1003.0)
- 2. Check that outside air is available through openings at the top and bottom of room. Each opening to be sized as follows: 1 square inch free area per 2,000 BTUH input rating for ducted openings; 1 square inch free area per 4,000 BTUH input rating for direct opening. (M-1004.0)
- 3. Check that outside air is available from a mechanical ventilation system at a rate of 1 CFM per 3,000 BTUH input rating. Amount to be in addition to required room ventilation air. Appliance to be electrically connected to the ventilation system. (M-1006.0)

CHAPTER 12	CHIMNEYS AND VENTS
------------	--------------------

- 1. Check that chimney and vent terminations are 3 feet above highest point where they penetrate roof and 2 feet above any portion of the building within 10 feet. (M-1205.2.3 and M-1207.3)

CHAPTER 13	MECHANICAL REFRIGERATION
------------	--------------------------

- 1. Check maximum allowable Group 1 refrigerant quantities for direct systems. (Table M-1303.1)
- 2. Check maximum allowable alternative refrigerant (R-123, R-134A) quantities for direct systems. (Table M-1303.4)
- 3. Check that requirements for general machinery rooms are met for indirect systems utilizing alternative refrigerants (R-123, R-134A). (M-1303.4.1)
- 4. Check that refrigerant relief devices are piped to outdoors for any system containing more than 100 pounds of Group 1 refrigerants. (M-1306.2.1)
- 5. Check that a compound specific refrigerant detection system is installed for refrigerant R-123.
- 6. Check that an oxygen sensing system is installed for refrigerant R-134A.

CHAPTER 16	VENTILATION AIR
------------	-----------------

- 1. Check that required ventilation air is provided in accordance with Table M-1604.3.
- 2. Check for areas requiring all ventilation air to be exhausted. (Table M-1604.3)

CHAPTER 17	ENERGY CONSERVATION
------------	---------------------

- 1. Check for economizer requirements considering exceptions listed in M-1903.2.
- 2. Check minimum equipment performance requirements. (M-1904.0)

25.03 1994 NFPA 101 – LIFE SAFETY CODE CHECKLIST

1994 NFPA 101 – LIFE SAFETY CODE CHECKLIST – HVAC	FORM QC-25.03
PROJECT NO.:	DESIGNER:
PROJECT NAME:	DATE:

CHAPTER 4	CLASSIFICATION OF OCCUPANCY AND HAZARD OF CONTENTS
-----------	--

- Identify use and/or occupancy classification. Verify with Architect. _____

CHAPTER 5	MEANS OF EGRESS
-----------	-----------------

- Penetrations through exit enclosures, assemblies (stairs, bridges, balconies, ramps, etc.) are prohibited except:
 - Ductwork and equipment necessary for independent stair pressurization.
 - Steam or water piping necessary for heating or cooling of the exit enclosure. (Section 5-1.3.1)
- Penetrations or communicating openings between adjacent exit enclosures are prohibited. (Section 5-1.3.1)
- Natural ventilation of smokeproof enclosure. (Section 5-2.3.7)
- Mechanical ventilation of smokeproof enclosure. (Section 5-2.3.8)
- Stair pressurization of smokeproof enclosure. (Section 5-2.3.9)

- If mechanical ventilation and/or stair pressurization of smokeproof enclosures are/is required, is the activation control sequence in accordance with NFPA? (Section 5-2.3.10)
- Fire barriers forming horizontal exits shall not be penetrated by ducts except as noted in NFPA. (Section 5-2.4.3.3)
- If interlocking or scissor stairs are used as separate exits, penetrations or communicating openings between the stair enclosures are prohibited. (Section 5-5.1.5)
- Is the mechanical, boiler, or furnace room arranged in accordance with NFPA? (Sections 5-12.1, 5-12.2)

CHAPTER 6	FEATURES OF FIRE PROTECTION
-----------	-----------------------------

- Are ductwork penetrations through fire barriers protected in accordance with NFPA Std. 90? (NFPA 101 – Section 6-2.3.6.1)
- Are smoke dampers required? (Section 6-3.5)
- Do smoke dampers close upon detection in accordance with NFPA? (Section 6-3.5.3)
- Is the space between penetrating ducts and pipes and fire/smoke barriers filled with a material with the same fire/smoke resistance of the barrier? (Sections 6-2.3.6.2, 6-3.6.1)
- If the penetrating item uses a sleeve through a fire/smoke barrier, is the space between the sleeve and the penetrating item filled with a material with the same fire/smoke resistance of the barrier? (Sections 6-2.3.6.2, 6-3.6.1)
- Duct and/or pipe insulation coverings shall not pass through fire barriers unless the material maintains the fire resistance of the barrier. (Section 6-2.3.6.2)
- If vibration isolation is used, it should be made on either side of the fire/smoke barrier. (Sections 6-2.3.6.2, 6-3.6.1)
- If shafts are required, fire ratings shall be per NFPA. (Section 6-2.4.4)
- If there are unenclosed floor openings forming a communicating space between floor levels, the ratings shall be per NFPA. (Section 6-2.4.5)
- If there is an atrium, is a smoke control system required? (Section 6-2.4.6)
- Are explosion vents required? (Section 6-4.2)

CHAPTER 7 BUILDING SERVICE AND FIRE PROTECTION EQUIPMENT

- Is gas equipment installed in accordance with NFPA 54?
- Ventilating and heat-producing equipment shall be installed in accordance with NFPA. (Section 7-2.2)
- Commercial cooking equipment ventilation systems shall be installed in accordance with NFPA 96.
- Ventilating systems in laboratories using chemicals shall be installed in accordance with NFPA 45 and/or NFPA 99.

CHAPTERS 8 & 9 NEW & EXISTING ASSEMBLY OCCUPANCIES

- Are stage smoke control systems required? (Sections 8-3.2.1.5, 9-3.2.1.5)
- Are projection room ventilation systems required? (Sections 8-3.2.2.2, 9-3.2.2.2)
- Are smoke control systems required for windowless or underground buildings? (Sections 8-4.1.3, 9-4.1.3)
- Are smoke control systems required for smoke-protected assembly seating? (Sections 8-4.3.1, 9-4.3.1)

CHAPTERS 10 & 11 NEW & EXISTING EDUCATIONAL OCCUPANCIES

- Are stage smoke control systems required? (Sections 10-3.2.5, 11-3.2.5)
- Are smoke control systems required for windowless or underground buildings? (Sections 10-4.1.3, 30-7)

CHAPTERS 12 & 13 NEW & EXISTING HEALTHCARE OCCUPANCIES

- Transfer grilles with or without fire dampers through walls or doors are prohibited except as noted in NFPA. (Sections 12-3.6.4, 13-3.6.4)
- Windowless buildings shall be per NFPA. (Section 30-7)
- Is HVAC designed and installed in accordance with NFPA?(Sections 12-5.2, 13-6.5.2)

CHAPTERS 14 & 15 NEW & EXISTING DETENTION & CORRECTIONAL OCCUPANCIES

- Windowless areas shall be per NFPA. (Sections 14-4.1, 15-4.1)

- Underground buildings shall be per NFPA. (Section 30)
- Is HVAC designed and installed in accordance with NFPA? (Sections 14-5.2, 15-5.2)

CHAPTERS 16 & 17	NEW & EXISTING HOTEL & DORMITORY OCCUPANCIES
------------------	--

- Louvers and grilles are prohibited in partitions or doors separating corridor and guest rooms. (Sections 16-3.6.5, 17-3.6.6)

CHAPTERS 22 & 23	NEW & EXISTING RESIDENTIAL BOARD & CARE OCCUPANCIES
------------------	---

- Is mechanical room location per NFPA? (Sections 22-3.3.2.1, 23-3.3.2.1)
- Louver and grilles are prohibited in partitions or doors separating corridor and sleeping rooms except as noted in NFPA. (Sections 22-3.3.6.5, 23-3.3.6.5)
- Unvented fuel-fired gas heaters are prohibited. (Sections 22-3.6.2.3, 23-3.6.2.3)

CHAPTERS 24 & 25	NEW & EXISTING MERCANTILE OCCUPANCIES
------------------	---------------------------------------

- Windowless or underground buildings shall be per NFPA. (Section 30-7)
- Is a smoke control system required for covered malls? (Section 24-4.4)

CHAPTER 28	INDUSTRIAL OCCUPANCIES
------------	------------------------

- Are smoke/heat control systems required? (Section 28-2.6.2)
- Are explosion vents required? (Section 28-3.2)

CHAPTER 30	SPECIAL STRUCTURES AND HIGH RISE BUILDINGS
------------	--

- Does underground structure require smoke venting system? (Section 30-7.3)

25.04 1995 PA L&I – FIRE AND PANIC CHECKLIST

1995 PA L&I – FIRE & PANIC CODE CHECKLIST – HVAC		FORM QC-25.04
PROJECT NO.:	DESIGNER:	
PROJECT NAME:	DATE:	

- Are smoke detectors required in air distribution systems? (Section 50.52)
- Is combustion air required for internal combustion generator systems? (Section 50.64)

- Is combustion air required for boilers or other heat equipment taken direction from and are products of combustion discharged directly to the outside?
- Is stage ventilation required? (Section 50.93)
- Are explosion vents required? (Section 59.81)
- Is paint spray exhaust operating in accordance with L & I? (Section 59.81)

25.05 ASHRAE STANDARD 15-1994 CHECKLIST

ASHRAE STANDARD 15-1994 CHECKLIST – HVAC		FORM QC-25.05
PROJECT NO.:	DESIGNER:	
PROJECT NAME:	DATE:	

CHAPTER 4	OCCUPANCY CLASSIFICATION
-----------	--------------------------

- Identified occupancy classification from those listed in Chapter 4?

CHAPTER 5	REFRIGERATING SYSTEM CLASSIFICATION
-----------	-------------------------------------

- Identified refrigerating system type as defined in Subchapter 5.1?
- Identified refrigerating system classification as High Probability or Low Probability as defined in Subchapter 5.2?

CHAPTER 6	REFRIGERANT CLASSIFICATION
-----------	----------------------------

- Identified refrigerant safety group from Table 1. If refrigerant is not listed in Table 1, referred to ASHRAE Standard 34?

CHAPTER 7	RESTRICTIONS ON REFRIGERANT USE
-----------	---------------------------------

- Determined system application requirements from rules identified in Table 2? Referred to appropriate rule(s) in Subchapter 7.4.2 before proceeding?
- Refrigerant piping is not installed in enclosed public stairway, stair landing, or means of egress (7.3.1).
- Refrigerating system located in corridor or lobby is unit system containing not more than quantities of Group A1 refrigerants specified in Table 1 (7.3.2).
- Maximum permissible refrigerant quantities in refrigerant containing equipment or parts located in unventilated spaces checked against volume of smallest occupied space (7.3.3).

- When evaporator or condenser is located in an air duct system (i.e. direct expansion), system refrigerant quantities checked against requirements specified (7.3.4).

CHAPTER 8	INSTALLATION RESTRICTIONS
-----------	---------------------------

- Refrigerant piping is at least 7.25 feet above passageways (8.12.1).
- Refrigerant piping passing through floors, ceilings, or roofs meets listed exceptions (8.12.3).
- Systems located in machinery rooms (see 7.4.2 System Application Requirements) are in accordance with the following provisions:
 - Clear head room not less than 7.25 feet below equipment situated over passageways (8.13.1).
 - Doors and openings coordinated with Architect in accordance with requirements (8.13.2).
 - Refrigerant leak detector installed in location specified with appropriate control outputs (8.13.2).
 - Room is vented to outdoors, utilizing mechanical ventilation in accordance with 8.13.4 and 8.13.5 (8.13.3).
 - Combustion equipment is not located within the room unless one of two exceptions are met (8.13.6).
 - Airflow to or from an occupied space through a machinery room is sealed to prevent refrigerant leakage from entering airstream. Duct and equipment access doors are gasketed and tight-fitting (8.13.7).
- Systems located in machinery rooms with special requirements (see 7.4.2 System Application Requirements) are installed in accordance with specifications listed (8.14).

CHAPTER 9	DESIGN AND CONSTRUCTION OF EQUIPMENT AND SYSTEMS
-----------	--

- Evaporators located downstream of, or within 18 inches and upstream of, a heating coil are fitted with pressure relief devices discharging outside the building in accordance with 9.7.8 (9.4.4). See listed exceptions.
- Stop valves are not located between pressure relief devices and systems protected thereby (9.4.6).
- Seats and discs of pressure relief devices are constructed of suitable material to resist refrigerant corrosion or chemical action. Cast iron is not being used (9.4.9).

- Pressure relief valve settings do not exceed design pressure of the protected system (9.5.1).
- Pressure relief devices are vented to the building exterior in accordance with 9.7.8 for systems containing the following types and quantities of refrigerant:
 - Any quantity of Group A3 or B3 refrigerant.
 - More than 6.6 lb of Group A2, B1, or B2 refrigerant.
 - More than 110 lb of Group A1 refrigerant.
- Discharge piping is sized in accordance with 9.7.8.4. Drawings are noted to indicate sizing for basis of design only.
- Discharge piping length was checked against requirements of 9.7.8.5.

CHAPTER 11	GENERAL REQUIREMENTS
------------	----------------------

- Two self-contained breathing apparatus are located outside of, but close to, machinery room.
- The building owner was notified of the following machinery room general requirements:
 - Controls and piping identification (11.2.2).
 - Changes in refrigerant or lubricant (11.2.3).
 - Charging, withdrawal, and disposition of refrigerants (11.3).
 - Containers (11.4).
 - Storing refrigerant (11.5).
 - Periodic tests (11.7.3).
 - Responsibility of operation and emergency shutdown (11.8).

25.06 MECHANICAL ACOUSTICS CHECKLIST

1993 MECHANICAL ACOUSTICS CHECKLIST – HVAC		FORM QC-25.06
PROJECT NO.:	DESIGNER:	
PROJECT NAME:	DATE:	

COOLING TOWERS AND AIR-COOLED CONDENSERS

- For installations where community noise is critical, fanless ejector tower considered.
- Equipment located at least 20 feet from large sound-reflecting surface.
- Equipment *not* located over or next to a noise-sensitive area.
- If equipment is located over a noise-sensitive area, roof construction and interior ceiling assembly provide adequate sound isolation.
- For rooftop installations, supporting structure has adequate stiffness.

CHILLER/CENTRAL PLANTS

- For installations where community noise is critical, ventilation passages are treated with acoustical louvers, duct silencers, or lined plenums.
- If there are noise-sensitive areas either above or below, the following options were considered:
 - For upward noise control, sound control enclosure around chillers and air compressors.
 - For downward noise control, a drywall ceiling suspended below using spring hangers.
 - Floating floor assembly.
- For rooftop or mid-level central plants, the following options were considered:
 - Electrical conduits serving central plant do *not* penetrate floor or ceiling of noise-sensitive area.
 - Floor drains penetrating into noise-sensitive areas have drywall enclosure or pipe lagging.
 - If central plant is next to a stair, duct, or elevator shaft, the common wall is either masonry or multi-layer drywall construction.

PUMPS

- Trimmed impeller radius is less than 90 percent of untrimmed radius.
- Flexible pipe connectors included. For sound critical applications, these are neoprene or rubber, *not* braided or unbraided metal hose.
- Attached piping has vibration isolators.

PIPING

- Piping is not undersized near sound critical areas.
- Vibration isolators are located at riser and horizontal pipe attachment points.
- Wall / slab penetrations are sleeved and isolated where required.

FANS/AIR HANDLING UNITS

- Considered optimal fan type for critical application.
- Selected fan at efficient operating point.
- Fan inlet and outlet sound ratings have been tested in accordance with AMCA Test Code 300. (Include in Specifications.)
- Considered acoustically rated/treated air handler housing.
- Duct connections to air handler have minimal systems effect.
- Duct has flexible connections to air handler.
- Considered off-peak sound power levels for VAV applications.

DUCTWORK

- Followed SMACNA guidelines for maximum airflow velocities and duct fittings and transitions. For duct branches near sound critical areas, air velocity is less than 1,000 FPM and pressure drop is less than 0.10" WG/100 LF.
- Considered using circular ductwork for first 100 feet of supply trunk to resist oil canning and breakout noise.
- Considered internal liner to attenuate mid- and upper-frequency sound power.
- Volume dampers are located at least 10 feet from duct openings.

- Duct branches are laid out to minimize probability of cross-talk.
- Wall penetrations are sleeved and acoustically treated.

TERMINAL UNITS (SHUTOFF AND FAN-POWERED VAV)

- No units are located over noise-sensitive areas (i.e. \leq NC40).
- Selected unit based on rated discharge and radiated sound power levels, *not* based on nominal CFM.
- Utilized manufacturer recommended inlet lengths for straight duct.
- Radiated and discharge sound ratings tested in accordance with latest revision of ARI Industry Standard 880. (Include in Specifications.)

DUCT SILENCERS/SOUND TRAPS

- Considered self-noise of silencer in layout.
- Attempted to place silencer in mechanical room wall to prevent mechanical room breakout noise. If this is impossible, attempted to place silencer as close as possible to wall within mechanical room.
- Utilized manufacturer recommended inlet and outlet lengths for straight duct.
- Included silencer pressure drop in fan static pressure calculations.
- Silencers tested in accordance with latest revision of ASTM E477, "Standard Method of Testing Duct Liner Materials and Prefabricated Silencers for Acoustical and Airflow Performance." (Include in Specifications.)

DIFFUSERS / REGISTERS / GRILLES

- Diffuser size selected at rated NC-Level 5dB less than room masking level.
- Good inlet connections shown on Drawings. Minimum 3 equivalent duct diameters of straight duct upstream of collar.
- Placement does not permit room cross-talk.
- Linear slot diffusers with side-fed plenums selected for 10 dB less than rated NC-level.
- No integral balancing damper for sound critical areas.

VIBRATION ISOLATION

- Vibration isolators and bases selected in accordance with Table 34 on Page 42.34 of the 1991 ASHRAE HVAC Applications Handbook.
- Vibration isolators are shown connected directly to structural members and *not* at the bottom or mid-span of hanger rods.

25.07 ICE STORAGE SYSTEM CHECKLIST

ICE STORAGE SYSTEM CHECKLIST – HVAC		FORM QC-25.07
PROJECT NO.:	DESIGNER:	
PROJECT NAME:	DATE:	

- Selected optimal discharge strategy for applicable utility rate structure. In general, rate schedules that have low to moderate peak demand charges and little to no cost for off-peak energy usage (i.e. GPU Energy schedules) are ideally suited to partial storage, ice priority systems. Three major electrical utility factors to consider when choosing strategies are:
 - Ratchet clauses.
 - Time-of-Day rates.
 - Construction cost rebate program availability.
- Charging/discharging strategy considers the relationship of building occupancy schedules to electricity time-of-day rates.
- Considered implementing low temperature air distribution to reduce duct clearance requirements and fan size and operating costs.
- Received low temperature chiller derated capacities directly from manufacturer.
- When using Calmac as design basis, do *not* plan on cooling tanks below 23 deg F inlet and 28 deg F outlet. This will cause freezing of tank expansion water.
- Considered effect of brine solution on system pressure drops and chiller capacities.
- Since no two ice systems are alike, took into consideration other manufacturers that may be bid when planning operational strategies and system layout. May want to limit bid invitations.

- Put required ice storage capacity in Drawing schedules (i.e., not only tank nominal capacities). This will help to avoid confusion and overpricing or underpricing during competitive bidding.
- When using Calmac as design basis, include sequence of operation for eliminating ice cap in tanks. This should be done once or twice a year.