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F M O C

Design Standards Manual: Chapter 8 – Mechanical Design

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8.0 Mechanical Design Standards

8.1 Introduction

The primary objective of these guidelines is to achieve consistency and accuracy in mechanical facilities engineering design through awareness and standardization. These guidelines are general in nature and shall be supplemented by the applicable codes, standards, and guides referenced in this manual. Specific conditions outlined in the project-specific Design Criteria take precedence over these design guidelines.

For general requirements associated with all phases of the project, see Chapter 2, General Design Standards and Procedures. For individual project requirements see the Design Criteria.

For standard product specifications, refer to the applicable section in the Facilities Construction Standard Specifications. Where manufacturers are specifically called out, the purpose is to indicate the desired features and associated level of quality.

As a minimum, all new construction shall conform to the International Code Council (ICC) group of codes. These building code requirements shall be supplemented in a graded manner with additional safety requirements associated with the identified facility hazards. Base design decisions on the lowest life cycle cost of the system.

8.2 Construction Drawings

8.2.1 Drawings Required

To illustrate the scope of a project, an approximate list of the plans and/or drawings required is presented in the Design Criteria for each discipline. Additional drawings may be suggested. Check the Facilities Standard Drawings for applicability to project. Refer to the Facilities CADD Standards Manual for specific CADD standards and processes. The following is a list of plans and/or drawings required for a typical job. (Note: Sandia/NM follows the Uniform Drawing System (UDS) for numbering drawings.) The UDS discipline designators are listed for common systems:

1. **Exterior Utilities:** Includes but is not necessarily limited to new and existing yard plans showing district steam, condensate return, exterior chilled water, natural gas, fuel oil, special waste disposal system, etc. Other utilities are listed in Chapter 3.2, Construction Drawings. The UDS discipline designators are 'WG'-Natural Gas, 'WM'-Steam & Condensate, 'WH'-Chilled Water.
2. **Plan and Profile:** Drawings of new site utilities.
3. **Interior Plumbing Layout:** Show domestic hot and cold water, non-potable water, sewer, vents, drains, lab waste and vents, pressure drains, rainwater leader, and storm drains. Use an isometric diagram to show the sewer, vents, drains, and pressure drains. Use a separate isometric diagram to show the domestic hot and cold water.
4. **Interior Gas and Process Gas Plan(s):** Show compressed air, nitrogen, natural gas, vacuum, process gases, gas bottle racks, etc. Use a separate Piping Schematic drawing to show all gasses. The UDS discipline designator is 'DJ'.
5. **HVAC Piping Plan(s):** Show heating water, pressurized steam and condensate return, tower water, fuel oil, chilled water, condensate drains, or other type of distribution system. In areas

where the HVAC piping becomes involved, or where piping is overlaid on the plan, use above-ceiling and below-ceiling plan(s), and use additional sections, details, or piping schematics for clarification. The UDS discipline designator is 'MP'

6. **Process Liquids Plan(s):** Show de-ionized water, process chilled water, hydrochloric acid, process oil systems. In areas where piping becomes involved, or where piping is overlaid on the plan, use additional sections, details, or piping schematics for clarification. The UDS discipline designator is 'DP'
7. **HVAC and Exhaust Duct Plan(s):** Show all air distribution, exhaust handling equipment, ductwork, hoods, diffusers, fittings drawn to scale and thoroughly dimensioned. Provide isometric and/or sectional details where the layout becomes complex. Provide separate HVAC and Exhaust Duct plans for extensive exhaust systems. The UDS discipline designators are 'MP'-HVAC' and 'MJ'-Exhaust.
8. **Separate Roof Plan:** Show all roof-mounted equipment, vents, special exhausts, catwalks, etc.
9. **Flow Diagram:** Schematically shows all heat-transfer processes involved. Show exhaust systems; indicate each source of exhaust, room number, design flow rates, riser flow rates, fan flow rates, dampers, and all other components.
10. **Riser Diagram:** Show all piping and air handling systems in buildings other than single- story buildings. Key each riser to the appropriate plan.
11. **Detail Drawings:** Drawings for the above items, showing sections and details. Do not present details and sections on the plan sheets. Include details of security barriers (mesh or rigid bars) installed in ductwork.
12. **Control Drawings:** Create Control Plans Drawings, Diagrams, Sequence of Operations, Panel Details, Equipment List, and Ladder Diagrams. Group the entire set of controls drawings together in a separate discipline with the UDS designator 'MI'. On plan drawings, show the location of each item of control equipment, a scale of 1/8 inch per foot or smaller is suggested for most areas of buildings to allow better coordination of the various items in the system drawings. Scales of ½ or ¾ inch per foot may be required in congested equipment rooms. Provide schematic diagrams referring to all control functions and actions. The control diagram shall show control components on a flow diagram with the control piping or wiring in heavy gauge lines. In addition, show the associated heat transfer items such as fans, ductwork, dampers, pumps, coils, pipes, and valves, in light gauge lines such that the total system operation can be determined from the diagram. Provide Sequence of Operations that fully describes the operation of all controlled systems in all modes of operation. (See Chapter 8.23, Controls, for further guidance on controls definition.) Create a layout schedule of panel control devices using an Excel spreadsheet as a format. (See FCS Standard drawing MI5001STD for further guidance.) Because the Facilities Control System (FCS) is unique, the required drawings are listed with the system description. Criteria listed above, applicable to the FCS components, will hold. For reference, utilize FCS Standard drawings; MI5001STD, MI6001STD, MI6002STD. See Chapter 8.23.1, Facilities Control Systems, for additional information for FCS.
13. **Equipment Symbols and Schedules:** Group these together on a special drawing(s) rather than scattering them throughout the set. Start the equipment schedules in the upper left hand corner of the drawing. Use Sandia/NM standard format and symbols. Do not duplicate numbers.

8.2.2 Piping Drawings

Generally, one-line drawings are satisfactory for designating piping. In certain instances where piping is complex and crowded with other piping or equipment, to-scale, two-line drawings are required to ascertain that all items will fit without interference (for example, the rising screw on an outside screw and yoke must have adequate clearance when the valve is open). Provide pipe elevations and/or sections for pipes that cross in the plan view.

8.2.3 Schedules

Where the same information is repeated several times, provide a complete, well-arranged schedule (for example, traps and coils could be put in one schedule, complete with capacities, pressure drops, temperatures, etc.). Group schedules together on a drawing(s) adjacent to the equipment list sheet(s) rather than scattering them throughout the set of drawings. Use a standard, sequentially numbered symbol for each item. When scheduled items share a common description, a letter can be appended to the symbol number (e.g. 15a, 15b, 15c, etc.)

8.3 Access and Layout

8.3.1 General Requirements

In general, provide approximately 8 percent of the gross area of the building to house mechanical equipment (fans, compressors, chillers, pumps, electric motor control center, etc.). This area will allow for installation and maintenance of equipment. The following guidelines should be followed for the mechanical equipment room:

- The aspect ratio of the room should not exceed 3 to 1
- Indicate tube pulling space for boilers, chillers, and heat exchangers
- Verify that equipment can be installed during construction
- Provide access to remove equipment that has a relatively high rate of failure
- Where feasible, do not install piping or ductwork below 7 feet above the finished floor where passage is required.
- Indicate coil removal and filter access space for air handler units.

Locate items needing periodic repair, adjustment, or lubrication where they can be accessed from a standing position. Lay out equipment rooms to allow for 36 inches of clear floor and aisle space around all major equipment. Arrange or provide space so tube bundles can be withdrawn or major items of equipment can be replaced without repiping or relocating other equipment. Where necessary, provide areaways and/or removable wall panels for access. Anticipate and eliminate head-bumping or tripping hazards. On the structural drawings, accurately detail and locate sleeves through walls and floors. Field welding or cutting structural steel is forbidden. Lay out manholes so personnel can exit quickly. Where possible, locate a manhole cover over the ladder.

Size and ventilate workspaces to provide adequate working conditions for maintenance personnel. Clearly state mounting heights for wall-hung items, or provide elevations of crowded walls, particularly where electrical and structural items are also involved. Arrange pipes in pipe space/chases to allow a mechanic to conveniently get into the pipe space and work on a section or part of the piping.

Inform the architectural and structural designers of all ladders, catwalks, access doors, and special structural equipment needed for the proper maintenance of mechanical equipment.

The space above suspended ceilings shall be adequate to run ductwork and piping. Normally allow a 3-foot-minimum clearance from the top of light fixtures to the bottom of construction for the installation of ductwork and piping.

Provide a minimum 6-foot-edge clearance for roof-mounted equipment unless pipe guardrails are provided.

Provide access doors to gypsum board ceilings and other restricted spaces where mechanical equipment is located.

8.3.2 Security Requirements

All Security Area and VTR boundaries must have consistent penetration resistance. Openings in the boundary of such areas must be protected to DOE Order requirements. Examples of such openings are heating, ventilating, and air conditioning ducts, air intakes, exhaust fans or ducts; and doors, crawlways, tunneled areaways, and sewers.

Where the mechanical designer is responsible for the design and placement of such items, communicate the information to other responsible consultants who will take the necessary electrical or structural steps to ensure compliance with security requirements. Ensure that these steps have not introduced excessive resistance or other problems into the original design. Recalculate and modify as required. See Chapter 11 for specific requirements.

8.4 Modular Design

Design mechanical systems in the most flexible manner possible, since changing programs and occupants result in changing needs. Do not oversize systems dramatically. Arrange diffusers, registers, sprinkler heads, and other semi-permanent features on the module system for future flexibility of walls and partitions. Contact the Sandia/NM systems architect for additional information on the module system.

8.5 Equipment Selection–General

Because the selection of mechanical equipment is involved, provide copies of calculations and standard or actual conditions used for the selection of all mechanical equipment, even when following the manufacturer's procedures. Make adjustments to manufacturer's altitude rating as required for the Sandia/New Mexico altitude of 5,500 feet. Comply with ASHRAE Std. 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings, for minimum equipment efficiencies.

A brief but complete description of equipment shall appear on the equipment list drawings. The designer shall locate and describe one manufacturer's model that meets design requirements. Present the manufacturer's complete catalog number and all rating and performance information. Generalities in selection are unacceptable. Provide additional special specifications to equipment schedules to more fully describe complicated equipment. Use performance specifications that will ensure a quality product. Key mechanical item numbers to the plans and elevation drawings.

A partial load schedule, in 10-percent steps, will be established, and the manufacturer's actual performance data shall be listed for all variable-capacity, heat-transfer equipment.

All equipment assemblies requiring line electrical power shall have a local power disconnecting means rated for the service. Refer to paragraph 9.3.5 for requirements.

Whenever mechanical equipment is specified as a complete unit with electrical components such as motors, VFCs, disconnects, lighting and wiring, the associated electrical specifications shall be referenced to insure that these components meet those specifications as well.

8.5.1 Air-Handling Units

Fans and blowers for cooling and heating equipment are generally large-diameter, low-speed, low-horsepower (HP) and capable of maintaining the required system static pressure. Air-foil fan blades are preferred but backward inclined may be acceptable. Select and specify extra-heavy-duty, long-life bearings (minimum 50,000 hours) from standard bearing manufacturer charts provided by the fan manufacturer for the maximum published speed and HP rating of the fan. Select load-limiting (backward curved) wheels whenever practicable. High-velocity systems are discouraged, but if used, select fans that minimize surging and air noise. Present calculations, including temperature and altitude corrections. Select fans to operate on a stable portion of the curve. Discourage the use of small-diameter, long shaft fans except in small packaged equipment.

8.5.2 Motors

The minimum energy efficiency requirements for all single-speed, National Electrical Manufacturers Association (NEMA) Design B induction motors having nominal speeds of 1200, 1800, or 3600 rpm with open, drip-proof (ODP), or totally enclosed fan cooled (TEFC) enclosures, 1 HP or more shall comply with the requirements of table 10.2 of ASHRAE 90.1-1999 (matches NEMA Standard MG 1-1998). Motors for driven systems greater than 5 HP that operate for long periods of time (>3600 hours/year) may justify efficiencies which exceed the minimum requirements ("premium efficiency motors") and should be evaluated for simple payback on new or retrofit installations.

Annual savings (S) = 0.746*BHP*$/kWh*annual hours operation* [(100/effA) – (100/effB)], where effB is the efficiency (percent) of the higher efficiency motor.

An electric motor should be considered as always being connected to a driven machine, with specific operating characteristics, which dictate the starting and running load of the motor. As such, the motor selection is based on many factors, including the requirements of the driven equipment, service conditions, motor efficiency, power factor and initial cost. The driven system efficiency is the combination of the efficiencies of all the components of the system, e.g., the fan efficiency, the power transmission (belts), the air distribution system, and the motor controllers (such as Variable-Frequency Controllers [VFCs]).

Provide 3-phase motors for 1 HP and above. Provide across-the-line starters on smaller motors, and reduced voltage, auto-transformer, or other inrush, current-limiting, starter types on motors greater than 25 HP, or where system capacity or mechanical requirements indicate the need on smaller motor applications. Select motors with a sufficient rating for the duty they are to perform and not to exceed their continuous HP rating, including service factor, when the driven equipment is operating at its greatest HP. Coordinate starting and running characteristics with the driven machine and the motor control equipment. Motor enclosures shall be ODP for indoors dry locations and totally enclosed or totally enclosed fan-cooled for outdoor or wet locations, except where special conditions require otherwise.

Single-phase motors 1/8 HP and smaller shall be shaded-pole or permanent split capacitor; those larger than 1/8 HP shall be capacitor-start. Polyphase motors shall comply with NEMA Design B, unless other characteristics are required by the driven machine or the speed controller. Design motors for continuous service at 104°F (40°C) ambient temperature. Motors shall operate at full capacity, with a voltage variation of plus or minus 10 percent of the nameplate voltage. Consider high-efficiency and premium-efficiency motors where loading and continual use may result in significant energy savings.

Consider VFCrs where motor speed requirements vary widely during normal operation. Solid-state, variable-frequency units are recommended for smaller HP motors. In all cases, select the motor in accordance with the drive manufacturer's recommendations to ensure a coordinated system and to avoid damage to the motor. In particular, induction motors driven by a VFC shall have provisions for rotor shaft grounding and VFC output filtering so as to prevent bearing fluting from inductive buildup and discharge.

8.5.3 Pumps

Where circulating pumps are used in open systems such as cooling towers, install a suitable straining device (basket-type for base-mounted pumps) in suction lines and provide for easy removal to allow for cleaning. Connect all circulating pumps to the piping system through flexible couplings. Never connect a 90-degree elbow directly to the suction opening of any pump.

8.5.4 Air Filters

Air handlers shall be designed to accept bag type filters. Preferred size for filters is 24 inches x 24 inches x 15 inches deep, and the preferred media is fiberglass. Filter frame assemblies shall be specified such that there will be no leakage around the filters or filter bank. Farr Type 8 front-loading filter frames or Farr 3P Glide/Pack side loading frames, or equal, should be specified. Cartridge filters and slide rack frames are permitted in fan coil units and small roof top air handler units. Filter banks shall be sized for no greater than 500 feet per minute face velocity.

General office area and light lab air handling equipment will use 50 percent efficient bag filters. Process, manufacturing, and special use area filter efficiencies will be determined by the project need. Air filters shall be rated either as Class 1 or Class 2 in accordance with UL900 Standard for Safety Air Filter Units and NFPA 90A.

Use only Class 1 filters in clean room applications. Nuclear Grade HEPA filters shall be listed under UL 586, Standard for Safety Test Performance of High Efficiency Particular Filter Units.

8.5.5 Humidifiers

Avoid humidifiers using a standing water reservoir. Equip all humidifiers with a drain-down, bleed-off, and overflow. Humidifiers supplied with non-potable water shall have a demineralizer tank installed to reduce scale build-up.

8.6 Plumbing Design

8.6.1 Design Conditions

Water main pressure is 60 to 110 pounds per square inch gauge (psig). Maximum water pressure varies depending on the location within the site. Consult with the systems engineer for design water pressures. Natural gas main pressure is 20 psig.

Flush valves shall have a 25-psig-minimum residual pressure; all other fixtures shall have a residual pressure of 15 psig minimum.

Water velocities shall not exceed 10 feet per second.

8.6.2 Potable versus Non-potable Water Connections

Supply Potable Water:

- To all plumbing fixtures except for fixtures located within a fume hood.
- To evaporative coolers and air washers, and provide an air gap between the supply and the flood rim.
- To landscaped (trees, lawns, shrubs, etc.) areas, and provide a vacuum breaker after the last valve (do not install shutoff valves downstream of a vacuum breaker).
- To eyewash and safety showers.
- To dishwashers and ice machines, and provide an air gap.
- To sinks with hose connections, yard hydrants, and hose bibbs. Provide with vacuum breakers.

Supply Non-Potable Water:

- To fume hoods
- To de-ionizing or de-mineralizing water systems
- To any connections provided in laboratory space for future use.
- To make-up water connections to circulated water systems.

Always consider the use of a distributed Non-Potable Water (NPW) system for multiple users as opposed to a Backflow Preventer (BFP) at each point of use. Make the decision based on life cycle cost. Refer to Chapter 7.3, Fire Protection Backflow Preventers, for backflow prevention requirements.

Provide signs at fume hood faucets and any outlet on the non-potable water system stating: **"Danger – Non-potable Water."**

8.6.3 Calculations Required

Hot and cold water systems:

- Demands in fixture units or gallons per minute
- Pipe sizing
- Shock absorber sizing
- Water heater storage capacity sizing
- Hot water expansion tanks.

For buildings with 50 or more occupants, base the selection of domestic water heaters on an economic balance of the maximum daily demand, the maximum hourly demand, the first cost and operation cost, and the availability and cost of fuel.

Sewer, vents, and drain lines:

- Load capacities (fixture units) to determine sizing
- Absorption rates for drain fields and seepage pits established by actual field percolation tests.

Gas supply system:

- Capacity used to size from tables in International Fuel Gas Code. (See Chapter 3 for exterior gas piping.)

Roof drains and piping:

- Rainfall rates (Sandia/NM=2 inches per hour)
- Flow rates
- Pipe sizing.

Backflow Preventers:

- Sizing shall account for the head loss through the device at typical flow rates not to exceed 7.5 feet per second through the device.

8.6.4 Piping Materials and Labeling

Refer to Facilities Construction Standard Specification Sections 15051, Piping Systems, and 15401, Plumbing.

For selection of drainage piping in buildings that use corrosive chemicals, coordinate with the user to determine what corrosive chemicals will be drained, the temperature range of the effluent, and the amount of their dilution. Consult the Sandia Materials group or Environment, Safety, and Health when a possibility exists for a combination of corrosive chemicals to go into drains, and to determine the need for a neutralizing tank as a substitute for, or in addition to, corrosive drainage piping.

Construction Standard Specification 15401 specifies materials and installation requirements for "Laboratory/Process/Acid Waste and Vent systems that apply to systems so designated on the drawings. While no single material is capable of handling every chemical, the specification is based on either Polypropylene or PVDF with electric fusion joints. These materials are capable of withstanding corrosion from the widest number of chemicals but they may not be satisfactory for all conditions. The mechanical designer shall determine the appropriate material to be used based on the chemicals and their concentration, pressures and temperatures, system life and cost.

Identify piping with self-adhesive labels. Refer to Facilities Construction Standard Specification Section 15050, Basic Mechanical Materials and Methods.

8.6.5 Plumbing Fixtures

Standard plumbing fixtures (toilets, drinking fountains, sinks, etc.) are listed in Facilities Construction Standard Specification Section 15401, Plumbing. The designer shall specify special laboratory fixtures to meet customer's requirements. Flushometer valves for urinals and water closets shall be specified as Sloan or Zurn without exceptions.

8.6.6 Backflow Preventers

Design Conditions

Backflow prevention (BFP) assemblies are required to prevent cross-connection contamination between potable water systems and non-potable, potentially polluted, or potentially contaminated systems, such as drainage systems, soil lines, and chemical lines.

BFP assemblies are required to be approved by Sandia/NM and the Foundation for Cross-Connection Control and Hydraulic Research, University of California, and the International Association of Mechanical and Plumbing Officials.

Keep the number of BFP assemblies to a minimum through connection of non-potables on a common system.

Apply the devices in accordance with the following general guidelines:

- Atmospheric vacuum breakers must be installed on the discharge side of the last shutoff valve and a minimum of 6 inches above the highest overflow level.
- Vacuum breakers must be installed a minimum of 12 inches above the highest piping or outlet downstream of the device and must not be used where backpressure may occur. Discharge pressure should be maintained above 5 psig at all times.
- Double check-valve backflow preventer may be used if there is a possibility of backpressure, or if a low or nontoxic hazard exists.
- Use a reduced-pressure double check valve if there is a possibility of back pressure and a toxic hazard exists.

Installation for the above backflow preventers shall provide the following:

- Positive drain for all discharges to an appropriate point with positive air gaps, as required
- Easy accessibility for testing and maintenance
- Protection from freezing
- Proper support when necessary
- Provisions for excessive pressure or thermal expansion downstream
- Placement between 12 inches and 60 inches above finished floor level.
- Configure the device to provide protection for high-hazard service with necessary check valve, relief valve, test cock, and isolation valve to conform to all codes having jurisdiction.

Refer to Chapter 7.3, Fire Protection Backflow Preventers, for sprinkler system backflow prevention requirements.

8.6.7 Calculations Required

Sizing shall account for the head loss through the device at typical flow rates not to exceed 7.5 feet per second through the device.

8.6.8 Plumbing-General

Provide building water pressure regulators for any building where the water system pressure is over 80 psig.

Provide building water flow meters for all facilities. Where possible, specify a meter which can report through the FCS system and provide a communication dataway to the device.

Provide suitable facilities for emergency quick drenching or flushing of the eyes and body in workplaces where occupants may be exposed to injurious, corrosive material. For all installations, involve the occupants' organization's Industrial Hygienist in selecting the type and location(s) for emergency eyewash and shower equipment. Generally, these will be:

- Positioned 100 feet or less from the hazard,
- Located in accessible areas that can be reached in 10 seconds or less,
- Labeled with a highly visible sign, and
- Illuminated with proper lighting (coordinate with electrical designer).

All eyewashes and safety showers shall meet the American National Standards Institute (ANSI) Z358.1 standard requirements. Hand-held drench hoses may provide support for emergency shower and eyewash units, but shall not replace them. Due to the infrequent of use of safety showers, floor drains generally are not required. Showers can be tested with a curtain and bucket. Unless water is supplied directly from outdoors, tempered supply water also is not required. Refer to Facilities Construction Standard Specification Section 15401, Plumbing.

Water lines with solenoid valves, flush valves, or other quick-closing devices should be fitted with an accessible, valved and sealed shock chamber to absorb water hammer. Lengths of pipe that are capped to form air chambers are unacceptable.

Install wall hydrants 18 inches above grade on each major outside building surface, not to exceed 100 feet apart. Do not cast hydrants into masonry. Incorporate a vacuum breaker at each wall hydrant. Locate hydrants to insure that they will not be subject to freezing.

Do not cast any piping within the structure into concrete, except cast-iron sewers.

For future extension show service piping such as gas, compressed air, and domestic water (where applicable), with plugged tees instead of elbows. Provide isolation valves for ease of isolating sections of piping for future modifications without the need to shut down most of the system.

Plumbing accommodations in government facilities shall conform to 28 Code of Federal Regulation, Part 36, Nondiscrimination on the Basis of Disability by Public Accommodations in Commercial Facilities. See Chapter 6.7, Accessibility Requirements, for further information.

Install a minimum of one floor drain per room in toilet rooms, darkrooms, janitor closets, and equipment rooms. Install adequate floor sinks, wherever needed, to take indirect wastes. Provide steam and valve pits with a French drain, 2 feet in diameter by 5 feet deep, filled with 1/2- to 1-inch clean, graded gravel. Coordinate with the structural drawings to ensure that floors are pitched downward toward all floor drains. Floor drain gratings shall be of heavy-duty construction and made from nonferrous material. Floor drain bodies shall be galvanized. Trapped floor receptacles shall be primed. Do not specify trap primers that rely on pressure fluctuations in the piping to activate the primer. Timed solenoid valves have been the most useful device for priming traps.

Do not connect floor drains to the storm drain system. The design team shall ensure by visual inspection, drawing search, and/or dye testing that plumbing connections are made to appropriate sanitary sewer piping. Do not make piping connection that would result in the flow of non-storm water to the storm drain system. Storm water is defined as those flows that result from atmospheric precipitation which have not been confined in any way (see Sandia/NM Environment, Safety and Health (ES&H) Manual). Consider the use of "water harvesting" for the discharge of roof drains on new facilities. Refer to section 3.6 – Drainage Requirements.

Detail roof drains in cross section and incorporate a suitable removable strainer or gravel guard, seepage pan, and clamping device. Connect the roof drains to the storm drainage system. Insulate roof drain piping in ceiling spaces.

Space sewer cleanouts to grade no further than 50 feet in buildings. Terminate each branch run in a full-size cleanout. Show sewer cleanouts on both the plan and isometric drawings. Locate cleanouts so a power-driven snake can be used without the need to relocate.

Make extensive use of re-venting, where practicable, to minimize roof penetrations. Hubless cast-iron pipe and fittings are acceptable above grade.

8.7 Heating/Cooling/Ventilation and Energy Calculations – General

Heating and cooling load calculations and energy and economic analysis shall be performed using Trane Trace 700 software. Analysis shall be performed early in the conceptual stages of the design to evaluate system size and compare alternatives. The analysis should also be performed for the as-designed conditions reflecting the construction, layout, and system configuration. Analysis of alternatives shall be based on life cycle cost analysis and consider first cost, maintenance, and energy cost as well as the project budget. The latest utility cost shall be obtained from the system engineering organization.

Provide ventilation to all occupied spaces to meet the requirements of ASHRAE Standard 62 'Ventilation for Acceptable Indoor Air Quality' latest addendum. Describe in the design analysis the procedures used and the necessary controls to meet the requirements.

Calculations shall be submitted as a part of the Design Analysis that include the following:

- **Narrative** – Describing the type of construction, alternatives analyzed, assumptions for internal loads, airflows, construction, and schedules and supporting documentation.
- **Drawings, sketches and schematics** – Fully describe the zoning layout, system configuration, and construction types as referred to in the program.
- **Reports** – Provide the reports necessary to document the design decisions.
- **Archive Files - FILENAME.TRC** – The project file that contains all the information you entered into the program, including project, weather, room, system, zone, and load parameter information and any Project Templates that you used for entering room information. It also contains the results of the design calculations.   LIBRARY.DB (optional) - The library database that contains all the information from the libraries that the program uses (Weather, Schedules, Construction Types, Glass Types, Materials, Internal and Airflow Loads, and Shading), plus all of the Global Templates.

NOTE You only need to archive this database if your project file uses "custom" library members, e.g. a library member that you created.

Provide calculations to support the ventilation levels the system and individual spaces.

8.8 Heating Design

8.8.1 Design Conditions

Unless otherwise specified in the Design Criteria, use the tabulated weather data tables in the American Society of Heating, Refrigeration, and Air Conditioning (ASHRAE) Fundamentals volume per the following: Laboratory Occupancy 99 percent column, Personnel Comfort 97.5 percent column for outdoor temperatures.

Infiltration, except where exceeded by ventilation, should be taken into account by using the air-change method outlined in the ASHRAE guide. Pressurize all structures to approximately 0.03 inches of water to minimize infiltration, except where noted in the Mechanical Design Criteria. The minimum outside air required to provide ventilation for each zone shall be in accordance with the latest edition of ASHRAE Standard 62. Include an additional air allowance for pickup when sizing boilers and converters. Systems shall not be additionally oversized unless otherwise noted in the Design Criteria.

Do not take credit for the heating contribution of light fixtures when sizing heating equipment for buildings that will be partially occupied during nonwork hours. Full credit will be taken for buildings that are occupied during working hours only.

In Tech Area I at Sandia/NM, use district steam only when life-cycle cost effective considering complete Steam Plant shut-down by the year 2012. In general, systems should be planned to migrate to decentralized hot water boilers. Use gas fired hot water boilers as the primary source of heat for new and renovated buildings. Provide proper zoning so areas will not overheat as the result of winter sun and/or interior room heat that affects only part of a zone.

Design heating water systems with 180°F maximum supply temperature and a 20-40°F drop.

Provide a design for all piping supports for above- and below-grade steam, condensate, and hot water piping. Include in the design the locations of supports, support details, and specifications for piping restraints, piping guides, expansion loops, and expansion compensation devices. Piping outside the Steam Plant (building 605) shall be designed and constructed to meet ANSI B31.3, Process Piping. Piping within the Steam Plant shall be designed to meet ANSI B31.1 Power Piping.

8.8.2 Calculations Required

Heating Systems

- Heat loss by rooms, zones, and buildings
- Capacity of the distribution systems
- Heat-generating and heat-transfer equipment
- Hydronic calculations
- Pump sizing

- Fan sizing.
- Thermal expansion of steam, condensate, and hot water piping

Fouling Factors

Present calculations to show the effects of fouling factors on either side of heat-exchange surfaces.

8.8.3 Piping Materials

Refer to Facilities Construction Standard Specification Section 15051, Piping Systems.

8.8.4 Heating System – General

Where possible, install local gas fired hydronic heating systems.

Size steel boilers by matching the net Steel Boiler Institute output ratings, corrected for altitude, with the calculated heat loss for the structure. Use net IBR ratings (Institute of Boiler and Radiation Manufacturers on Hydronics Institute) for cast-iron boilers or 30 percent allowance for pickup on other types of boilers and converters.

Boiler selection shall be by life-cycle cost and shall include the significantly different life expectancy and efficiencies of boiler types. Estimates of seasonal efficiency shall consider the effect of type of control, (on/off, high/low/off, fully modulating), number of boilers, and oversizing. Leave spare floor space for future expansion.

Use an outdoor reset water temperature control through the FCS to provide hot water supply temperatures according to outside air conditions without overheating.

In heating water systems, the control scheme shall cause the heating water pumps to operate only when there is a call for heating and to shut down during unoccupied hours. See Chapter 8.23, Controls.

Design all large heating water distribution systems that use a two-pipe, reverse-return primary system. In large buildings, give consideration to a primary and secondary system.

For water treatment requirements for heating water systems refer to the Water Treatment section later in this chapter.

Air vents on exposed hot water lines over 7 feet above the floor shall consist of ¼-inch copper tubing extended down to a petcock located 7 feet above the floor. Vents on hot water lines above ceilings need not extend below the ceiling.

Show flow-limiting devices and isolating valves for each use point. Size the piping so a minimum use of balancing valves will be required. Diverting tees are acceptable, provided the drop in main temperature is taken into account. Make extensive use of insertion test plugs to assist in balancing. Install flow meters or other flow measuring devices to indicate rate of flow in each system and zone. Use flow meters on small systems up to 10 gallons per minute. Use Delta P venturi fittings (less meter) on larger systems. Use a pumped coil for freeze protection on outside air applications.

Give special attention to wind pressure in warm air distribution systems, noting that severe winds are experienced at Sandia/NM. Incorporate features or zoning so the major portion of air will travel to the upwind side of the structure where it is needed most.

Gas-fired heaters shall have double wall vents and 100-percent stainless steel heat exchangers when 100-percent outdoor makeup air is used. Combustion air is not to be taken from the occupied space. Direct-fired makeup air handler units shall not be used without approval of the systems engineer. Direct-fired makeup units should not be used for makeup air to a chiller plant due to the possibility of vented refrigerant reacting in the gas flame.

Provide electric duct heaters, where required, with a manual and automatic reset, high-limit control, and a differential pressure switch (or other flow sensing device). Stage electric heaters.

8.8.5 Air Emissions Permits

In accordance with Section 17B-Air Permits of the Sandia/NM ES&H manual, fossil fuel-fired equipment will require an air permit for Bernalillo County before construction can begin if one or more of the following conditions exist:

- Potential emissions of a regulated air contaminant greater than 2,000 pounds per year
- Potential emissions of a regulated air contaminant greater than 10 pounds per hour
- Emissions from fossil fuel (e.g., natural gas, Diesel)-fired boilers.

As soon as the mechanical designer has designed the heating system, selected equipment, and determined that any of these conditions are met, the Sandia/NM Project Manager shall be notified of the potential need for an air permit and provided with the specifications of the fossil fuel-fired equipment. Contact the Environmental Programs & Assurance department for questions concerning air emissions and additional details. Obtaining a permit may take up to 180 days.

8.8.6 Boiler Controls

All boilers less that 12.5 MMBTU/hr. input rating shall meet the requirements of ASME CSD-1, ‘Controls and Safety Devices for Automatically Fired Boilers'. Boilers 12.5 MMBTU/hr. and larger shall meet the requirements of NFPA 85.

8.9 Evaporative Cooling Design

8.9.1 Design Conditions

Applications to be considered are as a supplemental source of cooling for office and lab applications; and, should be considered as primary cooling for warehouses, shops not requiring close (plus or minus 5°F) temperature controls, nonresidential-size kitchens, makeup air ventilation units, and mechanical equipment spaces.

Spray pumps shall be located outside of the air stream when used in process exhaust systems and for any air handling system requiring 24-hour, 7-day-per-week operation.

Specify indoor design dry bulb temperatures for spaces air conditioned by adiabatic cooling systems by project-specific criteria. Operating efficiency for adiabatic cooling equipment shall be a minimum of 70 percent. Base the system-installed capacity on the conditioned space peak design cooling load. Do not use an arbitrary air-change rate for design airflow. State adiabatic cooler specifications in terms of air capacity, the entering ambient dry and wet bulb temperatures, and leaving dry bulb temperature.

When evaporative coolers are installed as supplemental cooling in an air handler unit, they should be installed downstream from the chilled water coil and controlled to operate as a first stage of cooling whenever the outside air dew point is below the highest allowable space dew point. The chilled water valve would then be modulated to maintain the required supply air set point. This setup will allow the use of warmer chilled water temperatures, more frequent use plate & frame heat exchangers, and more efficient operation of chillers.

Consider air duct design, number, and location of coolers, and reliefs of the higher rate of air supply (for two-speed fan operation) to the atmosphere to ensure a satisfactory operating system. Also, consider multi-stage indirect evaporative cooling systems.

8.9.2 Calculations Required

- Heat gains by rooms, zones, and building
- Capacity of distribution systems
- Psychrometric analysis (trace process on chart corrected for altitude)
- Heat dissipating equipment.

8.9.3 General

Specify drip-pad coolers on small installations where the use of fan curves is not required in the design. Specify high-efficiency rigid media coolers with stainless steel water sumps on medium and large size systems and where fan curves are needed in the design.

For energy conservation, specify the lightest color available from the manufacturer for the exterior finish coat of the cabinet.

Specify two-speed motors on all fans serving evaporative cooling equipment.

Detail a bleed, overflow, and drain on the piping diagram for each piece of evaporative equipment. Set the bleed amount for 1 gallon per minute per 1,000 cubic feet per minute of air flow. Arrange overflow and drains so fan suction does not empty a trap and thereby allow sewer gases to be pulled into the system. Inactive traps shall not evaporate the water seal with the same result. Discharge the bleed line to a sanitary sewer.

Detail a system for thoroughly draining (without the use of tools) supply-water piping that is subject to freezing. Include a slide damper in the design of small evaporative units. Install a spare set of guideways on the duct or other similar structure to provide for summer storage of the slide damper. When larger units are included and motor-operated dampers are used, the slide damper guideway is installed upstream of the evaporative section. Provide access doors to facilitate working on the evaporative media, the pumps, motors, etc.

8.10 Refrigeration Design

8.10.1 System Selection

Unless specified otherwise in the Design Criteria, analyze all options for providing cooling for new facilities and renovations to existing facilities to determine the option with the lowest life cycle cost. Fully consider impacts to energy efficiency, reliability, flexibility, and maintainability. A number of campus type chilled water distribution systems exist within the tech areas that should be looked at for a source of cooling. The choice of direct expansion (DX) vs. local chilled water vs. campus chilled water systems should be reviewed with the systems engineer during the design phase to insure the system meets Sandia's long term needs. In all cases avoid the use of small local DX equipment within a building (other than MO and T-buildings) due to high maintenance requirements.

Refer to the Master Chilled Water Plan for the campus chilled water loops. The Campus Chilled Water Loops include:

- Tech Area 1 Central Chilled Water System (850/894/890)
- Tech Area 1 South Chilled Water System (823)
- Tech Area 1 Southeast Chilled Water System (899/726)
- Tech Area 1 East Chilled Water System (858N/870)
- Tech Area 1 North Chilled Water System
- Tech Area 4 Chilled Water System

Connecting to an existing chilled water system is the preferred method for providing cooling if system capacity is available and the distance to run chilled water does not make the life cycle cost unfavorable. Chilled water systems have advantages of higher efficiency, lower maintenance, flexibility to adapt to local cooling loads as facilities are modified, and they can be a source of cooling if a process chilled water system is required. Before connecting to a campus chilled water loop consult with the systems engineer to determine if capacity is available, the type of connection to use, the expected supply water temperature, the temperature difference to design for, and pumping pressure requirements. Supply the systems engineer with annual cooling load profiles and peak design loads for current and future estimated requirements. Most chilled water systems are of the variable flow type requiring VFCs on the pumps and 2-way control valves at the coils. Provide BTU meters for monitoring water flows and cooling loads for each building.

8.10.2 Design Conditions

For calculating building cooling loads, unless otherwise specified in the Design Criteria, use the tabulated weather data tables in the ASHRAE Fundamental Volume per the following: Laboratory Occupancy 0.4 percent dry bulb and 0.4 percent wet bulb column; Personnel Comfort 1 percent dry bulb and 2 percent wet bulb column. Size cooling towers and air-cooled condensers for the maximum actual conditions to which they are subjected.

Unless otherwise mentioned in the criteria, inside design conditions for personnel comfort shall be the 1 percent outdoor design dry bulb conditions, 72°F dry bulb. Comply with ASHRAE 90.1 for sizing of equipment and component. Present other indoor temperatures and humidities that are required for process or sensitive equipment in the Design Criteria. Present complete room-by-room and zone-by-zone heat-gain calculations. In general, pressurize all structures to minimize infiltration.

8.10.3 Calculations Required

Heat gain by rooms, zones, and building.

- Capacity of the distribution systems
- Heat-dissipating equipment
- Hydraulic calculations
- Psychrometric analysis (trace process on a chart corrected for altitude)
- Compliance within the Code Footprint to the International Building, Mechanical, Plumbing and Fuel Gas Codes for refrigerant quantity limits, as well as any need for a machinery room.
- Calculations for normal and emergency ventilation rates of machinery rooms within the design analysis document.

Provide within the Code footprint compliance with the IBC, IMC, IPC, and IFGC for refrigerant quantity limits and any need for a machinery room. Provide calculations for normal and emergency ventilation rates of machinery rooms within the Design Analysis document.

Calculations for sizing chillers and supply-air quantities shall take into consideration both space and building electrical loads. The electrical loads are obtained from the electrical designer, who will determine loading from the electrical drawings and partial loading from the energy schedule in the Design Criteria. Modify the laboratory equipment portion of the full-load quantities to actual loading values by an appropriate diversity factor. Consult Sandia/NM Facilities Engineering to determine this factor. The equipment shall not be sized for future additional capacity or redundancy unless indicated in the Design Criteria.

8.10.4 Piping Materials

Refer to Facilities Construction Standard Specification Section 15183, Refrigeration Systems.

8.10.5 Refrigeration System—General

Show detailed provisions for draining condensed moisture from the cooling coils to a floor drain. Pay special attention to showing how the moisture is collected as it comes off the coil.

For built-up systems, use a control diagram to describe the appropriate safety, temperature, and pressure controls. Each reciprocating compressor shall have a high- and low-pressure cutout, low-oil-pressure cutout, and low-temperature cutout (to prevent freezing of tubes in water chillers). Where capacity reduction is needed at low loads to prevent short cycling, use automatic unloaders and/or properly staged multiple smaller compressors. Where possible, avoid using energy-wasting hot gas bypass designs. Install a time delay to prevent short cycling.

Fit compressors that are 5 hp and greater with an elapsed running time meter.

Heat rejection devices such as air-cooled condensers are preferred, except where size and equipment dictate the use of cooling towers. Select air-cooled condensers at least one size larger than determined by calculations, with corrections for altitude when the condenser is installed on roofs that experience high temperatures. Specify cabinets for air-cooled condensers with the lightest color available from standard manufacture. Specify a minimum ground clearance of 12 inches for condensers over 3 tons installed on grade. Smaller condensers should be installed on concrete pads or rails at least six inches above grade.

Specify hail guards for all exposed condenser coils. Unless required by space or cost restrictions, locate air-cooled condensers away from direct sun exposure and where they will be suitable for operation at low ambient conditions. Pay attention to oil return and where equipment must operate in cold weather. Provisions must be made to guard against low-head pressures and backslugging of liquid (low ambient protection). Where short-cycling or capacity reduction can become a problem provide several smaller compressors. To prevent freeze-up and extend the life of the cooling towers, provide a sump tank on cooling towers being used for year-round cooling. Include an automatic condenser water temperature control to maintain optimum refrigeration equipment operating efficiency. Specify cooling towers constructed of fire-resistant materials.

Air-to-air heat pumps are permitted for T-buildings or mobile offices only or to transfer energy within a building.

Design medium to large chilled water systems using either a two-pipe, reverse-return flow, or oversized mains and with a 10-15°F temperature differential. When a primary-secondary system is designed, additional circulators are required on each secondary loop. Consider variable flow systems with variable speed pumping in systems over 100 tons. In constant flow systems, install flow controllers and heat exchange devices (coils, etc.) in each zone. Although balancing valves are generally not necessary in variable flow systems, they can be useful for troubleshooting problems later. Use Bell and Gossett circuit setters on small systems up to 10 gallons per minute. Minimize the use of balancing valves in variable flow systems.

Refer to Chapter 8.28.2 for water treatment requirements for chilled water piping.

Air vents on exposed chilled water lines over 7 feet above the floor shall consist of ¼-inch copper tubing extending down to a petcock located 7 feet above the floor. Vents on chilled water lines above ceilings do not need extending down to below the ceiling.

Specify Air Conditioning and Refrigeration Institute certified water coils. Size coils for 500 feet per minute maximum face velocity.

Two-way water control valves are preferred over three-way valves, except that a minimum number of three-way valves shall be used to provide the minimum flow needed for chillers. Use series and parallel pumps with automatic controls to limit the valve differential head increase to twice the initial head. Systems with lower heads (60 to 70 feet) shall use parallel arrangement. Systems with higher heads shall use a series arrangement.

Wherever possible, include economy cycle provisions in the system.

Choose refrigeration equipment to comply with the minimum coefficient of performance ratings as listed in ASHRAE Standard 90.1. New equipment should be limited to using refrigerants classified A1 or B1 by ASHRAE Standard 34 and either hydrofluorocarbons or hydrochlorofluorocarbons. Typical refrigerants meeting these requirements are R-22, R-123, and R-134a.

Design refrigeration systems to meet the requirements of the International Mechanical Code.

8.11 Refrigeration Machinery Rooms

When a refrigeration machinery room is required design the room to meet the requirements of the IMC and related sections of the IFC.

8.11.1 Architectural Requirements

The mechanical designer shall insure that the architectural requirements for a machinery room are met the by the design team. Pay particular attention to the following issues:

- Tight construction to prevent migration of vapors to others parts of the building.
- Tight fitting doors opening outward with self-closing devises if they open into the building.
- Adequate number of exits located to ensure freedom for persons to escape in an emergency.

8.11.2 Refrigerant Detection and Alarms

Provide both audio and visual alarms both inside the machinery room and outside each entrance. The horn and strobe shall have a different tone and color than that used for fires.

Provide refrigerant specific detectors for each type of refrigerant used by equipment used in a machinery room.

The detector shall have a means of manual reset. Remote reset is required if the detector is installed outside of the machinery room.

Pay particular attention to the location and number of intake points of sensors needed to detect a refrigerant leak. Locate sensor points 12-18 inches above the floor and in any pits that could be occupied where refrigerant could accumulate. A sensor point may be placed between two systems with the same type of refrigerant. Locate sensor points down stream of the system in the direction of ventilation airflow.

A multi-channel scanning system may be used for multiple systems with the same refrigerant type.

Refrigerant detectors specified with the following:

- Three levels of alarms plus a trouble alarm utilizing individual relays with 240 VAC 5 amp resistive SPDT contacts. Each relay shall be capable of being latched to a manual reset.
- Refrigerant specific sensor technology such as photoacoustic or non-dispersive infrared. Linearity greater than or equal +/- 5 ppm in the 20 to 100 ppm range, or +/- 6% of reading in the 100 to 1000 ppm range.
- A 4-20 ma analog output shall be tied to the FCS.

8.11.3 Ventilation

Provide both normal and emergency ventilation using outdoor supply and exhaust with a system that is independent from the remainder of the building. Normal ventilation air shall be tempered to maintain a temperature between 65-85 degrees F. Emergency ventilation air shall be heated sufficiently to prevent pipes from freezing with the machinery room. Exhaust air shall be discharged to a safe location outside the building. Normal ventilation shall be based on 0.5 CFM per square foot of machinery room area. As long as temperatures are maintained the normal ventilation may be switched by an occupancy sensor such as a light switch or motion detector.

The ductwork shall be arranged with inlets and outlets placed to provide a sweeping of air past equipment with no dead spaces.

Emergency ventilation shall be started by a high level alarm in the refrigerant monitor and also by switches placed outside of each entrance.

8.11.4 Alarm Levels

Alarm levels and responses shall match the following tables:

Refrigerant	"Caution"	"Alert"	"Alarm"	"Trouble"
R-11	50 PPM	250 PPM	700 PPM	Sensor/Controller Fault
R-22	50 PPM	250 PPM	700 PPM	Sensor/Controller Fault
R-134a	50 PPM	250 PPM	700 PPM	Sensor/Controller Fault
R-500	50 PPM	250 PPM	700 PPM	Sensor/Controller Fault
R-123	30 PPM	40 PPM	50 PPM	Sensor/Controller Fault
R-407c	50 PPM	250 PPM	700 PPM	Sensor/Controller Fault

	Panel Alarm	Fcs Alarm Message	Alarm Priority & Action
Alarm Level 1 Contacts	CAUTION	Building ___ Refrigerant Level CAUTION. Level has reached ___ ppm in the equipment room. Leak check the refrigerant system.	Priority 6 alarm (FCS alarm at the building operator's control terminal. Operator Actions: Leak detection, portable gas detector optional, and no respiratory protection required.
Alarm Level 2 Contacts	ALERT	Building ___ Refrigerant Level ALERT. Level has reached ___ ppm in the equipment room. Immediate Attention Is Required.	Critical alarm message to the Steam plant. Ventilation system is automatically started. Operator Actions: Leak detection, portable gas detector optional, and no respiratory protection required. (BUT EQUIPMENT STAGED AND READY FOR USE)
Alarm Level 3 Contacts	ALARM	Building ___ Refrigerant Level ALARM. Level has reached ___ ppm in the equipment room. Immediate Attention Is Required. I.C. emergency response required. DO NOT ENTER THE EQUIPMENT ROOM WITHOUT A SUPPLIED AIR RESPIRATOR.	Alarm light beacons signal need to evacuate. Alarm horn sounds. Critical alarm message to the steam plant. Ventilation system is operating. Operator Actions: Leak Detection, portable gas detector required, supplied air respirator required.
Trouble Contacts	TROUBLE	Building ___ REFRIGERANT MONITOR TROUBLE. Refrigerant monitor is inoperative. Immediate attention is required.	Same priorities and actions as "Caution"

8.12 Exhaust Design

8.12.1 Design Conditions – General Exhaust

Thoroughly exhaust toilet rooms, darkrooms, battery rooms, and other areas that contain noxious, harmful, or objectionable fumes. In the design calculations, indicate the quantity of air exhausted and air made up to the area, balanced so a slight negative pressure exists to prevent exfiltration from the room.

Provide exhaust in restrooms to meet the requirements of ASHRAE 62. Provide exhaust for refrigeration machinery rooms to meet the requirements of the IMC for normal and emergency ventilation rates.

Use sight-proof and nonadjustable door louvers. Use special exhaust grilles and door louvers in darkrooms to prevent passage of light.

8.12.2 Design Conditions – Local Exhaust Ventilation

Local exhaust ventilation (LEV) is preferred over dilution ventilation for controlling hazardous vapors, gases, and particles. The Local Exhaust Ventilation Program is managed by the Industrial Hygiene Department (10327). Industrial hygienists are assigned to Customer Support Teams (CSTs) who support Sandia/NM line organizations requesting work, and are knowledgeable about the operation and conditions of exposure. They are an essential source of information during the design of the LEV system. The CST shall be consulted in the planning stages of any new LEV/High-Efficiency Particulate Air (HEPA) filtration system or upon request to modify any existing LEV/HEPA system. Refer to the ES&H manual (Chapter 6, Section P) for additional information about LEV systems.

Clearly define the source of all exhaust air, and provide clean, tempered air into the space to replace exhaust air. The designer shall assist the line organization and Industrial Hygiene in the selection of exhaust hoods and controls for each application, and the exhaust system for which the hoods are to be used.

Design hoods, and calculate exhaust requirements based on similar applications found in "Specific Operations" of the latest edition of the American Conference of Governmental Industrial Hygienists' (ACGIH) Industrial Ventilation Manual or Sandia/NM's Mechanical Standard Drawings. All "non-standard" LEV designs require an Industrial Hygiene review. Non-standard is defined as a design that does not appear in common reference text such as the Industrial Ventilation Manual. LEV systems must be installed per manufacturer instructions, the requirements/guidelines identified in American Industrial Hygiene Association (AIHA)/American National Standards Institute (ANSI) Laboratory Ventilation Z9.5, the ACGIH Industrial Ventilation Manual, and good engineering practices for systems intended for worker health and safety, as defined by Sandia National Laboratories Facilities and Industrial Hygiene.

The location of the fume hood within a space can have an impact on the effectiveness of the exhaust equipment. The mechanical designer shall provide guidance to architectural designers on layout requirements for fume hoods. Locate fume hood faces 10 feet or more from the closest air supply or exhaust point, but not in or along normal traffic routes. A fume hood should not be located where room air currents greater than 50 linear feet per minute will disrupt uniform air entrance at the hood face.

Fume hood face velocity depends on the capture containment requirements of the hazard, room supply air distribution, traffic past the hood, and the amount and location of equipment in the hood. Fume hood full-open-area face velocity settings can be between 80 and 100 feet per minute, depending on the quality of supply air distribution, the level of hazard, and the quality of the fume hood. Generally, a face velocity of

100 feet per minute is satisfactory if the quality of supply air distribution is adequate, traffic past the hood is low, and there is no equipment in the hood closer than 6 inches to the hood's face. Regulated carcinogens and radiological hoods require higher face velocities.

All fume hoods require an airflow indicator: a simple vanometer, differential pressure gauge, or a more complex Variable Air Volume (VAV) control system. Coordinate with the Sandia/NM line organization to determine which device to use, and whether to order it with the hood or install it during construction.

Systems handling particles require that minimum transport velocities be maintained throughout the system. Although systems handling vapors and gases have no minimum duct velocity criteria, duct velocities of 2000-3000 feet per minute usually result in a good balance between initial and operating cost. Use round ducts for exhaust systems whenever possible. Round ducts resist collapse, provide better aerosol transport, seal easier, and use less metal than rectangular ducts.

Provide separate exhaust systems for process exhausting of incompatible hazardous fumes, gases, etc. Specify the type of duct material and coatings to use throughout the system, compatible with the material being exhausted. Consult with Industrial Hygiene when unsure of how chemicals will react.

Calculate exhaust requirements for closed-type glove boxes for 50 cubic feet per minute (minimum) per glove box.

Exhaust vacuum-pump-oil mist to the outside, or to the building exhaust system.

HEPA systems used in radiological applications shall be installed per manufacturer instructions, the requirements/guidelines identified in the DOE Nuclear Air Cleaning Handbook DOE-HDBK-1169, and the Code on Nuclear Air and Gas Treatment American Society of Mechanical Engineers ASME AG-1, and good engineering practices for systems intended for worker health and safety, as defined by Sandia National Laboratories Facilities and Industrial Hygiene.

Exhaust system flow schematics shall be prepared for all systems with multiple exhaust hoods. Existing flow schematics shall be modified to reflect all changes made to exhaust systems. Schematics shall indicate each source of exhaust, room number, type of hood, design flow rates, riser flow rates, fan flow rates, dampers, filters, and all other components of the exhaust system.

8.12.3 Exhaust Fans

Calculate the total pressure requirements for sizing exhaust fans. Account for system effect losses, and lay out the supply and exhaust connections to fans to reduce the system effect losses as much as practical.

Roof exhausters for general room exhaust shall be all aluminum, roof-mounted, curb-type, and centrifugal, with an integral weather cover, bird screen, back-draft damper, and roof disconnect. Mount the motor outside the air stream. Direct connection is preferred.

Specify the following operating conditions (altitude = 5500 feet) for roof-type exhaust fans:

- Air quantity
- Static pressure
- Motor hp and rpm
- Fan wheel size

Exhaust fans that serve acid, corrosive, or other fume hoods shall be utility-type, and epoxy-coated. Discharge fumes vertically upward at an exit velocity of 3000 feet/minute at a location and height sufficient to prevent re-entry of hazardous fumes. Extend exhaust stacks at least 10 feet above roof level or air intakes that are within 50 feet. Do not install a weather cap on stacks that discharge hazardous chemicals. Final determination of exhaust stack height shall be based on the ASHRAE Handbook of Fundamentals, "Airflow Around Buildings," to effectively dissipate effluent.

Coordinate design with structural and electrical designers to ensure proper stack support and lightning protection.

8.13 Ductwork Design

8.13.1 Design Conditions

Unless otherwise mentioned in the Design Criteria, design supply ductwork using the static-regain or equal friction method to ensure that design quantities of air will reach final outlets in the system. Examples of static-regain and equal friction system design are outlined in the ASHRAE Handbook of Fundamentals and the Carrier Corporation Design Manual.

Design return-air and exhaust systems in accordance with principles of equal pressure drop. This method ensures that proper air quantities will be returned from even the most remote opening. (Every path of air being removed from a particular area or room shall have the same pressure drop back to the fan inlet.) Coordinate ductwork layout with the structural designer to minimize penetrations through firewalls and fire-rated partitions. At these penetrations, fire and smoke dampers and access doors are required.

Specify that Duct Coordination Drawings be submitted on larger and more complicated system as per Standard Construction Spcecification15810 "Ductwork" Section 1.03, 'Submittals', when the design drawings cannot adequately show all the possible interferences.

Consider the requirement for a return air fan when return duct resistance exceeds 0.25 inches of water.

Duct run distances shall be as short as possible. Size the runs on the critical pressure path for minimum practical pressure.

Select diffusers for their ability to quickly mix supply air with room air introducing a maximum of supply air with a minimum throw. Ensure that airflow does not short circuit from the supply diffuser to the return-air openings. Avoid using combination air supply and return diffusers.

During design, select the throw from each diffuser so the throw is 90 percent of the distance from the diffuser to the nearest wall or other obstruction. In the case of diffusers with a downward vertical air pattern, select the throw to terminate above breathing level.

Provide means for balancing the air systems. Devices shall include but are not limited to dampers, flow measuring stations, temperature and pressure test connections, gauges, and flow sensors. Provide permanently installed devices on major equipment. Air monitoring devices shall be multi-point devices that can continuously measure total and static pressure.

Coordinate ductwork layout with Physical Security to minimize the number and size of ductwork penetrations through vaults, vault-type rooms and designated security areas. The penetrations larger than

96 square inches in diameter and larger than 6 inches in the smallest dimension (greater than 11 inches in diameter) require barriers or alarms. (See Chapter 11 for security barrier requirements).

8.13.2 Calculations Required

Present calculations for the design of all air-handling duct systems:

- Duct sizing
- Fan sizing
- Size dampers that admit outside air by pressure drop, rather than face velocity. Calculate the largest drop from a return air register, then make the damper drop an equal value
- Noise criteria (noise criteria curves).

8.13.3 Ductwork-General

Refer to Facilities Construction Standard Specification Section 15810, Ductwork, for sheet metal gauges, materials, equipment, and methods to be used, and the construction of ductwork.

Draw ductwork to scale (single-line diagrams are not acceptable). Thoroughly dimension the drawings. Clearly show register size, equipment list number, cubic feet per minute, pressure drop, and throw. Show all turning vanes in elbows, transitions, duct liners, and air proportioning vanes. Show the detail of all security barriers installed at vault, vault-type room and security area boundaries.

Diffuser size, cubic feet per minute, and throw should appear on plan drawings for each type and size of diffuser. Refer to diffusers with volume controls affixed to the upstream side as registers. A diffuser or return-air device with no volume control may be referred to as a grille. Identify noise criteria ratings in equipment lists.

Install access covers on both sides of heat-exchange devices in ducts. Ensure adequacy for complete cleaning and servicing.

A plenum ceiling return may be used where feasible.

Install fire dampers in all ductwork passing through firewalls, between floors, and where dictated by code requirements. Provide all fire dampers with standard commercial and catalog-listed access doors. For duct areas smaller than 1 sq. ft. provide a removable section of duct to fully access the fire damper.

Install security barriers in all ductwork greater than 96 square inches passing through security area boundaries. Inspection ports shall be installed for future audit verification of security barrier installations. Contact Physical Security (4243) for ductwork in which design or conditions do not allow for inspection ports. See Chapter 11 for security barrier requirements.

List the required duct pressure classification required for each duct segment on the schematic drawings. Unless otherwise stated on the drawings, Specification 15810 Ductwork, will require the following pressure classifications:

- From the fan to the VAV box – 4" w.g. positive
- Downstream of the VAV box – 1" w.g. positive

- Return air – 1" w.g. positive or negative
- Lab exhaust – 4" w.g. negative
- Restroom and general exhaust – 2" w.g. negative

For pressures less than negative 4" w.g. or greater than positive 10" w.g., and for highly corrosive exhaust, ductwork shall be constructed to SMACNA Round Industrial Duct Construction Standards of SMACNA Rectangular Duct Construction Standards. In these situations the designer is required to specify other operating criteria for the contractor to use in applying the standard such as materials, joint type, exterior loads, maintenance loads, corrosive environment.

Provide duct support details for ducts located on the exterior of the building and for all equipment.

Fire and smoke dampers shall be specified for "Dynamic Closure" in a fire event to shut off against airflow at a minimum of 2375 FPM and 4 in.wg. for horizontal or vertical flow.

For large and more complicated jobs, the designer, in accordance with Specification 15810 Ductwork, may request shop drawings, duct reinforcement information, and hanger details. This additional information must be requested through the submittal list.

8.14 Compressed-Air System Design

8.14.1 Design Conditions

Normal Shop and Controls – Pressure: 125 psig.
Laboratory and Special Use – Determine the pressure based on equipment requirements.

8.14.2 Calculations Required

Capacity and pressure drops
Storage capacity
Percent of running time for the compressor selected.

8.14.3 Piping Materials

Refer to Facilities Construction Standard Specification Section 15051, Piping Systems.

8.14.4 Equipment

For normal shop and control air applications, the compressor shall be a two-stage, air-cooled, pressure-lubricated, motor-driven, tank-mounted unit. For units above 15 hp, a water-cooled model is indicated and a separate vertical air receiver is preferred. The compressor shall be capable of delivering rated cubic feet per minute of free air at the design altitude. Laboratory applications may require clean, dry compressed air from oil free rotary screw or rotary lobe compressors or oil lubricated rotary compressors with high efficiency oil removal filters and dryers.

The receiver shall be ASME National Board registered, rated, and certified, and stamped for 200-psig working pressure. In extended distribution systems, show auxiliary receivers at remote points. Receiver tanks between 18 and 36 inches in diameter shall have two 4- by 6-inch handholes at each end of the shell. Tanks over 36 inches in diameter shall have a 12- by 16-inch manhole. Install air receivers so all drains, handholes, and manholes are easily accessible. Show details of tank support.

Install ASME-approved relief valves, preferably on the receiver or at the output of the compressor. Set for the rated working pressure of the most vulnerable portion of the system, that is, the receivers. These relief valves shall be 3/4-inch National Pipe Thread or larger and have an outside lifting lever. Relieving capacity shall be larger than the compressor displacement.

Systems 5 hp and greater shall be provided with an elapsed-run time meter.

When two or more compressors are installed, install a means to efficiently operate the compressed air system.

Gauges on receivers shall have a range equal to 1-1/2 times the safety valve setting.

8.14.5 Compressed-Air System-General

Size the distribution system to provide extra storage capacity at times of maximum demand and to provide for possible future expansion of the system. Show valved drip legs at low points in the system.

Install a refrigerant air dryer for air compressors 5 hp and greater. If available year-round, run chilled water through an after-cooler. If chilled water is not available, use a self-contained refrigerant dryer. Use a float trap to remove any condensed material above a drip leg before the material enters the receiver. Drain the low point in the receiver with a timer operated solenoid valve

The first 4 feet of service line from the tank of a tank-mounted air compressor shall be reinforced braided flex connections. Install larger, water-cooled models having separate tanks with lengths of flexible metal hose in two planes, one of which is installed between the compressor and the aftercooler and parallel to the compressor crankshaft.

Wherever possible, large air compressors should take their air from outside the building through a suitable oil filter.

8.15 Pressure Systems

8.15.1 General

Sandia defines a pressure system as an assembly of pressure-containing components typically consisting of pressure vessels, piping, valves, pumps, instruments, etc., which are capable of maintaining fluid (liquid or solid) at a pressure different than atmospheric. This definition is intentionally broad to include the variety of systems with both positive pressures and vacuums that can present hazards to individuals and facilities.

The Sandia facilities organization is responsible for designing a wide variety of pressure systems that ultimately are owned, operated, and maintained by either the facilities organization or a line organization.

In an effort to provide a safe environment for pressure related applications Sandia has instituted a Pressure Safety Program that contains policies for all designers, installers, and operators of pressure systems. The mechanical designer of a pressure system is responsible for meeting the requirements of the

Pressure Safety Program as contained in the Pressure Safety Manual. The program and manual are located at psi.sandia.gov:

8.15.2 Minimizing Risk and Exposure

The design shall consider the following techniques to achieve minimal risk and exposure to the hazards of pressure systems:

1. Identify all hazards and consequences.
2. Minimize pressure and volume.
3. Use recognized standards.
4. Design conservatively
5. Use materials with predictably safe failure modes. Brittle materials sometimes fail unpredictably.
6. Demonstrate structural integrity by overpressure test.
7. Operate within the original design intent.
8. Provide backup protection.
9. Use proven hardware.
10. Use protective shields.
11. Use tiedowns.
12. Go "remote."

8.15.3 Pressure Limitations

The mechanical designer shall review the pressure limitations of all components and their relationship to the following levels of pressure:

- System Operating Pressure
- Set Pressure and Opening Range of Relief Devices
- Maximum Allowable Working Pressure (MAWP)
- Overpressure Test Pressure
- Predicted Failure Pressure

Sandia Facilities Standard Construction Specifications have been developed to meet the requirements of the Pressure Safety Program for their intended systems. The designed shall consider the limitations of each standard specification before selecting it to use for a new system or modifications to an existing system. When any new system will operate outside the range of the standard specifications the designer shall either modify the standard specifications or create a new specification that incorporates all of the requirements and intent of the Pressure Safety Program.

8.15.4 Data Package

A data package is required for all pressure systems. It contains information on the system description/hazards and contains ratings, materials of construction, and documents the configuration of the system. For most facilities owned systems the requirements of the data package are contained in the facilities drawings, specifications, and component submittals and no additional effort is required to prepare the package. For systems owned by a line organization the designer shall assist the owner in preparing the data package by forwarding drawings, specifications, and submittals to the owner upon completion of the project.

8.16 Special Gases

See the Design Criteria for design conditions and required calculation.

All compressed-gas cylinder valve outlet and inlet connections shall conform to the standard of the Compressed Gas Association Standard V-1.

Provide gas cylinder wall racks for gas cylinders at all manifold and storage locations.

8.17 Pressure Vessels

8.17.1 Design Conditions

All vessels shall conform to the ASME Code, including Section VIII, Division I. All vessels shall be ASME National Board certified, registered, and stamped, and meet the impact requirements of UG-84 with no exceptions. Include the requirement for ASME Form U-1A, Manufacturer's Data Report for Pressure Vessels, in the list of required descriptive submittals. Pressure vessels shall be fully described in the equipment list. Include the statement, "No ASTM A-515, ASME SA-515-type steel will be used in the fabrication of this vessel," in the description and specifications.

8.17.2 Calculations Required

Present calculations on the sizing of all portions of the pressure vessels, including connections and fasteners.

8.17.3 Pressure Vessel–General

The pressure vessel detail drawing shall show all construction and installation dimensions and sizes. Provide a 2-inch plugged opening in the center of the head at each end of vessels under 18 inches in diameter. Use openings for inspection purposes only. Locate inspection openings for clear access. Maintain at least a 24-inch clearance in front of all access holes. Pressure vessels between 18 and 36 inches in diameter will have two 4- by 6-inch handholes at each end of the shell. Tanks over 36 inches in diameter will have a 12- by 16-inch manhole. Show the tank support structure on the pressure vessel detail.

Provide suitable taps for a thermometer well, a pressure gauge, and a relief valve in addition to taps required for service connections. Provide a 3/4-inch minimum tap at the low point to facilitate complete gravity drainage of the vessel. Details of the tank shall show locations and sizes of all openings.

8.17.4 Above-Ground Storage Tanks for Flammable and Combustible Liquids

Above-ground storage tanks for flammable and combustible liquids shall be installed in accordance with the International Building Code (IBC), the International Fire Code (IFC) and NFPA 30. All plans concerning the installation or use of above ground storage tanks shall be submitted to Sandia/NM Fire Protection Engineering for review prior to installation.

8.18 Relief Valves

8.18.1 Design Conditions

Without exception, size the relief valve(s) to relieve the unregulated capacity of the PRV, burner, pump, and compressor or prime mover, with no more pressure accumulation than the appropriate code recommends. Factory set the PRVs at the pressure rating of the piece of equipment having the lowest working pressure for that section of the system. All relief valves shall be 3/4-inch minimum pipe size and have an external lifting lever. Set the temperature and pressure relief valve on domestic hot water systems for 125 psig and 210°F.

Because the unregulated capacity of devices manufactured by different companies may vary, do not call out the size of the relief valves on the drawings unless it is known beyond doubt (that is, existing installed equipment or Sandia/NM-furnished equipment).

From the manufacturer's regularly published ratings, report the unregulated capacity for a given device as unregulated capacity. The highest ratings shown in standard capacity tables are usually not unregulated and shall not be treated as such. Where the issue is in doubt, a letter from the manufacturer (not the local agent) is required.

In the case of steam-fired equipment, assume that a tube could break and the control valve could simultaneously deliver unregulated flow. Provide the water side with a relief valve sized to relieve the unregulated capacity of the steam control valve. A relief valve sized only for the capacity of the heat-transfer surface is not acceptable.

8.18.2 Calculations Required

Present relief valve calculations to show the maximum amount of medium in question to be released.

8.18.3 Relief Valves—General

Provide each steam, compressed air, compressed-gas, hot water, or hydraulic system with ASME National Board certified, registered, and stamped relief valves. Pipe the discharge from a steam relief valve to the outside in a manner that will protect passers-by when it discharges. Pipe liquid effluent from other relief valves to the nearest floor drain or floor sink through an air gap two pipe diameters of the supply inlet, but in no case less than 1 inch. Ensure that relief valves are not obstructed or prevented from discharging by other equipment.

8.19 Standby Equipment

Only when indicated in the Design Criteria (which defines design requirements for the specific project), install tower, chilled, and heating water pumps in pairs with suitable valving so one pump can be turned on within minutes while the other pump is taken off-line for repairs.

8.20 Bird Screens

Provide all exterior building mechanical and equipment penetrations with a 1/2-inch-mesh, galvanized bird screen. Provide insect screens to areas that handle food, service equipment, or do not have filters to stop insects. Locate screens so they can be easily changed or cleaned.

8.21 Equipment on Roof

It is preferable to locate air intakes and exhausts on roofs and orient them to minimize adverse wind effects. All outside intakes should be at least 15 feet from flues, sewer vents, and exhausts. Where air intakes or exhausts are located on walls or less than 2 feet above the roof peak, prepare detailed wind-pressure calculations and show the discharge of air at the various wind velocities. Thoroughly detail stacks and vents to show flashing and counter flashing.

If a curb other than those shown on standard detail drawings is used, then curb details shall appear on the architectural sheets. Set up items not suitable for curb mounting at a minimum of 18 inches above the roof surface on an angle-iron stand with steel-pipe legs (per architectural standard drawings) so reroofing can be done under them. Extend the stand's legs to the structural members and flash with flexible pipe boots or single-ply flashings where appropriate.

Provide walkway pads on the roof leading from the access door to mechanical equipment that requires regular service. Whenever mechanical equipment is roof-mounted, call out permanent access ladders leading to the roof, except where security measures dictate otherwise. Locate water-using equipment so

- Over-spray will not be a problem
- Equipment can be readily drained, will not freeze up, and can be easily worked on
- No short-circuiting of air will occur.

Provide at least a 6-foot clearance between roof-mounted equipment and the edge of the roof, or provide suitable pipe-rail guards.

The mechanical designer is responsible for transmitting accurate information concerning size, weight, and dynamic loadings associated with roof-mounted mechanical equipment to the structural designer.

8.22 Instrumentation

Drawings shall indicate self-sealing test plugs, pressure gauges, thermometers, flowmeters, draft gauges, thermometer wells, and other instrumentation so equipment performance can be evaluated without shutting the equipment down or resorting to portable instrumentation when installing necessary instruments. Instruments shall measure temperatures and pressure drops in and out of heat-exchange devices using in-line installed self-sealing test plugs. In addition, install a diaphragm-actuated, dial-type gauge to measure (in inches of water) the drop across all filter banks and fans, with the possible exception of fans in small packaged units. Supply outdoor units with weather shields. Use bimetal dial type thermometers for mounting in thermowells in the piping. Mount remote-bulb thermometers on a centrally located panel together with remote-bulb or sensing controllers. Show instrumentation on the flow schematics and details.

Remote monitoring and alarm instrumentation is done by an FCS. See Chapter 8.23.1, Facilities Control Systems.

8.23 Controls

8.23.1 Facilities Control Systems (FCS)

Sandia/NM uses a Landis & Siemens System 600 FCS with direct digital control, to monitor and control HVAC systems in the buildings. This FCS shall be included in the design of all facilities greater than 10,000 square feet, unless otherwise specified by Sandia/NM. Because of the unique design of this control system, all of the information pertaining to this system is provided below.

Specifications and Design Guidelines

The mechanical engineer issues the control discipline specifications. The following documents should be obtained before starting the control design:

- Project – Specific Design Criteria
- Facilities Construction Standard Specification Section 13943, Facilities Control Systems
- Sandia/NM Standard Drawings: MI5001STD, MI6001STD, MI6002STD

Monitoring

HVAC systems are monitored by a system of digital and analog sensors located throughout equipment rooms and at selected locations in the building. The sensors are connected through a system of conduits and wires to field interface devices (FIDs). Critical alarm conditions are also reported at the existing reader/printer in the Central Steam Plant, which is continuously monitored. These alarm points are selected by Facilities Systems Engineering with input from Facilities Operations and Maintenance.

Control

Control of HVAC systems is by start-stop functions and direct digital control (DDC) generated by the FIDs and host computer, unless the HVAC application (for example, fan coil unit) warrants conventional electronic controllers. Analog output control signals will be programmed into the FIDs and connected to the various damper operators, valve operators, motor starters, etc., by a system of conduit and wires. Drawings shall contain complete sequences of control for each system (cooling, heating, exhaust, domestic hot water, smoke removal, solar, etc.). The relay contacts in the FIDs are rated at 5 amps at 250 VAC. Smoke detectors and freeze-stats should be hard wired to fan motors.

Smoke Removal and Fire Functions

The FCS does not respond to smoke, fire, or sprinkler water flow alarms unless the sequence of operations designates that a unit, such as a supply fan, which is already controlled by the FCS, change its mode of operation. When this is a requirement, provide a contact closure from the Fire Alarm Control Panel (FACP) or Signal Line Circuit (SLC) control module that alerts the FID to the situation. If additional requirements must be met, such as starting smoke removal fans (functions that are not controlled by the FID), then these requirements will have to be accomplished by other control means, such as a relay that operates off an FACP or SLC control module contact.

When packaged air handler units are provided with smoke detectors, the detectors shall meet the requirements of Standard Specification 13852 (Intelligent Fire Alarm Systems)

System Definition and Presentation

The following drawings are required to define and illustrate the monitoring and control systems described above. Sample drawings of each type are available upon request from FCS Office, Mechanical Systems Engineering Department, and may be used to illustrate the desired format, symbols, etc. The samples shall not be considered as standards and reused as such. The only formats that should be regarded as standard are the FID layout drawing and the point numbering scheme, both of which are available from the FCS Office. The mechanical engineer shall develop a full set to be used in construction.

Flow Diagram and Sequence of Operation Sheets

Develop these drawings in two phases. The first submission shall provide the flow diagram of the intended system configuration, the proposed sequence of operation, and the DDC point selection. This set defines the base system for approval. After this basic approach has been accepted, then the monitoring and alarm points will be selected by Facilities Engineering. After the complete point selection is accepted, the remaining FCS drawings will be developed.

Field Interface Devices Layout Sheets

These drawings illustrate the layout and termination of input and output field connections in the FID cabinets. Twenty-five percent capacity of each point type shall be reserved in the panels.

Point List and Definition Sheets: Input/Output (I/O) Summary

These drawings provide a compilation of the total points selected and show point nameplate data, reference drawings, device symbol and number, and device range (established by the designer).

Component Location Plan

These floor plans shall locate all components in a system (for example, FIDs, sensors, actuators for dampers, valves, motor starters, etc.) and the conduit that interconnect the items. A scale of 1/8 inch per foot or smaller is suggested to allow better coordination of the various items in the system. Keep all FID cabinets a minimum of 5 feet (1.5 meters) away from power sources greater than 100 kVA and any Variable Frequency Controllers.

Conduit Schedules

These sheets present the coordination of the wires contained in conduits between sensors and FIDs.

Control Ladder Diagrams

Provide ladder diagrams for each piece of equipment energized/de-energized by the FCS.

Equipment List

These drawings list only the equipment or components peculiar to the control discipline. Identify the items in a similar manner as other items but with a number enclosed in a diamond. Include the full specifications for ordering. Specify sensors that are totally compatible with the Landis and Siemens System and that are field-calibratable. There are, however, many vendor sources to provide competition for bidding. A sample listing of sensors of high reliability and performance, that still ensures competitive selection, can be obtained from the Facilities FCS Department.

The intent of the design procedures just presented is to develop a complete set of contract documents so the contractor will furnish and install sensors, conduit and wire, pneumatic damper and valve operators, and tubing field locations to the FID panels. The contractor installs the FID cabinets and internal components and connects the wiring and pneumatic tubing. Reference Facilities Construction Standard Specification Section 13943, Facilities Control Systems, for the complete set of requirements.

Sandia/NM furnishes the following:

- FID cabinets and all internal components, and instructions on how to terminate the wires and tubing. Plant Control Center personnel install the majority of the internal components
- All required programming and loading at points listed in the I/O summary into the host computer to implement the sequence of operation delineated on the drawings
- Downloading of programs into the FID and assisting the contractor with commissioning of the complete monitoring and controls system for the building.

8.23.2 Pneumatic, Electric, Electronic Controls

The use of pneumatic controls shall be avoided on future projects whenever other types of controls are available to perform satisfactorily and safely.

Thoroughly detail temperature, humidity, pressure change, action, and type of each controller. Where pneumatic systems are used, consider the entire effective range on industrial controllers.

Completely describe the step-by-step sequence of operation for each device in the control system (whether electric, electronic, or pneumatic) on the drawings, rather than in the specifications. Show the pneumatic pressures for both ends of the throttling range that correspond to temperatures on the drawings. In every instance, specify a pressure gauge at each unit of a pneumatic system. No air gauges are required where thermostats are flush-mounted with concealed connecting tubing.

Where FCS does not provide the control function, set up the control system around electronic or direct digital controllers that can be provided by a single supplier, and identify each item of equipment with the current product number. On the mechanical equipment list, show those items with an electrical connection. Provide a device description, range, set point, differential, contact rating, product number, etc., on the equipment list.

Equip pneumatic control systems with an automatic refrigeration air dryer, a compressed air prefilter, and an oil coalescing filter installed in the system's supply line to ensure dry and clean control air. Provide an automatic low-limit bypass to bypass air around the dryer in the event of a freeze-up.

Do not install pneumatic controls outside or in other unheated locations. Use electric actuators wherever control equipment may be exposed to sub-freezing weather.

Designs for building additions should be compatible with the original building system.

Where FCS sensing and control is not utilized, use a combination heating/cooling thermostat in preference to separate heating and cooling thermostats in a given area. Use 7-day programmable auto-changeover thermostats wherever possible.

In addition to detailed wiring diagrams that may appear on the electrical drawings, include a functional diagram on the mechanical drawings for all systems to show the entire sequence and general scheme of operation and all set points. Superimpose the functional diagram on a flow diagram of the heat transfer process.

See Chapter 8.23.1 for Facilities Control Systems requirements. Where FCS does not provide the control function, see Chapter 9.7, Control System Design, for the control drawings required on electrical control systems.

Size control valves with consideration to operate at system pressures and with flow and pressure drop clearly indicated.

Refer to Facilities Construction Standard Specification Section 13943, Facilities Control Systems, for additional information.

8.23.3 Controls for Non-FCS Buildings

Install the following special controls for energy conservation in small-sized buildings (less than 10,000 square feet) that do not merit FCS involvement. If a nearby building has an FCS installed, connect the small size building to the nearby FCS and use the FCS in lieu of the programmable time switch mentioned below.

Equip smaller buildings with a programmable thermostat that provides night temperature setback and disables cooling during unoccupied hours.

Buildings with central systems shall have the following special automatic controls:

A 7-day programmable time switch with a bypass switch to shut down the following:

- Noncritical exhaust system
- Heating water circulating pump and steam coil
- Supply fans
- Return-relief and noncritical exhaust fans
- Building air conditioning equipment, such as chilled water circulating pumps or air conditioning condensers and compressors
- Domestic hot water circulating pumps
- Outside air dampers (close).

Provide the following to protect the building during extreme outside low temperatures:

- Thermostat located in a sensitive place in the building that will restart the following when the interior temperatures drop below 55°F
  - Supply fans, if the building does not have perimeter heating
  - Heating water circulating pump and steam coils.

- Time-delay relay for fast warm-up to turn on the following if the building low-temperature thermostat has not reacted. (Provide a bypass switch around the timer.)
  - Supply fans
  - Heating water circulating pumps, steam coil during winter season, or air conditioner and chilled water pump during summer
  - Bypass the hot water reset control from the normal heating schedule.
- Additional features to reinstate the building to normal operating status at the beginning of the work period per the following:
  - Startup of domestic heating water circulating pump
  - Startup of noncritical exhaust fans
  - Opening of dampers to the normal, mixed, and outside control position
  - Restart of the return-relief fans.

8.24 Vibration Isolation and Alarm

8.24.1 Design Conditions

Select rotating equipment to vibration levels measured in any plane on the bearing cap (in the installed and operating condition) in accordance with Construction Standard Specification 15200, Vibration Limits and Control.

Show large supply fans, compressors, utility exhausters, and other rotating and reciprocating equipment mounted on vibration isolating bases incorporating springs, so 90 percent of the lowest disturbing frequency is isolated from the structure. Indicate in the equipment list the type of isolation that is to be supplied. Add special instructions for the equipment manufacturer to provide a coordinated isolation system.

Isolate mechanical equipment that has extremely high noise or vibration levels, including the distribution piping, on springs to minimize the transmission of vibration or noise into the building components and occupied spaces.

Connect an alarm signal to the FCS at the same location where special vibration switches are installed to shut down equipment.

8.24.2 Calculations Required

Provide written evidence of how isolation was selected for equipment installations that produce vibration or noise in usual ranges. Installation of equipment that produces extremely high levels of noise or vibration requires the following calculations:

- Static deflection
- Fundamental natural frequencies of machine mounting system.

8.24.3 General

Provide raised concrete pads isolated from the building structure with elastomer-bonded glass fiber material under all major items of equipment, pumps, etc. It is the responsibility of the mechanical designer to transmit this information to the structural designer so it can be shown on the structural drawings.

Make the final attachment of ductwork to fans with inorganic flexible connections. Use weatherproof connections when exposed to the weather. Flame-retardant flexible connections are generally recommended. Use noncombustible connections on piping that contains flammables. Use flexible connections to connect building piping to air compressors (see Chapter 8.15, Compressed-Air System Design).

Connect refrigeration piping to compressors with refrigerant pressure-rated flexible metallic sections, oriented parallel to the crank shaft.

Make final connections of fluid piping to pumps, towers, and other vibrating machinery with suitable flexible connections, such as "Resistoflex" bellows. Provide adequate anchoring of piping next to flexible connections.

Use spring-loaded pipe hangers when necessary to prevent vibration and sound transmission.

Add notes to the description in the equipment list to instruct the vendor of noise or vibration-producing equipment in excess of 5 hp. The vendor shall certify that the equipment and its supporting structures have been balanced statically and dynamically and that they are free from natural frequencies within 30 percent of its operating speeds.

Detail mounting frames where required (for example, roofs). Do not indicate overall dimensions. Relate the size to the equipment being supplied to obtain a coordinated system.

8.25 Sound Control

8.25.1 Design Conditions

Unless otherwise noted in the Design Criteria, establish design goals according to good engineering practice and the ASHRAE Guide and Data Book tables of design goals for sound control.

8.25.2 General

Minimize noise transmission throughout the structure. Establish that noise generated from outdoor equipment will not disturb neighbors or indoor occupants.

Select fans, or other equipment that radiate directly into an occupied area, that are quiet enough to meet ASHRAE noise criteria curves for the occupancy. Select diffusers and grilles with sufficiently low velocity to provide a noise level that meets the ASHRAE noise criteria curve for the occupancy.

Design or select sound attenuating devices as required to meet the ASHRAE noise criteria curve for the occupancy.

8.26 Insulation

8.26.1 Calculations Required

Specify insulation for ducts, piping, and heat-producing equipment where economic operating cost savings will offset the cost of the insulation within its life expectancy. Assume that the life expectancy of insulation is not more than 20 years for laboratory and administrative applications. Insulation is usually required when the following conditions occur:

When the heat loss or gain of the ductwork or piping, without insulation, increases the energy requirements of the building.

When condensation can occur on the surface of the ductwork or piping. This is possible when the ambient dew point temperature is lower than the air or fluid temperature in the duct or pipe.

Calculate the insulation thickness necessary to prevent condensation on piping where domestic cold water or chilled water lines with 65°F or cooler water runs through spaces where the pipe temperature could be below the dew-point. Comply with ASHRAE Standard 90.1.

8.26.2 Insulation Materials

Refer to Facilities Construction Standard Specification Sections 15081, Duct Insulation, and 15083, Pipe and Equipment Insulation.

8.26.3 Insulation – General

In no case specify or accept a combustible-type insulator or duct liner.

8.27 Water Treatment

8.27.1 Open Recirculating Systems

All cooling towers and fluid coolers shall have a water treatment system installed. Install Schedule 80 PVC piping such that a sample line is taken from the tower water supply line, to a conductivity controller, and returned to the tower water return line. Provide chemical injection points downstream of the controller. Check valves shall be installed on either side of these chemical injection points on a vertical section of pipe so as to protect the controller and chemical feed tanks from reverse flow conditions. Minimize the use of pure chemical feed lines, when feasible to do so. The controllers, sensors and injection pumps shall be Sandia/NM furnished and contractor installed. Each system shall have:

- Sized make-up and bleed lines and valves
- Flow meters installed on both the makeup and bleed lines. These shall be pulsing-type flow meters, with an acceptable operating range. Where possible, the flow meters will be tied into the FCS.
- Conductivity controller(s) and associated flow switch(es) installed, but not calibrated.

- Provisions for the injection of biocide and scale/corrosion inhibitor chemicals downstream of controller by providing tie-ins for future installation of chemical feed lines (typically 3/8" or ½" lines).
- Sufficient footprint and wall space for tanks, flow meters, controller(s), and sample line.
- Sample line at controller.

Contact Sandia/NM systems engineer responsible for water treatment for further details of open, recirculating water treatment systems.

8.27.2 Chilled and Hot Water Closed Loops

Make provisions for the periodic injection of corrosion-inhibiting and biocide chemicals on closed loop systems. Install chemical pot feeder with sufficient clearance to pour in 5-gallon drum of chemical. Standard chemical pot feeder shall be stainless steel with a 0.5-micron polypropylene bag filter, operating pressure up to 150 psig, operating temperature up to 200°F, 40-gpm maximum flow and 3-psi pressure drop. Feeder shall be piped to the nearest floor drain. Consult Sandia/NM Standard Drawing MP5013STD, "By-Pass Feeder," and the Sandia/NM Systems Engineer responsible for water treatment for further details of closed loop water treatment systems.

8.28 Painting and Pipe Identification

8.28.1 General

Where practical, specify a factory finish for all mechanical equipment. Paint all other mechanical items except in the equipment rooms. See Facilities Construction Standard Specification Section 09900, Painting.

After painting is complete, thoroughly identify all piping with appropriate Brady self-adhesive labels. Ensure that the mechanical contractor understands that he or she is responsible for the accuracy of labeling and the direction of flow.

8.28.2 Underground Utilities

Mark the location of all underground utilities with a continuous identifying tape buried in the pipe trench above the pipe. Refer to Facilities Construction Standard Specification Section 02200, Earthwork. In addition, mount utility marker posts with painted descriptive titles over underground utility lines in remote areas.

For utilities installed in remote locations, specify underground utility markers per Standard Drawing WU5006STD, Utility Markers for Buried Pipe and Cable.

8.29 Test and Balance

The mechanical designer is responsible for determining the extent of Test and Balance that is necessary to prove that systems and equipment are operating as intended. Normally the Test and Balance service is provided by a Test and Balance agency hired by Sandia/NM and working jointly with the construction contractor as specified in Construction Standard Specification 15901 – System Component Checkout and

Balance. The designer is responsible for reviewing the final report to determine if the design intent will be achieved and for providing options on how to correct deficiencies.

- End of Chapter -