

SECTION 15050

COMMON WORK RESULTS FOR HVAC

PART 1 –GENERAL

1.1 INTRODUCTION

A. This section is an introduction to the mechanical division of the Stanford School of Medicine Facilities Design Guidelines. The purpose of this section is to provide direction to the Design Consultant and Contractor for use in the design, specification, documentation, and construction of mechanical systems/equipment for the Stanford University, School of Medicine construction projects. This section includes, but is not limited to:

- 1. Sustainability
- 2. Mechanical System Types and Applications
- 3. Design Criteria
- 4. Design Considerations
- 5. Documentation Requirements

1.2 REFERENCES

A. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):

- 1. ASHRAE Fundamentals: Heating and Cooling Load Calculation Methods
- 2. Standard 55 Thermal Environmental Conditions for Human Occupancy
- 3. Standard 62.1 Ventilation for Acceptable Indoor Air Quality
- 4. Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings

B. American Society of Mechanical Engineers (ASME)

C. American Society for Testing and Materials (ASTM)

D. California Energy Commission (C.E.C.) Title 24

E. Sheet Metal and Air Conditioning Contractor's National Association (SMACNA)

F. Stanford Guidelines For Life Cycle Cost Analysis

G. Stanford Guidelines for Sustainable Buildings

1.3 SUSTAINABILITY

A. For a complete summary of Stanford’s vision refer to the Stanford University Guidelines for Sustainable Buildings.

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## B. Mechanical Systems

1. Systems shall be selected with energy and water conservation as primary goals. The Designer must think long term with respect to life cycle energy and water costs, durability, and maintainability when making key decisions. All such options will be presented to Stanford with supporting calculations and documentation of recommendations.

## C. Energy

1. Reduce the loads: Work with the architect in designing a high performance envelope with appropriate insulation, glass characteristics, and shading. Challenge plug and lighting loads and consider diversity.
2. Passive systems: Attempt to meet loads with passive design such as natural ventilation.
3. Active systems: Design high performance, low energy mechanical systems that meet the building program while reducing energy consumption as much as possible.
4. Energy Recovery: Consider a heat recovery system from exhaust air streams, particularly on 100% outside air systems. Utilize air and water side economizers as appropriate.
5. Self Generation: Work with other consultants to integrate onsite power generation, if applicable.

## D. Water

1. Conserve potable water by utilizing reclaimed water for process cooling needs such as cooling towers. Carefully weigh energy and water consumption of different technologies to find the best holistic solution.

## E. Other Issues

1. Refrigerant: do not use CFC based refrigerants. Select refrigerants with low ozone depletion and global warming potentials.
2. Outdoor Air: ensure adequate ventilation is supplied for all occupied hours. Consider outdoor air delivery monitoring and/or demand controlled ventilation. Consider increasing minimum outdoor air flow rates above the Standard. Utilize distribution systems with high ventilation effectiveness ( $\geq 1$ ).
3. Filtration: Design and install at least MERV-13 final filters to encourage improved indoor air quality.
4. Commissioning: provide fundamental and enhanced commissioning services to ensure systems are operating as intended.
5. Measurement and Verification: coordinate with other consultants to provide an M&V system via the building controls system to monitor energy and water by end use.

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1.4 SYSTEM TYPES AND APPLICATIONS

A. Variable Air Volume (VAV) Systems:

1. VAV is an all air system with air supplied at a constant temperature with modulation of supply volumes to match the room sensible load. VAV is primarily to provide cooling and requires supplementary systems for heating, typically perimeter finned-tube convectors or terminal re-heat.
  - a. VAV is the most common office distribution system and should serve as a baseline for system comparisons.
2. VAV fan system control shall be through the use of variable frequency drive fan motor control unless accepted by the University's Project Manager.
3. Fans, variable frequency motor drive units, and controls generally shall be selected to yield a minimum air flow system turndown ratio of 3:1.
4. VAV Supply fan delivery shall be controlled based on the supply duct static pressure control set point.
5. VAV Return/Relief fan shall be controlled by air flow measuring stations in the supply and return streams.
6. All VAV zones serving office space shall be provided with reheat capability if the minimum air flow delivery to that space requires such for comfort. Zoning shall be performed such that habitable spaces with differing exposures or loads are in independent zones.
7. Maximum number of Office per VAV Box Zone: 3 – 4
8. Provide RE-HEAT Coils on all Perimeter (Envelope) Zones and All Zones serving Top Floor and Bottom Floor

B. Natural Ventilation and Mixed Mode

1. Natural Ventilation shall be defined as ventilation provided by thermal, wind, or diffusion effects through doors, windows, or other intentional openings in the building (ASHRAE Standard 62.1).
  - a. “Naturally ventilated spaces” shall be permanently open to and within 25 ft. of operable wall or roof openings to the outdoors, the openable area of which is a minimum of 4% of the net occupiable floor area (ASHRAE Standard 62.1). Also building/mechanical codes apply to natural ventilation systems.
  - b. “Naturally conditioned spaces” are those spaces where the thermal conditions of the space are regulated primarily by the occupants through opening and closing of windows (ASHRAE Standard 55).
  - c. The ASHRAE Adaptive Comfort Model shall apply when users have access to a manually operable window as defined above.
2. Mixed Mode shall be defined as a hybrid approach to space conditioning that uses a combination of natural ventilation from operable windows (either manually or automatically controlled) and mechanical systems that include air-distribution

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equipment and refrigeration equipment for cooling (Center for the Built Environment, UC-Berkeley). Mixed mode systems are further broken down by type, including:

- a. Concurrent (same space, same time), a mechanical system is designed and installed for the full building load, while operable windows are also provided as an amenity.
- b. Changeover (same space, different times), a space has the ability to switch between natural and mechanical ventilation systems based on variables such as outdoor air temperature, wind speed, etc.
- c. Zoned (different spaces, same time), some spaces are always naturally ventilated, such as north facing offices, while others are always mechanically conditioned, such as internal classrooms.

C. Floor Level Supply Systems

1. Underfloor Air Distribution (UFAD)

- a. UFAD is a system where conditioned air is supplied to the space by the pressurization of a raised floor and swirl type diffusers that mix the room air in the occupied zone. Beyond the occupied zone air temperatures stratify.
- b. UFAD systems are common in office spaces because they are easily re-configurable when office furniture and partitions are remodeled.

2. Displacement Ventilation (DV)

- a. DV is a system where conditioned air is supplied at lower velocities to form a puddle or cold air along the floor. This can be achieved via a raised floor or wall supply and displacement type diffusers. Cold air pools along the floor until it reaches a space load, where the air heats up and rises. Thus the temperature of the entire volume of air in the space is stratified.
- b. Displacement systems are applicable in classrooms and offices. There is however a limitation to wall type supply systems in the distance from the wall to the furthest occupant.

D. Chilled Ceilings/Beams

- 1. Chilled ceiling and beam systems use water as their cooling medium, so these systems will typically use less distribution energy than ‘all-air’ systems. Room air movement is uncontrolled and will depend on the heat sources in the room at any time. Location of chilled ceilings/beams will determine areas of downdraughts. These systems will occupy a large proportion of the ceiling area and therefore integration with other services and architectural details requires more planning than with conventional cooling terminals. Consideration is required of likely spatial layout changes with regards to the zoning of chilled water feeds and provision for changing control zones. In order to avoid condensation the chilled water supply temperature (i.e. cooled surface temperature) must be maintained above the space dew point temperature.

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- 2. Chilled Ceilings
  - a. Chilled ceilings are static cooling devices which cool by natural convection and radiation in roughly equal proportions. Chilled water at elevated temperature (to avoid condensation) is fed to panels arranged in parallel to reduce pressure drop and excessive temperature rise. Chilled ceilings can provide an energy efficient solution as the prime mover is water not air but output is limited. Chilled ceilings can be used where ceiling void space is limited although ductwork for minimum outside air (for ventilation & dehumidification) will often dictate space requirements.
- 3. Chilled Beams
  - a. Chilled beams consist of water cooled finned tube convectors which make use of natural and/or induced convection to provide sensible cooling. Chilled beams have a higher convective cooling component than chilled ceilings and can provide for higher cooling loads. Chilled beams can be active or passive.
  - b. Active Beams
    - 1) Active beams sensibly cool and incorporate a primary air supply to induce high rates of convection and generally provide higher cooling output than passive beams. To obtain this cooling duty, higher primary air flow rates are required as well as higher pressure. An active beam cools mainly by convection and as a consequence is able to deal with larger room sensible loads than the chilled ceiling or a passive beam. Utilizing a 4 pipe arrangement active beams can also provide heating to the space.
  - c. Passive Beams
    - 1) Passive beams provide sensible cooling to spaces. An air supply for fresh air and dehumidification is required. The beam can be located in buildings with low floor to ceiling heights and surface mounted on the soffit without the need of a false ceiling. Be aware of possible draught conditions in this situation - active beams may be preferable. Passive beams sensibly cool using natural convection. Typically cooling output is 80% convective and 20% radiant if exposed to the room but depends on beam configuration. This may interfere with a true displacement flow in the space. The passive beam will have a quiet operation. Passive beams are not intended for heating, so a supplementary system is needed either via the air system or using perimeter finned-tube convectors.
- 4. Chilled ceilings/beams are applicable in offices with high loads (south or west facing), labs, and potentially classrooms (depending on ventilation requirements).

E. Radiant Floors

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1. Radiant floors consist of plastic tubing (typically PEX) installed in loops in the concrete floor. The floor can be the structural slab or a shallow topping slab depending on the coordination and building specifics. Loop spacing depends on the load density and loops are connected to a piped water supply distribution via manifolds. Radiant floors can provide heating and cooling and are a tested and established system for providing efficient conditioning. Similar condensation restrictions apply to floors as to chilled ceilings/beams. Ventilation air must be provided either by natural or mechanical means.
2. Radiant floors are applicable in large, tall height spaces such as building lobbies and in spaces where no floor covering such as carpet is acceptable.

#### F. Variable Refrigerant Volume (VRV)

1. Variable refrigerant volume (VRV) systems, also known as variable refrigerant flow (VRF) systems, are essentially a multi-split DX system in which a number of indoor units are connected to a single outdoor unit. The amount of refrigerant circulated is varied to match the load by one or more variable speed compressors to improve energy efficiency. VRV systems were introduced in the 1980's with a single refrigeration circuit containing an inverter speed controlled scroll type hermetic compressor. Since then they have been gaining in popularity because of their claimed performance, modularity and perceived relative cheapness. Further developments include heat recovery, more efficient compressors and fans and network control options. Good pipework system design and installation is crucial for effective and reliable performance so selection of a specialist contractor with a good track record is important.
2. VRV systems are applicable for small low-rise buildings where chilled and heating hot water connections are not anticipated.

#### G. System Selection Criteria:

1. Acceptable System Types: The types of HVAC systems acceptable for new and existing University facilities are as identified herein. For specific cases not covered, only proven technology shall be acceptable.
2. Functional Attributes: Beyond the normal requirements of meeting program needs, the following functional attributes shall be given special design consideration.
  - a. Energy efficiency.
  - b. Simplicity of control.
  - c. Maintainability: accessibility, ease of operation, simple maintenance, and minimal maintenance frequency.
3. Life Cycle Cost Analysis: Life cycle cost analysis shall govern the selection of systems and equipment. Internal Rate of Return (IRR) is the accepted method of

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analysis, using parameters and calculation procedures provided by the University.  
Refer to Stanford’s Guidelines for Life Cycle Cost Analysis.

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1.5 DESIGN CRITERIA

A. Definitions:

- 1. Heating, Ventilating, and Air Conditioning (HVAC) systems shall be defined herein as mechanical systems designed to control building space temperature, humidity, air cleanliness, and air movement within and between individual spaces.

B. Weather Data

- 1. General: The University's micro climate differs somewhat from the climates at the nearest weather stations located at Moffet Field and the Palo Alto Airport. Until more accurate design data is available, the weather data provided below shall suffice.
- 2. Design Temperatures: Summer: 86°F dry bulb, 66°F wet bulb  
Winter: 34°F dry bulb, 30°F wet bulb
- 3. Precipitation, Barometric Pressure, and Prevailing Winds: Weather data from Moffet Field and Palo Alto Airport is acceptable.
- 4. Solar Radiation: ASHRAE insulation values are acceptable. Weather data in Energy Plus, TMY, TMY2, or TMY3 format is also acceptable for hourly calculations.

C. Control of Building Environment:

- 1. Indoor Temperatures:
  - a. Summer: 76 +/- 2°F
  - b. Winter: 70 +/- 2°F
  - c. Night setback: 55°F
- 2. Indoor Humidity: In general, indoor relative humidity shall not be controlled, except in computer rooms, libraries, or special labs, for which the environmental design criteria shall be as specified in the building program.

D. Outside Air Quantities and Recirculation:

- 1. Current issues of Building Codes, ASHRAE Fundamentals, and ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality, shall apply. However, since outside air infiltration rates are minimized in present energy-efficient designs, the above shall be considered minimum requirements only.
- 2. An outside air economizer system shall be designed per the requirements of C.E.C. Title-24.
- 3. Freeze Protection:
  - a. All HVAC systems shall be provided with preheat coils upstream of cooling coils.
  - b. The preheat coil shall be designed to maintain 55°F minimum discharge temperature.

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- c. Campus EMCS connection shall include a low temperature set point for the preheat coil discharge temperature. Alarm temperature shall be 43°F.
- E. Labs, Animal Rooms, and Other Special Facilities: Recirculation of building ventilation air from animal rooms or other facilities containing potential airborne contaminants shall not be permitted.
- F. Prevention of Exhaust Air Recirculation:
  - 1. The location of fresh air intakes shall be chosen to avoid drawing in hazardous chemicals or products of combustion either from the building itself, loading docks, or from other structures and devices. This may require building wind tunnel analysis, numerical modeling, and/or area-wide wind flow studies.
  - 2. Exhaust stack height and exhaust air exit velocities shall be selected to ensure that exhaust air is safely discharged vertically beyond the building's atmospheric boundary layer. Minimum exhaust stack height shall be seven (7) feet above roof, or in accordance with the latest Cal-OSHA requirements. Prevention of re-entrainment of hazardous fumes may require higher stacks.
- G. Air Distribution in Occupied Space:
  - 1. ASHRAE recommendations for air velocities in occupied space shall apply. In spaces with high ceilings, "stratified" design shall be considered as a means to condition occupied space only.
  - 2. The HVAC Design Engineer shall work closely with the Architect in selecting locations for air inlets and outlets. The School of Medicine's Project Manager shall be consulted to ensure that the air distribution design does not conflict with building program requirements.
- H. Air Filtration:
  - 1. Air filtration systems shall be designed such that filters have the capacity to last several years before they must be changed. Bag filters with ninety percent (90%) ASHRAE test dust holding capacity are acceptable for most standard applications.
  - 2. Each filter bank shall be equipped with a Magnehelic or similar gauge that indicates static pressure drop across the filters. The design change-out pressure drop, in inches water gauge, shall be indicated on the gauge.
  - 3. Prefilters shall be included during the construction phase and shall be considered for permanent installation where necessary.
  - 4. Built-up filter frames shall be designed to accommodate most filter manufacturers currently competing in the market.
  - 5. Air filtration systems for clean rooms and special clean areas shall be designed for ease of filter maintenance and minimum interruption of operation.

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I. Acoustics:

- 1. Special acoustical requirements shall be specified on a project-by-project basis.
- 2. Acoustic analysis of air distribution systems shall be included in the calculations submitted at the 100% Design Development phase of the University Plans Review Process.

J. Vibration Isolation:

- 1. All rotating or reciprocating equipment (e.g., fans, motors, compressors, etc.) shall be furnished with vibration isolation as dictated by program requirements.
- 2. All vibration isolation equipment shall be designed for seismic resistance in accordance with SMACNA Guidelines for Seismic Restraint of Mechanical Systems and Plumbing and Piping Systems.
- 3. Ductwork, piping, electrical conduit, etc. shall be suspended with vibration isolating hangers if required to control vibration in adjacent spaces as determined by program requirements.

K. Zoning:

- 1. Building zoning for temperature control shall be ascertained at the Preliminary Design Development phase of the University Plans Review Process.
- 2. The HVAC Design Engineer shall work closely with the Architect, especially early in the design process, to design for sufficient exterior shading, landscaping, orientation, etc. to provide the most effective, energy-efficient overall building environmental control system.

L. Piping:

- 1. Critical research is conducted in many University facilities around the clock, throughout the year, such that interruption of HVAC system operation is extremely undesirable. Hence, piping systems shall be sectionalized such that scheduled or nonscheduled shutdown will affect only a portion of the building (e.g., minimum of four (4) quadrants if designed for greater than eight (8) zones).
- 2. Location of valves in mechanical rooms and other spaces shall be selected for accessibility.
- 3. Freeze protection shall be included for all piping exposed to freezing environment.

M. Ventilation

- 1. Ventilation refers to air movement in a building space that frees the space from stale, stagnant air and provides a sense of cooling in warm weather.
- 2. When natural ventilation is used for cooling effect, in lieu of electric fans, it is generally assumed that the interior space will be maintained at a temperature no more than 10°F above ambient. ASHRAE Adaptive Comfort Model applies.
- 3. Ventilated spaces shall be provided with winter heating utilizing hot water finned-tube convectors, usually along the building perimeter.

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N. Air Handling Systems

- 1. Fan Sizing:
  - a. In general, larger fan sizes that allow lower operating speeds are preferred.
  - b. Fans and drive motors shall be sized such that one-hundred percent (100%) design air quantities for a given system are delivered when air handling equipment is operating at no more than eighty percent (80%) of the maximum available design static pressure or design CFM output, whichever is less. This sizing method is intended to allow for future expansion of system capacity.
  - c. For fans rated five (5) HP. or greater, maximum fan wheel speed shall be 1800 RPM, unless otherwise directed by the University's Project Engineer.
- 2. Motors:
  - a. For retrofit projects, special attention shall be given to motor selection and electrical system characteristics since voltage may change dramatically from building to building.
  - b. Motor sizing shall be based on the minimum appropriate size for equipment operation, based on maximum program requirements, except motors for air handling units as described herein. Minimum service factor shall be 1.15.
  - c. Energy-efficient motors shall be selected for all air handling applications.

O. Steam and Chilled Water Systems: The Cardinal Cogeneration Facility (COGEN) provides steam and chilled water for most campus buildings via an extensive underground distribution system.

- 1. Chilled Water:
  - a. The building chilled water system shall be a variable-flow system utilizing only 2-way valves at the distribution loop/building system interface and at cooling coils. Building control valve shut-off pressure shall be 1-1/2 times the building differential pressure or fifty (50) PSI, whichever is less. The chilled water main control valve shut-off differential pressure shall be minimum fifty (50) PSI. The University will provide differential pressure design values for specific buildings.
  - b. System data:
    - 1) Supply temperature 44oF
    - 2) Return temperature 60oF minimum
    - 3) The consultant shall determine the pressure design criteria through consultation with the University's Project Engineer.
- 2. Steam Distribution System:
  - a. Steam is the primary heat source for a variety of heating functions throughout the University. Saturated steam is generated at the Central Energy Facility and distributed via a loop piping system designed to produce steam at 125 psig, however the supply pressure varies throughout

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the Campus, therefore consult the University’s Project Engineer for each specific situation. The steam distribution system serves all sections of the Campus as well as the Hospital and Hoover Pavilion. Verify particular building steam supply pressure through consultation with the University Project Engineer.

- b. Condensate return system is designed to operate with 180oF condensate at 20 PSIG. Verify particular building requirements with the University Project Engineer.

3. Steam System Design:

- a. The design criteria shall specify the minimum size for steam system equipment, in order to provide the most efficient, economical and trouble-free building.
- b. The pressure reduction station (PRV) total capacity shall be determined based on the building design heat loss data and internal heat loads. The design basis (for heating) should be to provide one-hundred percent (100%) of the steam required to heat the building in two (2) hours from the night setback temperature (55°F) to the occupied design indoor temperature (68oF) with minimum outside air temperature (39°F). Do not use PRV's larger than two inch (2") in any case. If greater capacity is required, use several small PRV's in parallel. Reserve steam capacity is not required, due to the conservative nature of the building steam load design.
- c. The condensate return pump capacity shall be sized to handle the total steam load specified for the pressure reduction station sizing above.

1.6 GENERAL DESIGN CONSIDERATIONS

A. Energy Efficiency

- 1. Energy efficiency shall be a prime consideration in the design of mechanical systems. This concern shall be addressed in the selection of pumps, motors, etc., as well as in the selection of materials for and the sizing of piping and ducts.

B. Life Cycle Cost Analysis

- 1. Life cycle cost analysis shall be used to evaluate alternative systems and equipment (refer to Stanford “Guidelines for Life Cycle Cost Analysis”).

C. Access

- 1. Design of mechanical systems and components shall allow ready access to all equipment and provide for safe conditions for maintenance personnel to work.
- 2. Access for repair and replacement shall be provided for all dampers, valves, coils, VAV boxes, motors, fans, controls, etc.

D. Acoustics

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1. Mechanical design shall include special attention to potential acoustical problems.
2. Requirements of structural and mechanical design proposals must be coordinated for satisfactory acoustical performance.

#### E. Installation, Maintenance, and Future Modifications

1. Shut-off valves on all plumbing and mechanical lines and equipment shall be provided as needed to isolate various building areas for maintenance or remodeling activity without interfering with occupancy in other areas. This requirement is equally applicable to mechanical design as well as construction and installation.
2. The Consultant shall describe the design intent of and underlying assumptions related to the building systems and necessary to facilitate both installation and maintenance of mechanical systems.
3. Where piping runs under landscaped areas, special pavement, or other areas where maintenance and surface restoration would be difficult or expensive, the selection of piping materials and fitting types shall be made primarily on the basis of long life and reliability.

#### F. Design Calculation Procedures:

1. Calculations shall be based on methods and data from the most recent issue of the ASHRAE Fundamentals. Computer analysis, using programs approved by the University Project Engineer, is recommended.
2. Alternative methods of analysis, including computer analysis, shall be used only with the approval of the University's Project Engineer.

#### G. Coordination of Various Disciplines:

1. Design and installation of HVAC systems requires close coordination with all other disciplines. Designers and draftsmen shall consider coordinating the orientation and scale of all floor plans and critical elevations and sections to allow plan checks to be accomplished by the overlay method.
2. The Architect/Project Coordinator shall be responsible for allocating building space for the various disciplines to minimize conflicts between trades during construction.
3. Special attention shall be given early in the design process to provide for sufficient access space for maintenance of mechanical systems. The University shall not accept designs unless the drawings clearly indicate locations of ceiling and wall access panels and other necessary access space.
4. The Mechanical Design Consultant shall be responsible for the interface between the HVAC system design and all other design disciplines, in coordination with the Architect/Project Coordinator.

#### H. Offices

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1. The options for air conditioning office spaces are numerous. A single-duct variable air volume (VAV) with hot water reheat at the zone boxes is the baseline. Alternate systems such as chilled beams, radiant floors, underfloor air distribution, and natural ventilation, among others, shall be evaluated based on life cycle cost analysis. Refer to System Types and Applications above.
2. All air systems shall be provided with full economizer capabilities; i.e., when outside air temperature is appropriate it shall be used to provide the cooling for the building.
3. Operable windows should be considered for reduction in energy use during mild weather conditions.

#### I. Classrooms

1. Provide individual ventilation and temperature control for each room, where feasible.
2. Provide minimum of four (4) air changes per hour for general academic classrooms and seminar rooms.
3. Ensure that background noise level is less than NC 30, for television classrooms.

#### J. Laboratory Ventilation

1. Methods of providing emergency ventilation shall be considered, such as variable-speed fan systems, standby local exhaust systems, etc., to protect occupants against major chemical spills or similar hazards.
2. To maintain safe conditions in the lab in the event of fan system failure or maintenance shutdown, redundant supply and exhaust fan systems shall be considered for labs equipped with fume hoods or other critical exhaust systems. The fan systems may be scheduled for equal run times to facilitate reduced maintenance. A fifty percent (50%) redundant system, in which each fan is selected for fifty percent (50%) of the total load, may be considered where the project budget limits the feasibility of a one-hundred percent (100%) redundant system; however, the design of a fifty percent (50%) redundant system requires special attention to maintain the system in correct air balance.
3. Laboratory modules in which hazardous chemicals are being used shall be maintained at an air pressure that is negative to the corridors or adjacent non laboratory areas. An exception to this requirement is where operations, such as those requiring clean rooms, preclude a negative pressure relative to surrounding areas; in this case, special precautions shall be taken to prevent air leaks to the surrounding space. In labs where pressurization failure would create hazardous conditions, differential pressure alarms shall be provided.
4. Care shall be exercised in the selection and placement of air supply diffusion devices to avoid air currents that would adversely affect the performance of laboratory hoods, exhaust systems, and fire detection or extinguishing systems.
5. Unless otherwise specified, room ambient air velocity shall be no more than thirty-five (35) FPM at work stations and near fume hoods.

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6. Airflow within a lab module shall be from clean, non-hood areas toward fume hoods.
7. Laboratories using hazardous material will be equipped with proper fume extraction equipment design for the materials used. i.e. fumehood, gas cabinets, etc. The make-up air to the laboratory will be design to meet the following criteria:
  - a. Occupancy requirements @ 20 CFM / person
  - b. Required make-up air for fume exhaust equipment
  - c. Required air for heat load.\* If the heat load exceeds fume exhaust requirement and the make-up air is common to more than one lab the addition air required will be 100% fresh outside air only. If the make-up air is dedicated to the single lab, the heat can be dissipated by recirculation within the space only.
  - d. Some operations or research, such as plating facilities will required additional outside air to maintain a safe working environment. The amount of outside air will be designed based on the calculated air borne contaminate and the required fresh air to keep the working environment safe.
8. Special facilities ventilation: Some facilities will require outside air to be use for hazardous material treatment for dilution. I.e. gas storage bunkers. Where possible the outside air will not be environmentally treated for temperature. However, the air will be filtered to prevent dust contamination of the equipment inside.
9. Laboratories using hazardous materials shall be provided with twelve (12) air changes per hour minimum. Specific air change rates (and the potential application of VAV laboratory systems) for various types of laboratories shall be discussed with the University's Project Engineer on a project-by-project basis.
10. Controls and dampers, where required for balancing or control of the exhaust system, shall be of a type that, in event of failure, will fail open to assure continuous draft.
11. If energy recovery devices are used, they shall not re-circulate laboratory exhaust air or otherwise compromise the safety of the building occupants.
12. Air containing hazardous chemicals shall be discharged through duct systems maintained at a negative pressure relative to the pressure of normally occupied areas of the building.
13. Air exhausted from laboratory modules shall not pass unducted through other areas.
14. Special local exhaust systems, such as snorkels or "elephant trunks," shall have sufficient capture velocities to entrain the hazardous chemicals being released.
15. Appropriate space shall be provided for future addition of central exhaust scrubbing equipment if not included in the initial construction.
16. Laboratory exhaust fans shall be centrifugal type, single-inlet, with belts, sheaves, bearings, and other serviceable parts externally mounted to provide maintenance access without coming into contact with surfaces exposed to the exhaust stream. Laboratory exhaust fans shall be minimum Class II construction. Extended-life

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bearings and internal surface coatings shall be considered on a project-by-project basis.

K. Fume Hoods:

1. Early in the design process, the Mechanical Design Consultant responsible for the fume hood exhaust system shall obtain a list of the chemicals used and stored in the lab. This list shall be used to analyze fume hood exhaust for flammability, toxicity, corrosiveness, and explosion hazard. In selecting and analyzing fume hazard control techniques, the Mechanical Design Consultant shall work closely with the School of Medicine Project Manager, University Project Engineer and University Environmental Health and Safety personnel.
  - a. Toxic vapor hazards shall be controlled such that no persons will be exposed to concentrations at or above Permissible Exposure Limits (PELs) for each toxic chemical.
  - b. Where fume hood exhaust contains flammable vapors, codes may require installation of automatic fire extinguishing systems in exhaust ducts. However, this requirement shall be carefully addressed on a case-by-case basis, since it may result in a variety of other potential hazards associated with fume hood operation.
2. Air distribution around fume hoods shall be such that cross drafts at the hood face are avoided, thereby minimizing the occurrence of back drafts that spill vapors into the hood operator's breathing space.
3. The following air velocity shall be obtained at each fume hood face via hood suction only:
  - a. 100 feet per minute (+/- 10 FPM) with minimum vertical sash opening of fifteen inches (15"). The minimum value at any single point shall be 70 FPM.
4. All fume hoods shall be equipped with a local audible and visual alarm system that is activated by a differential pressure type switch when the hood exhaust flow deviates from specified safe ranges.
5. Fume hoods shall be located away from doors, operable windows, and major traffic corridors to avoid cross drafts at the hood face.
6. Fume hoods shall not be located next to doorways that are primary means of egress.
7. Fume hoods shall be equipped with a means of padlocking in place the sliding sash at fully closed, at three inches (3") open, and at the six inch (6") open position.

L. Exhaust Stack Design:

1. Exhaust stack design involves a complex web of risk management, engineering, and architectural design decisions that must be made despite uncertain and limited information. For this reason, it is important that exhaust stack design issues be

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- considered by the design consultants and appropriate University representatives during siting and schematic design as well as later phases of building design.
2. The determination of acceptable dilution ratios between the exhaust stack discharge point and building air intakes, courtyards, patios, etc., is a risk management exercise that involves the following issues:
    - a. Determination of probable stack discharge concentrations of known chemicals, considering probable process release rates, exhaust system flow rates, and any removal process efficiencies.
    - b. Determination of plausible worst-case failure release modes and assessment of the effect engineering controls will have on stack discharge concentrations.
    - c. Determination of occupational exposure standards for known chemicals. Note: occupational exposure standards are not necessarily acceptable for application to the general population, but merely provide limits that must not be exceeded. Additional safety factors must be included in accordance with direction from the University's Environmental Health and Safety Department.
    - d. Assessment of the risks of the release of unknown agents of unknown toxicity, in accordance with direction from the University's Environmental Health and Safety Department.
    - e. Assessment of the failure risks of proposed engineering controls.
    - f. Assessment of the overall uncertainty of the risk assessment process.
  3. Given the uncertainty involved in determining acceptable dilution ratios for research laboratory exhaust emissions, the general design approach for exhaust stack design shall be to optimize dispersion by discharging the stack emissions vertically at high velocity above the local turbulent boundary layer created by the building and surrounding structures. Physical stack height may not necessarily be required to extend above this boundary layer if the vertical momentum plume rise is sufficient to penetrate the boundary layer and provide acceptable dispersion.
  4. Boundary layer wind tunnel modeling provides the only reliable method for accurately predicting exhaust plume dispersion in the near field of a complex topography such as the Stanford campus. For buildings that will contain highly toxic gases, wind tunnel tracer gas dispersion studies shall be performed during schematic design unless specifically exempted. For buildings that present lesser degrees of emission hazards, wind tunnel flow visualization studies may provide guidance during schematic design for the location and height of exhaust stacks. Numerical dispersion calculations may be employed only under the direction of the Project Engineer if the specific conditions of the project design reasonably match the assumptions of the numerical model.
  5. The location of exhaust stacks must respond to the technical parameters and constraints of the building; the locations of all nearby air intakes, courtyards, and patios; the aesthetic context of the building and site; and the massing of the building and surrounding structures with respect to wind flow. Generally, optimal dispersion results are achieved by placing the stacks near the center of the building

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- massing (plan view) and at or near the highest part of the building, with the stack extending above the highest part of the building.
- For any given discharge velocity, larger diameter stacks exhibit better plume rise performance than those with smaller diameters, hence high-volume exhaust systems tend to exhibit superior boundary layer penetration. Smaller diameter stacks may be grouped in a tight cluster to increase effective stack diameter, thereby increasing plume rise performance.
  - Exhaust discharge velocity shall be between 3000 and 4000 FPM in the vertical direction, with a nominal design goal of 3500 FPM.
  - All exhaust stacks should provide at least five (5) duct diameters of straight run immediately prior to discharge.
  - Care should be taken in designing shrouds used for visual treatment of groups of stacks, because shrouds can create plume down wash problems. Rounded forms tend to exhibit more favorable wind flow characteristics than rectangular forms. Unshrouded stack designs usually exhibit superior performance.
  - The structural support for exhaust stacks shall allow for future stack height additions of at least twenty feet (20').

M. Building Air Intakes:

- It is generally desirable to maximize the horizontal and vertical distances from stack discharge points to air intakes. Acceptable intake locations typically are found on the lower two-thirds of the sides of buildings. Intakes should be located in regions where winds provide ample flushing with uncontaminated air. Air intakes shall not be located on the roof. Wind tunnel modeling should be considered to determine the best intake locations for each building.
- Care should be taken in designing ground-level intakes to avoid contamination from vehicle exhaust, nearby building exhaust, vegetation/mowing (pollen), and other regional sources. One common problem with ground-level or basement air intakes is contamination from heavy pollutants that are transported along the ground and pulled into the air intakes.
- Consideration should be given to providing more than one intake location or increasing the length of the intake, such that contamination in one area of the intakes can be mitigated somewhat by dilution with cleaner air from another intake area.
- Adequate space for special filtration systems should be considered in the design of air intake systems.

N. Animal Holding Rooms

- Design cooling load calculations to be based on animal heat load, and desired space temperature to be determined during design.
- Humidity control is not required, unless specified by the Project Engineer.
- Air supply shall be one-hundred percent (100%) outside air, with fifteen air changes per hour (15 ACH), and the room air pressure negative relative to the corridor.

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4. It is suggested that various supply air register configurations be tested in a full-scale mock-up to ensure that the configuration selected produces the most uniform air circulation in the room. Alternatively, the design may be very similar to an existing room which has air circulation judged to be satisfactory by the Project Engineer.

## 1.7 QUALITY ASSURANCE

- A. Designer Qualifications: All design work shall be signed and stamped by a mechanical engineer licensed in the State of California. Requests for exceptions to this requirement shall be evaluated by the School of Medicine Project Manager.

## 1.8 DESIGN SUBMITTALS

### A. General:

1. Design drawings, data, and calculations at various stages of completion shall be submitted for each phase of the University's plan review process. The specific submission requirements for each phase are outlined below.
2. University or Med School approval is required at each review phase. Approval of design work that proceeds ahead of the review schedule is contingent on the incorporation of recommended revisions from the most recent review phase.
3. Refer also to Section 01300, Submissions.

### B. 100% Schematic Design Submissions:

1. Preliminary system selection. Submission shall include criteria and calculations for selection of HVAC system type, estimated energy use (including lighting) in BTU/sq ft and KWH/sq ft, estimated system operating costs, and life cycle cost analysis of optional systems as directed by the University Project Engineer.
2. Preliminary initial cost estimate of system in terms of unit cost (dollars per square foot gross building floor space, dollars per system or component, or similar). Cost estimate provided by Contractor.
3. Preliminary design calculations, including heating and cooling loads if requested by University Project Engineer.
4. Location of mechanical equipment rooms and major equipment.
5. Major zoning and airflow diagrams.
6. Outline Specifications.
7. Written description of proposed systems and equipment, how they will operate and be controlled, and any special features.

### C. 100% Design Development Submissions:

1. Location of all HVAC equipment.
2. Single-line layout of all major air distribution and hydronic systems.
3. Major air and hydronic flow diagrams.
4. Schematic control diagrams. Include written sequence of operation.

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5. Design calculations, including:
  - a. Revised system energy use, broken down into: 1) heating 2) cooling, including percentage of load resulting from solar gain through fenestration 3) lighting 4) fan motor KWH 5) pump KWH 6) miscellaneous
  - b. Revised operating cost estimates.
  - c. Selection of air-handling equipment, heat exchangers, pumps, etc.
6. Preliminary system cost estimate by Contractor.
7. Life cycle cost analysis on optional systems as directed by the Project Engineer.
8. Revised description of systems and equipment.

D. 50% Construction Documents Submissions:

1. Double-line plan layout and sections of systems and equipment 50% complete; permission to show single-line layouts of selected systems may be granted by the Project Engineer.
2. Final selection of equipment and systems options considered under Schematic and Design Development Phases.
3. Design calculations as requested.
4. Revised system cost estimate by Contractor based on 50% construction documents.
5. Revised description of systems and equipment.
6. 50% complete specifications.

E. 100% Construction Documents Submissions:

1. Complete double-line plan layout and sections.
2. Complete design calculations as requested.
3. Final system cost estimate by Contractor based on 100% design documents.
4. Complete description of systems and equipment.
5. Complete drawings and specifications.

- F. A complete schedule of valves installed, together with drawings that identify the locations of numbered valves and the service which each controls, shall be submitted by the Contractor to the Project Manager. Also reference Section 01300 for other Submittal requirements.

## 1.9 DELIVERY, STORAGE, AND HANDLING

- A. Pre-Purchased Equipment: The Contractor responsible for the pre-purchase specifications for equipment or materials shall consult the Project Manager regarding coordination of delivery, inspection and acceptance, storage, and handling of the product.

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**PART 2 -PRODUCTS**

2.1 REFER TO INDIVIDUAL SOM FACILITIES DESIGN GUIDELINES SECTIONS.

**PART 3 -EXECUTION**

## 3.1 FIELD COORDINATION

- A. The Contractor shall be responsible for understanding the critical path of the total construction process including the scheduling of HVAC system installation and testing in relation to the work of other trades. The Contractor shall establish important scheduling requirements so that a proper construction schedule can be established.

## 3.2 FIELD OBSERVATION

- A. The HVAC Design Consultant's fees shall include periodic site visits for observation of HVAC system installation. The HVAC Design Consultant shall verify that the installation of piping, location of valves, etc. is executed according to the design.

## 3.3 SYSTEMS CLEANING

- A. The Project Specifications shall include a Cleaning Section for equipment, piping, ductwork, etc. The University will enforce the provisions of the Cleaning Section to the fullest extent.

## 3.4 BUILDING START-UP

- A. The HVAC Design Consultant shall, in combination with the Architect and the University Project Manager, develop procedures to assure that the building is ready for occupancy as listed below:
1. Procedures must be designed to operate within the parameters of the building's equipment physical limitations.
  2. A bake-out procedure shall be prepared to raise the building's internal temperature to stimulate off-gassing of various materials within the building. Consideration must be given to the design of the HVAC system, and all materials in the building.
  3. During bake-out, the building should be fully illuminated, furnished, and all other systems operating, where feasible, to raise the temperature as high as possible. The time required to raise and lower the temperature must be accounted for in planning.
  4. Bake-out procedure shall be defined to operate the systems in maximum heat mode for at least twenty-four (24) hours, or until the specified temperature is reached. Operate the systems in normal operation mode for twelve (12) to twenty-four (24) hours, or until the normal temperature is reached. Then repeat the maximum heat and normal operation cycles. Finally, conduct air sampling to verify indoor air quality (formaldehyde, volatile solvents, CO<sub>2</sub>, etc.).

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- 5. Each project varies in its complexity and schedule, the above procedure is a minimum guide and should be modified as required to produce the most reliable test for each situation.

END OF SECTION

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MECHANICAL FACILITIES GUIDELINES REVISION HISTORY

Section		Updated
15050	COMMON WORK RESULTS FOR HVAC	12-15-13
	1.5 Design Criteria	12-15-13
	M. Ventilation	12-15-13
	O. Steam and Chilled Water Systems	12-15-13
	1.4 General Design Conditions	12-15-13
	O. Specialty Rooms	12-15-13
	P. Main Electrical Room	12-15-13
	Q. Server Rooms – Small (< or = 100 sf)	12-15-13
	R. Server Rooms – Larger Rooms (> 100 sf)	12-15-13
	S. Storage Room – (Storage Rooms > 35 sf)	12-15-13

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