Mechanical Systems Guidelines: Standards for mechanical systems are separated into individual sections under the following headings:

- *HVAC Systems*
- *Cooling Systems*
- *Heating Systems*
- *Steam Systems*
- *Hydronic Heating/Cooling Systems*
- *Chemical Treatment Systems*
- *Ventilation Systems*
- *Laboratory Ventilation Systems*
- *Energy Recovery Systems*
- *Energy Management, BAS*

It should be noted that considerable overlap exists among these sections. For example, *HVAC Systems* is somewhat of an umbrella section addressing issues common to multiple individual sections. This overall approach considerably reduces repetition of content. This concept is reflected throughout various sections. Thus, when researching a specific topic or item it is necessary to review multiple sections to ensure that all applicable content has been identified.

Purpose of HVAC: The twofold purpose of HVAC at the University of Illinois is…

1. Provide a comfortable and healthy environment for building occupants, thus promoting learning, personal performance and productivity.
2. Provide reliable environmental control to support research activities.

Guiding Principles:

- Quality: Provide systems/components of high quality. Typically referred to as "institutional quality" as opposed to "commercial quality".
- Reliability: Provide systems that operate properly with minimal service interruptions.
- Maintainability: Provide systems that require minimal service and that facilitate convenient service when required.
- Operability: Provide systems that are as intuitive and easy to operate as possible while providing required functionality.
- Flexibility: Maintain options for potential future changes to spaces served within appropriate limits.
- Sustainability: Provide environmentally responsible designs with focus on energy efficiency and conservation.

Life Cycle Cost: Life cycle cost analysis shall be included as a significant factor in design decision making. As such, installed cost shall be weighed against long term cost of ownership. It is common knowledge that first cost is typically dwarfed by operating cost over the life of an HVAC system. However, it is not commonly considered that operating cost is dwarfed by the value of human performance and productivity. Unfortunately it is difficult to assign a numeric value to human productivity or to the impact of the HVAC system upon it. Yet, substantial value shall be assigned to it, numeric or not. At the end of the day, good engineering judgement shall prevail.
See previous paragraph entitle *Purpose of HVAC.*

Compliance: Design and construction of HVAC systems shall be in compliance with all applicable codes and standards including:

- *International Mechanical Code*
- *Illinois Energy Conservation Code*
- *ASHRAE Standard 90.1 - Energy Standard for Buildings*
- *ASHRAE Standard 62.1 - Ventilation for Acceptable Indoor Air Quality*
- *ASHRAE Standard 55 - Thermal Environmental Conditions for Human Occupancy*

See *Codes, Standards and Regulations Section* within the *General Requirements* section within these *Facilities Standards* for applicable editions/versions of codes and standards.

ASHRAE Handbook: HVAC system design issues not addressed within these *UIUC Facilities Standards* shall be governed by recommendations of the latest version of *ASHRAE Handbook – HVAC Applications.*

Climatic Design Conditions: Climatic design conditions for HVAC systems shall be as published within the latest version of the *ASHRAE Handbook – Fundamentals.*

Station Location: *University of Illinois Willard Airport.*

Outdoor Design Conditions: Design conditions for cooling, evaporation and dehumidification shall be based upon 0.4% annual cumulative frequency of occurrence. In order to achieve a conservative design, heating design conditions shall be based upon mean extreme DB in lieu of the 99.6% value. Humidification shall be based upon 99.6% annual cumulative frequency of occurrence.
(Cooling mean extreme is provided only as a reference for non-typical design.) As of the time of this writing, applicable values are as follows (per *ASHRAE 2013 Handbook – Fundamentals*):

Heating:
Heating DB: -0.5 Degrees F
Mean Extreme DB: -9.7 Degrees F

Humidification:
Humidification DP: -6.8 Degrees F
Mean Coincident DB: 1.4 Degrees F
Humidity Ratio: 3.9 Grains / Lb. Dry Air
Relative Humidly: 66% RH

Cooling:
Cooling DB: 92.0 Degrees F
Mean Coincident WB: 76.0 Degrees F
Mean Extreme DB: 95.7 degrees F

Evaporation:
Evaporation WB: 79.6 Degrees F
Mean Coincident DB: 88.8 Degrees F
Extreme WB: 88.0 Degrees F

Dehumidification:
Dehumidification DP: 76.9 Degrees F
Humidity Ratio: 144.3
Mean Coincident DB: 86.1 Degrees F
Relative Humidify: 74%

Enthalpy:
Enthalpy: 43.7 BTU / Lb. Dry Air
Mean Coincident DB: 88.5 Degrees F

Wind Speed:
Wind Speed: 27.5 MPH

Indoor Design Conditions, Occupied: Default indoor "design-to" conditions for HVAC systems that serve standard occupied spaces:

Heating DB: 70 Degrees F
Cooling DB: 75 Degrees F / 50% RH

When a system that serves a standard building/space is provided with positive humidity control, the space humidity set-point shall be limited as follows:

Heating: 30% RH Maximum
Cooling: 50% RH Minimum

ASHRAE Standard 55: Proposed indoor design conditions for occupied spaces other than the default *values provided above will be considered by Owner* for approval on a project-by-project basis. However, consideration will only be given to design conditions that fall within the range of acceptable thermal conditions presented in *ASHRAE Standard 55*.

Equipment Room Set-points: Space temperature within mechanical and electrical equipment rooms and similar support spaces shall typically be maintained between 55F and 85F. However, each such space shall be evaluated individually based upon specific equipment requirements.

Special Environmental Requirements: It is acknowledged that it is inappropriate to require "across the board" compliance with the indoor design conditions identified above for all space types. Non-standard spaces often require non-standard environments. Examples of such spaces include library archival storage, musical instrument storage, museums, clean rooms, animal facilities and data centers. Maintaining temperature and humidity requirements for such spaces often requires application of specialized HVAC equipment and/or special building construction. (See the *Doors & Windows, Glazing* and *Walls, Partitions* sections within these *General Guidelines*.)
Consideration: Provision of low space temperature in conjunction with high space humidity is a common professional recommendation and/or User request. Achieving and maintaining such environmental conditions is typically difficult and/or costly to accomplish. As such, non-standard HVAC systems required to support such conditions shall be provided only if truly required. For all projects involving special

environmental considerations an evaluation shall be conducted to determine which conditions are recommended versus those that are truly required.

Energy Conservation: HVAC systems of significant scope shall incorporate occupancy sensing to facilitate implementation of energy reduction strategies. Systems shall be configured to take advantage of energy recovery opportunities when possible without violating other design priorities. See the *Energy Conservation* section within these *Standards* for specific HVAC system guidelines and requirements related to energy conservation.

Institutional Quality: HVAC equipment/systems shall be institutional grade as opposed to standard commercial grade. For the purposes of this writing, intuitional grade equipment/systems shall have minimum life expectancy of 25 years for dynamic system components such as motors, switches, pumps, valves, fans, dampers, compressors and burners, and a minimum life expectancy of 50 years for static system components such as casings, cabinets, ductwork and piping.

Central Utilities: HVAC systems shall typically utilize central distributed chilled water, central distributed steam and central distributed electricity whenever these utilities are available. Direction regarding use of central utilities and specific design information shall be obtained from the *F&S Utilities and Energy Services Division* via a *Utility Program Statement*.

Central HVAC Systems: Each building shall be served by a minimal number of central HVAC systems rather than numerous smaller systems (e.g. less than 5,000 CFM). Each central system shall typically include an air handling unit, a return and/or exhaust fan or fans and air supply, return and/or exhaust ductwork.
The installation of a smaller number of larger systems typically results in higher equipment quality and reduced maintenance requirements while providing adequate opportunity for application of energy conserving features and control strategies.

Disallowed Equipment: The following types of HVAC equipment/systems shall not be installed in campus facilities without an approved variance:

1. Window air conditioning units
2. PTACs: Packaged Terminal Air Conditioners
3. Residential furnaces
4. DX split air conditioning units
5. Commercial grade “rooftop” units and similar packaged heating and/or cooling units
6. VRF systems. Note: These systems have grown in popularity yet they shall be treated as temporary solutions when central HVAC is not viable. An approved variance is required prior to installation of VRF systems.
7. Gas-fired heating equipment
8. Commercial or residential grade heat pumps, air source or ground source
9. Electric resistance heating equipment. Exception: Electric resistance heating may be used within packaged HVAC units with dehumidification control (CRAC units).
10. Fan coil and blower coil units. Exception: Cooling-only fan coil and blower coil units may be used for specialty cooling applications such as telecommunications rooms, computer server rooms and certain equipment room cooling applications (e.g. electrical transformer rooms, elevator machine rooms).
11. Ceiling-mounted cabinet unit heaters
12. Fan powered terminal air units (aka “fan powered boxes”)
13. Two-pipe combination hydronic heating/cooling units/systems

System Architecture: Spaces with similar uses, environmental conditions, fresh air ventilation rates and occupancy schedules shall generally be grouped together on the same HVAC system. Spaces with significantly dissimilar usage types and/or schedules shall not be served by the same system. Space types that require dedicated HVAC systems include:

1. Offices*
2. Classrooms*
3. Chemical and biological laboratories (aka “wet labs”)

4. Lecture halls/theaters**
5. Sizable public assembly areas/atria
6. Research animal facilities

Any area with distinct non-standard temperature and/or humidity requirements shall be served by a dedicated system. This overall approach to system architecture allows the design of each system to be tailored to the specific needs of the area it serves while facilitating energy conservation strategies. Night setback, system cycling and optimized demand control ventilation serve as examples.

*In some cases it is acceptable to serve offices and classrooms from a common system. This shall be discussed with *F&S Engineering* prior to project design.

** A lecture hall or theater is typically defined as a room with assigned occupancy of 100 or more individuals. Each room of such capacity shall be served by a dedicated system.

Dedicated Cooling:

Each space requiring uninterrupted cooling shall be served by a dedicated cooling unit independent of any centralized building system. Examples of such spaces include:

1. Electrical transformer rooms
2. Elevator equipment rooms
3. Telecommunications rooms
4. Data processing rooms
5. Mechanical equipment rooms, as applicable. See paragraph below entitled *Equipment Rooms* as well as section entitled *Mechanical Equipment Rooms* within these *General Guidelines*.

Also see *Building Cooling Systems* section within these *General Guidelines* for additional requirements.

Equipment Rooms: HVAC for mechanical and electrical equipment rooms and similar support spaces shall be "divorced" from applicable central HVAC systems given that uninterrupted operation is required. Further, in the case of ventilation systems, potential exists for compromising the central system via transfer of objectionable noise and odors.

Future Expansion: Within practical limitations each HVAC system shall be sized and configured to accommodate potential future expansion of capacity and/or infrastructure.

Flexibility: Within practical limitations HVAC systems shall be designed to be flexible and adaptable to accommodate changes in room layout and usage. This is particularly the case for laboratory spaces given that research objectives frequently require changes in laboratory operations and programs. Extreme flexibility such as that required to support major changes such as the conversion of an office to a wet lab or vice versa shall generally be avoided due to its negative impact on energy consumption.

***Simplicity*:** Einstein: *"Everything should be made as simple as possible, but not simpler."* Cantrell: *"…so simple it works."* In keeping with these popular quotes HVAC systems shall be kept as simple as possible without sacrificing performance or effectiveness to a significant degree. The following excerpt from the University of Chicago Standards shall apply: *"Overly complicated systems may perform exceptionally well on day one, but are prone to deterioration over time. Although "complexity" is a somewhat relative term, it is generally not difficult to recognize a design that has "crossed the line" into being overly complex. An example might be a system that relies on "bleeding edge" technologies with which the University's operations staff have little or no experience. Note: It is not the intent of the University to stifle innovation. In fact there are many examples of innovative designs that are highly maintainable. The key point here is to ensure that maintainability is given a high priority in design. "*

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Terminal Zoning: HVAC systems shall be configured such that each occupied space may be controlled as a separate zone with regard to temperature and/or airflow. In other words, a minimum of one terminal control unit (e.g. VAV unit with reheat coil) shall be provided for each occupied space. Each occupied space shall have a minimum of one dedicated thermostat (or equivalent). For the purposes of this writing, reception areas, lobbies, atria and public assembly spaces shall be considered occupied spaces.

Equipment Location: Each piece of motorized HVAC equipment shall be located within a building mechanical equipment room with the following exceptions:

- Approved roof mounted air handling equipment *(see Ventilation Systems* section within these *General Guidelines)*
- Roof mounted exhaust fans
- Unit heaters, cabinet unit heaters and similar unitary heating units
- CRAC units and similar specialty equipment designed for location within the space served

Location of motorized HVAC equipment above finished ceilings is not allowed. This includes suspended grid / drop-in tile ceilings. In no case shall motorized equipment (e.g. fan coil or blower coil units) be installed above a hard finished ceiling (e.g. sheet rock or plaster).

Motorized HVAC equipment shall not be located above sensitive equipment such as telecom switches, elevator control panels, computer server and sensitive lab equipment. This is particularly true of HVAC equipment that generates condensate.

Janitor Rooms: Given that janitor rooms are not accessible to maintenance personnel, mechanical equipment and devices shall not be located within them. Provision shall be made to adequately access mechanical equipment and devices without passing through a janitor room.

Outdoor Equipment: Air-cooled equipment such as chillers and condensing units need not be located within equipment rooms. Outdoor location and installation shall comply with all requirements of the *Impact on Surrounding Environment* section within these *General Guidelines*. Each outdoor unit shall be supported by and firmly anchored to a steel reinforced concrete pad with appropriate subgrade footing. The pad shall be of sufficient height above grade to effectively reduce exposure of equipment to dust and debris. Pad height shall be 6" minimum.

Support: All indoor floor-mounted mechanical equipment shall be supported upon and affixed to a steel reinforced concrete pad anchored into the structural floor. If required for vibration control, a spring supported inertia base shall be provided as addressed in the following paragraph entitled *Vibration Control.*

Vibration Control: Most floor-supported rotating HVAC equipment located within the lowest level of a building, with the exception reciprocating equipment (e.g. air/refrigeration compressors and internal combustion engines) may and shall be installed with virtually no special provisions for vibration isolation between the equipment and its support system or associated hydronic piping. This equipment shall typically be "hard mounted" directly to its concrete support/housekeeping pad without use of vibration isolation devices and "hard connected" to the piping systems they serve without the use of flexible pipe connectors. The use of flexible pipe connectors shall be minimized since they have proven to be leak/failure prone. An exception to these general rules may be necessary in cases where laboratory equipment is especially vibration sensitive (e.g. an electron microscope) is located in close proximity to an equipment area. Rotating HVAC equipment that is supported from any ceiling or supported by any floor other than the lowest floor of the building shall be individually evaluated to determine if vibration isolation devices, inertia bases and/or flexible pipe connectors are needed to prevent unacceptable levels of vibration from being transmitted into the building structure.

Access: Adequate access shall be provided within mechanical equipment rooms to facilitate operation, maintenance and repair activities. (See *Mechanical Equipment Room* section within these *General Guidelines* for requirements). Similarly, adequate (as in *generous)* access shall be provided to operate, maintain and repair all mechanical devices located outside of equipment rooms. Such devices include, but are not limited to, finned tube elements, VAV boxes, reheat coils, valves, dampers, controllers and control devices. Thus, office furniture shall not be located so as to hinder access to finned tube cabinets. Piping, conduit and ductwork shall not be located so as to hinder access to VAV boxes and controllers. Equipment and devices that are vulnerable to damage or tampering by

building occupants or activities shall be located and/or protected accordingly.

Backup Equipment: A 100% backup or duplex unit shall be provided for each critical piece of HVAC equipment. Included are the following:

- Hot water perimeter heating pumps
- Pneumatic control air compressors
- Steam condensate pumps
- HVAC for research animals
- HVAC for critical laboratory equipment
- HVAC for critical computer equipment
- HVAC for critical telecom equipment
- Critical lab exhaust systems -
  - At a minimum, one of multiple ganged exhaust fans

In general terms, N+1 redundancy shall be provided for each truly critical piece of equipment. Careful evaluation in conjunction with Owner input is required to determine the necessity of such redundancy.

Redundant Components: For critical applications, redundant components shall be provided within HVAC equipment as deemed prudent. Examples include multiple fans within an air handling unit, multiple control valves serving a single device, and multiple compressors/refrigerant circuits within a chiller.

Emergency Power: Critical HVAC equipment shall be provided with emergency power as deemed prudent. Consideration shall be given to each system listed above in the paragraph entitled *Backup Equipment*.

Variable Speed: All HVAC equipment with three phase motors shall be equipped with variable speed drives. When such requirement is deemed excessive for a given application concurrence shall be sought from the Owner.

Sound Control: Sound control as it relates HVAC systems shall be given adequate priority. As mentioned elsewhere, the best way to control noise is to not create it in the first place. When focused attention is given to maximizing the efficiency of HVAC systems, noise is much less of an issue. HVAC-related background noise fin a given space shall not exceed the guideline criteria provided in the chapter entitled *"Sound and Vibration Control"* in the *"ASHRAE Handbook, HVAC Applications".*

Control Systems: See the *Energy Management, Building Automation Systems* section within these *General Guidelines* for specific control system guidelines and requirements.

Troubleshooting: System components shall be located to facilitate troubleshooting procedures. For example, VAV boxes and control valves for heat transfer devices shall be located on the same floor as the spaces they serve. Specific example: control valves shall not be located on the floor below to serve up-fed finned tube elements.

Humidification: HVAC equipment/systems shall not incorporate space humidification unless required for a specific application. Humidification is costly, not only in terms of first cost but also in terms of maintenance and energy consumption. With the increased use of dedicated outdoor air ventilation systems and total enthalpy heat recovery wheels the need for space humidification has been reduced. When humidification is required it shall be provided by means of a steam-to-steam humidifier located adjacent to the applicable air handling unit. Makeup water to each humidifier shall be softened to reduce scaling. In some applications further conditioned with reverse osmosis and/or deionizing equipment is required. Steam from the campus-wide central steam distribution system shall not be used for direct injection humidification.

Animal Facilities: See the *Animal Facilities* section within these *General Guidelines* for specific HVAC system requirements related to animal facilities.

Laboratories: See the *Chemical and Biological Laboratories* and *Laboratory Ventilation Systems* sections within these *General Guidelines* for specific HVAC system requirements related to these applications.

Freeze Protection: Neither water, steam nor condensate piping systems shall be installed in locations where they are vulnerable to freezing (e.g. outdoors without sufficient earth cover, within unheated spaces, within building exterior walls or wall cavities, within exposed overhangs, within exposed exterior walkways, etc.) Exception shall not be granted for systems to be protected via the use of glycol solution. Over time, glycol solution can become diluted to the point that it is no longer effective at providing freeze protection.

Temporary Use of New Equipment: HVAC equipment shall not be used for temporary heating and cooling during construction except by specific approval by the Owner. Only after approval from the Owner, the AE shall document the conditions by which HVAC equipment may be used during construction and clearly require the Contractor to implement measures to assure equipment will be like new when delivered to the Owner. The AE shall balance the expediency of using new HVAC equipment with the negative consequences of compromised indoor air quality, equipment warranty, cost to restore the equipment to like new condition and the impact of commissioning out-of-sequence. The use of permanent HVAC systems for construction purposes is discussed in *Section 01 76 00 – Protecting Installed Construction*.

Equipment Identification: Identification of HVAC equipment and devices shall be provided in compliance with *UIUC AiM* asset management system. Drawing schedules shall incorporate asset identification numbers provided by Owner.