ENGINEERING DESIGN GUIDELINES

Purpose

The engineering design guidelines have been established to address the most common project elements at ASU. They are to be used in conjunction with the requirements set forth by applicable codes, laws and ordinances of this jurisdiction, recognized industry standards, good engineering practice and specific program needs. Omission of reference in these guidelines does not relieve responsibility for compliance with these requirements.

Consultants are encouraged to use professional judgment and ingenuity. The provisions of these guidelines are not intended to prohibit the use of alternative systems, methods or components. The consultant is ultimately responsible for the final design and its performance. Due diligence shall be performed to ensure the design is equivalent or superior to the prescribed elements of the guideline. As required, the consultant shall propose modifications to the guidelines to meet specific project goals, conditions and requirements through ASU’s formal variance process.

Design

Prudent engineering principles shall be followed, emphasizing efficiency, flexibility, maintainability, safety and reliability in an economic and environmentally responsible manner. Systematic analysis of life-cycle costs shall be performed to provide a basis for comparison amongst available options. Such factors to consider include energy, operation, maintenance, repair and replacement costs and escalation and residual value among others.

Systems shall be flexible and designed to accommodate future expansion and renovation. Equipment incorporating VFD’s shall be sized such that day-one operation, plus any designed future capacity, shall not exceed 60 hertz. The systems shall be effectively zoned and shall incorporate provisions for continued operation to perform maintenance or in the event of a failure.

System layouts shall be fundamental with necessary clearances to allow for ease of operation and maintenance. Space planning shall allow for the removal and replacement of equipment and components, including major equipment, without disturbing permanent walls or disrupting service to other systems.

Equipment and components shall be selected, and systems engineered, to provide reliable performance that is accurate and repeatable at full and part load conditions and under all operating modes. Experimental, unproven or proprietary equipment or systems are not allowed unless documented proof of historical capability is provided and accepted by ASU. Systems and components shall be selected to maximize the utilization of competitive standard elements.

Documentation

A Basis of Design (BoD) document shall be prepared by the consultant to establish the understanding of the program, and identify methodologies and systems to achieve programmatic goals. The BoD will serve as an oversight tool for the University and shall be updated and submitted at each project phase. A final BoD shall be submitted as part of project closeout and shall be aligned with the implemented design. At a minimum, the following information shall be provided:
- Assumptions
- Load calculations
- Applicable codes, standards, laws and ordinances
- Indoor design conditions for each space (dry bulb, relative humidity and control ranges)
- Outdoor design conditions (see Design Criteria section)
- IAQ requirements, i.e. filtration, location of intakes coordinated with contaminate sources, assumptions regarding recirculation of air, etc.
- Ventilation rates, air change rates, outdoor air and exhaust air requirements
- Pressure relationship between adjacent spaces
- Lighting and equipment loads
- Occupant density, activity, and heat rejection
- Building envelope construction and infiltration
- Diversity and sizing criteria
- Equipment scheduling assumptions
- Narrative describing each individual system’s:
  - equipment and distribution sizing criteria, operating conditions and materials
  - redundancy and reserve capacity
  - operation and control strategies

Sufficient information shall be included in the construction documents not only to permit and construct the project, but to also facilitate system maintenance and troubleshooting. Plans shall clearly identify and callout all equipment, valves and system instrumentation (i.e. differential pressure sensors, duct detectors, etc.). Equipment and valve numbering shall be coordinated with Facilities Development and Management (FDM). Plans shall identify all clearance spaces and access paths, pipe and duct sizes, pressure class/material transitions, slopes and elevations.

Flow and control diagrams shall be prepared as part of the contract documents for every project. They shall identify all equipment and instrumentation required for system operation. Accompanying points lists and sequence of operations shall also be submitted on the drawings. Uniformity of instrumentation symbols and identification shall be based on ANSI/ISA-5.1.

Room airflow balances and space pressurizations shall be clearly identified on plans, diagrams or in schedules.

Schedules shall be prepared as part of the contract documents and shall include pertinent information required for procurement and analysis of the equipment selections. Specifically, air handler schedules shall include the following information at a minimum:

  - Entering outside air dry bulb and wet bulb temperature
  - Return air dry bulb and wet bulb temperature
  - Mixed air dry bulb and wet bulb temperature
  - Leaving air dry bulb and wet bulb temperature
  - Minimum outside air percentage
  - Day one airflow quantity and designed airflow quantity
  - Coil velocity at day one and designed airflow quantity
  - Apparatus pressure drops at day one and designed airflow quantity

**Sustainability**
Environmentally responsible design shall be approached in a systematic and integrated effort to ensure the sustainability initiatives of the University are surpassed. The appropriateness of the available solutions, and the economic and environmental benefit of their implementation, shall be evaluated for each project. It is the expectation that the minimum requirements set by codes, standards and ASU’s Sustainability Guidelines will be exceeded in a fiscally responsible and proven manner.

**Campus Utilities and Existing Conditions**

Campus utilities shall be used whenever possible for any new construction or expansion projects. Systems operation and design criteria at each campus shall be verified with FDM. It is the responsibility of the consultant to perform due diligence to verify existing conditions and the availability of all campus utilities and building systems.

The routing and connection to existing campus utilities shall be coordinated with FDM. New tunnels shall be as wide as possible with a minimum walking clearance of 3'-0". Connections to existing utilities shall not impede walking clearances and shall have isolation means at an accessible location.

All building service entrance utilities shall be metered in accordance with the utility company, ASU FDM and ASU Energy Information System (EIS) requirements. Sub-metering building utilities is encouraged to provide measurable data to evaluate individual system performance and plan for future energy programs.

**Equipment Rooms**

The location and size of equipment rooms shall allow for ease of maintenance, and removal and replacement of equipment and components. Equipment rooms that house major equipment shall be directly connected to the outdoors and the outdoor path shall be accessible. The consultant shall allocate space for system expansion and addition.

Equipment shall be located on concrete equipment pads. Sufficient pad height shall be provided to allow for equipment appurtenances to be installed without the need to notch or penetrate the floor.

Equipment rooms shall have convenience outlets.

Floor drains and floor sinks shall be provided in equipment rooms to allow for continuous applications and intermittent maintenance without impeding paths of travel or cause damage to the floor. Provide exposed, non-mechanical type trap primers at these locations and other locations where subject to evaporation.

Equipment rooms housing HVAC equipment shall have at least one water supply.

It is preferred that vibration producing components, such as rotating equipment, boilers, etc., and large/heavy equipment and storage tanks be located on grade whenever possible.
HVAC

Reference

Applicable Codes, Laws and Ordinances
ACGIH Industrial Ventilation – A Manual of Recommended Practice
AIHA Z9 Series Standards
ANSI
ASU Project Guidelines
ASHRAE
ASME
FM
Guide for the Care and Use of Laboratory Animals
NIH
NFPA
OSHA
SMACNA
UL

Design Criteria

Indoor Design Conditions

Environmental conditions for human occupancy comfort are based on the sustainability principle of adaptive comfort. To achieve thermal comfort of this principle, design considerations shall factor in personal activity, humidity levels, air distribution, etc. without sacrificing the energy savings potential of this principle.

Special programs whose environmental conditions are dependent on processes or equipment requirements are exempt from this principle and their requirements shall be individually reviewed.

In the absence of any critical program needs, temperature conditions for human comfort shall be as follows:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Design Setpoint</th>
<th>Upper/Lower Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>70°F</td>
<td>68°F</td>
</tr>
<tr>
<td>Cooling</td>
<td>78°F</td>
<td>80°F</td>
</tr>
</tbody>
</table>

Outdoor Design Conditions

Outdoor design conditions shall be based on local climatic data tabulated from the ASHRAE Handbook - Fundamentals (current edition) unless a more appropriate and recognized source for local climatic data is proposed by the consultant and accepted by ASU.

Critical Program

Heating design criteria shall be based on the 99.6% column dry bulb temperature.

Sensible load cooling design criteria shall be based on the 0.4% column dry bulb
temperature with its mean coincident wet bulb temperature. Monsoon conditions shall be considered when determining outside air, infiltration and dehumidification loads.

Non-Critical Program (Comfort Only)
Heating design criteria shall be based on the 99% column dry bulb temperature.

Sensible load cooling design criteria shall be based on the 2% column dry bulb temperature with its mean coincident wet bulb temperature. Monsoon conditions shall be considered when determining outside air, infiltration and dehumidification loads.

Ventilation and Make-Up Air

Unless a more current version is required, the design of ventilation systems to provide indoor air quality acceptable for human occupancy shall follow ASHRAE Standard 62.1 – 2007 Ventilation for Acceptable Indoor Air Quality.

Special programs subject to contamination by odors or toxic, noxious or flammable/explosive/radioactive particles, vapors or gases, etc., or that require cleanroom type functions, shall be addressed on an individual basis.

Outdoor air intakes shall be located so as to not induce contaminants or entrain rain and shall be secure from public access. Measurement, access and balancing of outdoor air shall be addressed when locating the intakes.

Pressurization

The building pressure relationship relative to ambient shall prevent infiltration year round.

Room pressure relationships to adjacent spaces shall be from the cleanest spaces to least clean spaces. Depending on the application of the program, multiple step pressurization may be required. Where this is required, cascading type air locks shall be used for non-containment applications to prevent contamination of the room; sinks, bubbles or dual-compartment air locks shall be used for containment applications to prevent contamination of both the room and adjacent spaces.

For critical applications where room pressure differentials need to be sustained, the preferred method is through the use of a fixed volumetric offset between the supply and exhaust airflows. Room pressure monitors and alarms shall confirm room pressurization.

Zoning

Mechanical systems shall have an adequate number of zones, fundamentally laid out to perform each intended function, provide flexibility for future renovations, expansions and maintenance and incorporate energy saving strategies. Program spaces requiring 24/7 conditioning, or processes requiring different operating conditions, shall be provided with dedicated and independent HVAC systems and/or loops.
Systems

General

When central utilities are not available, preferred alternative systems are those that are reliable, efficient and with fewer, larger and less complex components. Refer to the ASU Technical Guidelines for equipment requirements.

Primary Cooling

Campus chilled water shall be used whenever available. When not possible, a life-cycle cost analysis shall be performed on available options to provide a basis for comparative analysis.

Considerations when using campus chilled water:
- A bypass around the building pumps for emergency situations.
- A temperature control strategy to allow for supply water temperature reset and elevated campus return water temperatures under part load.
- A building differential pressure reset strategy to operate the pump(s) at the lowest speed possible while maintaining temperature setpoints.
- Pump lead, lag/standby with a runtime equalizing control strategy.
- Consult FDM and the chemical company under contract to ASU for pipe pretreatment requirements.

Primary Heating Systems

Campus steam shall be used whenever available. When not possible, a life-cycle cost analysis shall be performed on available options to provide a basis for comparative analysis.

Considerations when using campus steam:
- A steam to hot water converter shall be used.
  - Steam coils shall not be used for heating applications.
  - Mount the converter at an elevation sufficient to allow for condensate drainage and with a vacuum breaker to eliminate stall and potential failures.
  - Use union/flanged spool pieces on the water side to allow for head removal and clear space for tube pull.
  - Parallel float and thermostatic steam traps should be considered, each sized for 100% of the full design load.
  - A pressure reducing station with a manually regulated bypass shall be used upstream of the control valve.
  - Depending on the size of the system, 1/3 – 2/3 valve control may be required.
  - The pressure reduction should provide the lowest possible steam pressure at the heat exchanger.
- A manually regulated bypass shall be used around the control valve(s).
- Unless otherwise required, the supply water temperature shall not exceed 140°F and a temperature reset control strategy should be implemented.
- A building differential pressure reset strategy should be considered to operate the pump(s) at the lowest speed possible while maintaining temperature setpoints.
  - Pump, lead, lag/standby with a runtime equalizing control strategy shall be used.
  - Condensate shall be collected and returned back to the central plant. High pressure condensate shall be flashed and reused on a low pressure steam system before being returned to the plant if feasible and economically viable.
  - All steam vents shall discharge to a safe location outdoors and at a location so as to not damage building components.

Humidification Systems

Campus steam shall be used whenever available. When not possible, a life-cycle cost analysis shall be performed on available options to provide a basis for comparative analysis.

When using campus steam:
  - A steam-to-steam (STS) generator shall be used.
    - Direct injection of central plant steam into the airstream shall not be used for humidification applications.
  - Condensate on the central plant side of the STS generator shall be collected and returned back to the central plant. Any high pressure condensate shall be flashed and reused on a low pressure steam system before being returned to the plant if feasible and economically viable.
  - Condensate on the humidification side of the STS generator shall be drained to waste through a drain cooler.
  - All steam vents shall discharge to a safe location outdoors and at a location so as to not damage building components.

Air Handling Systems

Air systems shall have the capability to provide 100% outdoor air to incorporate energy saving strategies, pre-occupancy startup and/or space purge functions. Control measures shall be incorporated to maintain proper building pressurization at all concentrations of outdoor air and to reset static pressure to operate the fan(s) at the lowest speed possible. Dedicated outdoor air configurations are preferred.

Outdoor air shall be measured and controlled to maintain the minimum required ventilation rates in the breathing zone whenever the zones served are occupied. Systems supplying 100% outdoor air are exempt. Demand based control is the preferred method to reset the minimum ventilation rate for systems serving multiple zones. Single zone systems or spaces with well-defined occupancy schedules may consider other methods of resetting the outdoor air flow rate. Increasing outdoor air requirements beyond the minimum requirement in the breathing zone is not desirable from an energy standpoint unless this can be accomplished passively or when used in conjunction with strategies that decrease overall energy consumption.

Alternative methods to traditional overhead VAV space conditioning and ventilation systems are encouraged. Proven concepts for energy recovery and reduction shall be investigated and proposed. The reduction of use, or the complete elimination of reheat systems, shall be considered.
Ductwork shall be directly connected to the air handler and exterior outdoor and relief openings, supply duct/plenums and return duct/plenums. Equipment rooms and penthouses shall not be used as plenum spaces.

**Exhaust**

The primary function of exhaust systems is to provide a safe and healthy environment through containment and removal of containates. Proven energy conservation strategies shall evaluated for each project, but shall not sacrifice the health and safety of building occupants or the public.

Exhaust and vents shall discharge directly, or first through air cleaning devices, in a safe manner to an exterior location. Minimum separation distances from the discharge shall be maintained in accordance with applicable codes and standards. Additional considerations shall be given to prevailing winds and airflow patterns around the building and building elements.

**Air Distribution Sizing Guidelines**

Low Pressure Duct Sizing (Pressure class 2" WG and less)
- **Supply:**
  - Maximum Pressure Drop: 0.1"/100ft
  - Maximum Velocity: 1,600 fpm
- **Return/General Exhaust:**
  - Maximum Pressure Drop: 0.08"/100ft
  - Maximum Velocity: 1,600 fpm

High Pressure Duct Sizing (Greater than pressure class 2" WG)
- **Supply:**
  - Maximum Pressure Drop: 0.15"/100ft
  - Maximum Velocity: 2,000 fpm

Chilled and Heating Hot Water Pipe Sizing Guidelines
- Maximum Pressure Drop: 4ft/100ft for pipe 6" and below
- Maximum Velocity: 10 fps for pipe 8” and above

**Plumbing**

**Reference**

Applicable Codes, Laws and Ordinances
- ADA
- ANSI
- ASU Project Guidelines
- ASPE
- CISPI
- FM
- Guide for the Care and Use of Laboratory Animals
- NIH
Design Criteria

General

Fixture unit quantities shall be assigned in accordance with applicable plumbing codes. Recognized methods to reduce the performance impacts of high-efficiency fixture loads on traditional sanitary waste pipe sizing methods shall be evaluated. This does not apply to non-potable water systems, storm drains or special waste.

Water Conversation

Strategies to conserve water use shall be considered for every project. Reuse and collection systems shall be evaluated for each new construction, addition or major renovation project. Reduction in water use shall be pursued through the use of waterless or low flow fixtures, hot water recirculation systems and other water saving technologies.

The use of potable water for once through equipment cooling is prohibited.

Systems

The design of building supply and distribution systems shall provide a volume of water at the required flows, pressures and temperatures to ensure safe, efficient and code compliant operation during periods of peak demand. Piping shall be sized at a velocity not exceeding six feet per second (fps) for cold and hot water and four fps for hot water return.

When central utilities are not available, preferred alternative systems are those that are reliable, efficient and with fewer components. Refer to the ASU Technical Guidelines for equipment requirements.

Domestic Hot Water

Campus domestic hot water shall be used whenever available. The next preference is the use of campus steam to produce domestic hot water at the building level. When neither is possible, a life-cycle cost analysis shall be performed on available options to provide a basis for comparative analysis.

Potable Water

Separate water systems into potable and non-potable with the required reduced pressure backflow preventers. Landscape irrigation shall be provided with a dedicated water meter separate from the building meter. Non-potable makeup water to equipment and systems shall be individually metered and totalized at ASU BAS for maintenance and troubleshooting purposes. Provide a bypass around meters.

All backflow protection will comply with the local ordinance of the municipality in which
the campus is located. Pipe relief from the backflow preventer indirectly to a drain of sufficient size to evacuate maximum flow discharge.

Bypasses around backflow devices are prohibited. Where interruption of service shall be avoided, separately valved backflow preventers may be installed in parallel. All domestic water services to buildings shall have two backflow devices in parallel.

**Hazardous Evaluations**

When it is necessary to have multiple piping connections to tanks, equipment or systems, the potential for cross-contamination shall be evaluated. The evaluation should consider the potential motive force for contamination and the severity of the consequences from cross-contamination.

The motive force for cross-contamination can come from pipe line pressure, static head, siphonage, sudden depressurization, or molecular diffusion (migration of fluids under static conditions). The greater the motive force, the greater the potential for cross-contamination.

The consequences of cross-contamination may include hazards to employee health, product contamination and/or equipment damage.

**Common Utilities for Laboratory Facilities**

For general laboratory use, allocate 1 scfm per outlet for compressed air and nitrogen, 5 cfh per outlet for natural gas, and 0.5 scfm per inlet for vacuum, plus the flow required for individual equipment. Apply reasonable diversity factors to the system sizing based on the number of inlets/outlets.

**Laboratory Waste**

In new buildings, do not connect sanitary and laboratory waste piping systems to each other inside the building. Collect waste lines independently at the site sanitary sewer. Consult ASU PM regarding collection and neutralization of laboratory waste before connection to the sanitary system.

Radioactive waste shall be independently collected and disposed of per the Office of Radiation Safety program.